Can Wormholes Be An Answer to the Ansible Problem?

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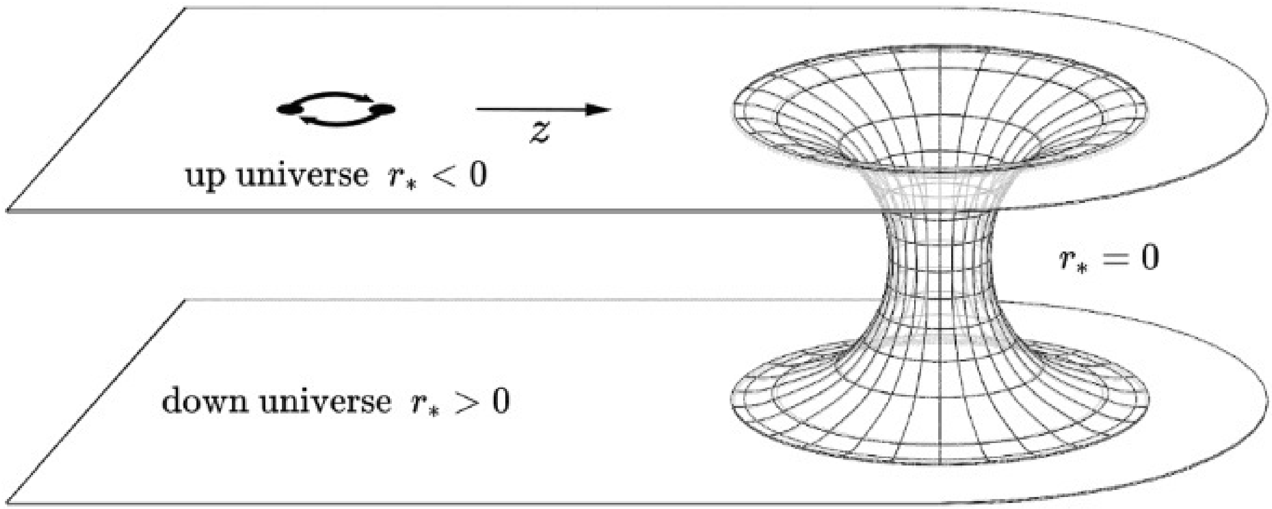
In *The Cosmic Challenge: Why Quantum Entanglement Won't Deliver The Ansible* in Principium 46, August 2024 (i4is.org/principium-46/), Arya Gonullu introduced us to the idea of communicating instantaneously, defying the light speed limit for information transmission. The idea is old in science fiction and it acquired a name in 1969 in *The Left Hand of Darkness* by Ursula K Le Guin.
Here she examines the idea of wormholes as the vehicle for such communication.
References at the end of this article.

The concept of the ansible—a device that enables instantaneous communication across vast cosmic distances faster-than-light—has fascinated science fiction enthusiasts for decades. However, a fundamental obstacle stands in its way: the laws of physics, specifically Einstein's theory of relativity, which prohibit faster-than-light communication due to its potential to violate causality.
In Principium Issue 46, we explored whether quantum communication via quantum entanglement could provide a viable ansible. We highlighted that while entanglement establishes correlations between particles, it does not allow control over the transmitted information. To achieve meaningful communication, classical channels remain essential, a point we explored in detail within the issue.
Now, with a big "if" in mind, we turn to one of the most interesting possibilities: wormholes, and what about entanglement through wormholes? Could wormholes offer a theoretical means to overcome the ansible problem?

Introduction to Wormholes



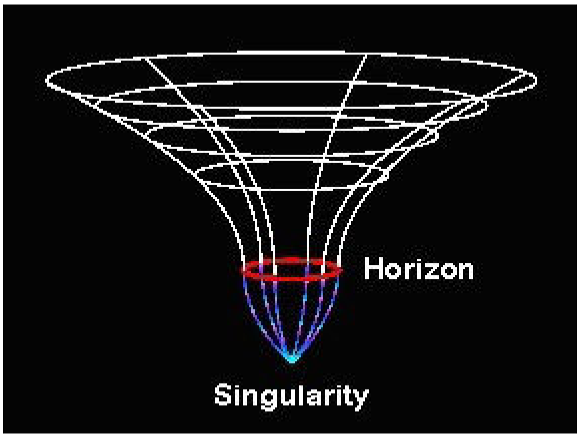
Wormhole theory did not emerge, as commonly believed, from concerns that quantum entanglement defied the principles of relativity due to its instantaneous nature. Although entanglement exhibits instantaneous correlations between particles, it does not enable faster-than-light communication or violate relativity, instead, entanglement is part of the probabilistic and relational aspects of quantum mechanics.

The idea of wormholes traces back to Albert Einstein and Nathan Rosen in 1935, in their attempt to unify electromagnetism with gravity (Lindley, 2005). Their work aimed to achieve a consistent understanding of quantum fields in curved spacetime (Marto et al., 2024). As Einstein and Rosen stated, "a particle in the physical Universe has to be described by mathematical bridges connecting two sheets of spacetime" (Einstein & Rosen, 1935).

To explore this alternative approach, Einstein and Rosen proposed what became known as the Einstein-Rosen bridge, a theoretical construct that arose from their work in general relativity, which describes how massive objects curve spacetime. The bridge was envisioned as a shortcut through spacetime, connecting two distant regions via a tunnel-like structure—a wormhole. A commonly used analogy to describe this concept is a pen piercing through a folded piece of paper, illustrating the idea of traversing between two points in spacetime more efficiently.

Initially, they conceived the bridge not as a means for travel between these two sheets of spacetime but as a way to explain the behaviour of elementary particles, imagining them as objects moving through these tunnels and bypassing conventional spacetime limitations. Einstein and Rosen's primary motivation was to investigate the possibility of an atomistic theory of matter and electricity that, while excluding singularities of the field, relied only on the variables of general relativity (**g**) and Maxwell's electromagnetism (φ) (ibid).

Einstein and Rosen's wormhole model wasn't originally conceived as a means of communication but rather as an effort to provide a singularity-free description of the physical universe. In classical physics, singularities occur when mathematical quantities, such as spacetime curvature, become infinite—like the idea of a particle having all its mass concentrated into an infinitely small point. In general relativity, a point mass curves spacetime around it in a way first described by Karl Schwarzschild in 1916 where the Schwarzschild solution introduced singularities both at zero and at the Schwarzschild radius (Schwarzschild, 1916).



Einstein and Rosen reinterpreted the Schwarzschild solution to rid physics of these singularities: They proposed an alternative view in which a path tracing radially inward would not encounter a singularity at the Schwarzschild radius. Instead of continuing towards an infinitely dense centre, their model proposed that the inwards trajectory would seamlessly connect to another region of spacetime, emerging outwards again—essentially linking two separate sections of spacetime. This concept can be visualised by imagining two adjacent rubber sheets, each with a funnel shape pulled from their surfaces and connected at their narrowest points, forming a continuous tube-like passage between them.

However, the idea of using such constructs for instantaneous communication emerged later as physicists began to explore the exotic implications of wormholes, leading to speculation about their potential role in enabling faster-than-light travel or information transfer.

Interstellar Travel via Wormholes: Ansible?

In theory, a traversable wormhole could allow information to pass through one "mouth" and emerge instantaneously from the other, regardless of the distance between the two ends. Such a mechanism would effectively permit faster-than-light communication, solving the ansible problem. However, there are several obstacles to making this concept a viable solution.

Wormholes, as described by the equations of general relativity, are dismayingly unstable. Any wormhole connection that happens to form between two points in space should pinch closed again so rapidly that neither material objects nor light-beam messages can pass across the wormhole "bridge" during its brief existence. Thus, at least in its pristine form, a wormhole is unsuitable for the instantaneous space transport that science fiction writers may have in mind. Most physicists will find this result satisfying, for it also avoids a simultaneity paradox (Cramer, 1989).

However, Morris, Thorne, and Yurtsever propose to create a stable wormhole, with the hope that someday we may be able to build one. Empty space, when examined with quantum theory on a sufficiently small distance scale, is not empty at all. Even at nuclear dimensions (10^{-13} cm), empty space is filled with particle-antiparticle pairs that are continually flashing into brief existence, bankrolled on the credit of borrowed mass-energy, only to wink out of existence again as the law of conservation of energy reasserts itself. If the length scale is contracted to a size appropriate to quantum gravity (10^{-33} cm , Planck-Wheeler length), this quantum fireworks intensifies to a "quantum foam" of violent fluctuations in the topology and geometry of space itself (Morris, Thorne and Yurtsever, 1988). In this environment, Morris, Thorne, and Yurtsever speculate, it may be possible for a civilisation considerably more advanced than ours, by "pulling a wormhole out of the quantum foam and enlarging it to classical size," to create a connection between two nearby points in space. This would use the well-known quantum mechanical process called "tunnelling," a jump from one allowed energy state to another across a barrier of intermediate states that are forbidden by energy conservation (Cramer, 1989).

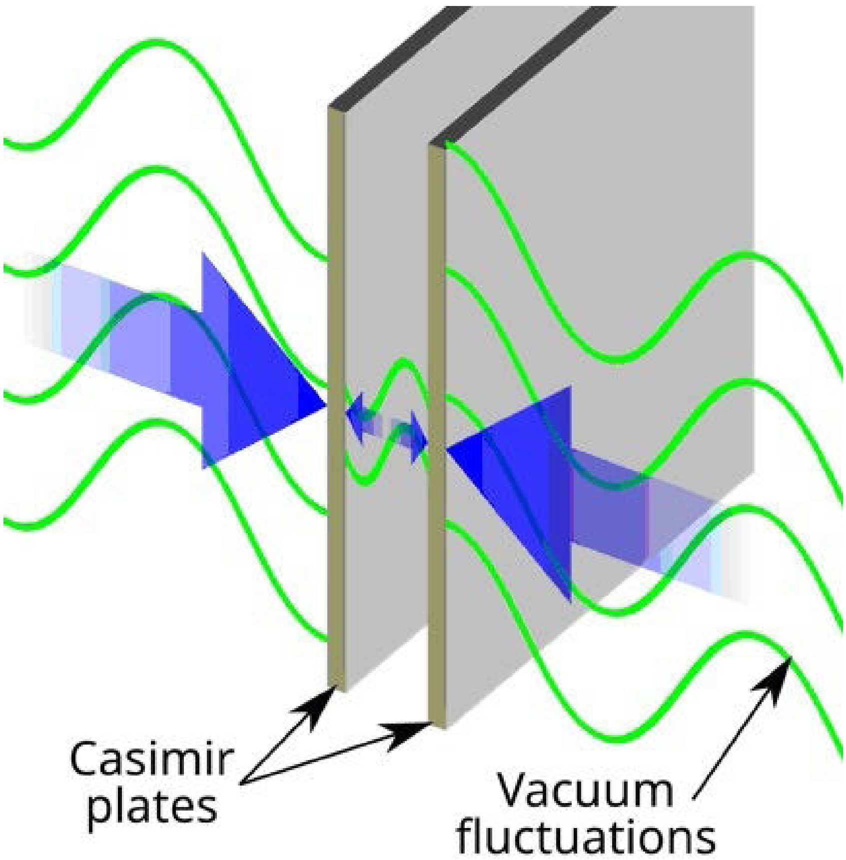
To stabilise the wormhole pulled from the quantum foam, preventing its immediate re-collapse, Morris, Thorne, and Yurtsever propose to use an electric field of such enormous strength that it creates enough energy in the mouth of the wormhole to force it to remain open. They suggest that this might be accomplished by placing a pair of spheres with equal electric charges at the two spatial entrances of the wormhole. The spheres would be held in place by a delicate balance, the force of their gravitational attraction just offsetting the force of their electrical repulsion. Such a system might be very small, an atom-scale opening permitting the passage of only a few photons at a time, or it might be large enough to pass a large vehicle with far-future technology, where instantaneous communication and transport through the wormhole would be available.

Hence, to keep a wormhole stable and traversable, negative energy or exotic matter would be needed to counteract the gravitational forces that would otherwise cause the wormhole to collapse.

Negative energy is found in quantum mechanics, eg, the Casimir effect (see below), but producing and sustaining the required quantities remains beyond our technological capability.

The big deal breaker for our universe, as far as we know today, seems to be the lack of what one might call "exotic" matter (Siegel, 2022). The simplest way of looking at the situation is to think of space as having an average energy density from all sources: matter, radiation, and even the (positive, non-zero) zero-point energy of empty space itself. Where you have positive energy, space curves in response to that; this is why massive particles exhibit the phenomenon of gravitational attraction. So far, all we've ever detected in the universe is matter and energy with positive values to it (ibid).

But if you want to have a traversable wormhole, you need some type of matter and/or energy that has a negative value to it, at least negative relative to the average energy density of the universe. Although we can create small regions of space that have this property – eg, the empty space between two parallel conducting plates, such as a setup exhibiting the Casimir effect (see the diagram below) – there are no species of negative energy quanta known to exist.



The Link Between Wormholes and Entanglement (EPR = ER)

The Link Between Wormholes and Entanglement

In recent years, physicists have begun exploring deep connections between wormholes and quantum entanglement, a conjecture often referred to as "EPR = ER". This conjecture suggests that Einstein-Rosen bridges (wormholes) and Einstein-Podolsky-Rosen entanglement (EPR) are interlinked: In this framework, a wormhole can be thought of as the geometric manifestation of entanglement, entangled particles might be connected by microscopic wormholes, providing a new way to think about the non-local behaviour of quantum systems (Susskind, 2016).

If confirmed, this conjecture would imply that quantum mechanics and spacetime geometry are fundamentally linked. While this doesn't solve the ansible problem outright, to keep an open mind, it might suggest that wormholes and entanglement might work together in some yet-unknown framework to enable faster-than-light communication. However, practical challenges, such as the stability of wormholes and the limitations of entanglement-based communication, remain unresolved.

Can Wormholes Solve the Ansible Problem?

At present, the answer is a tentative "no"—at least within our current understanding of physics. Wormholes offer inspiring glimpses of how nature might allow shortcuts in spacetime or instantaneous connections, but the practical solutions can only come via a breakthrough, or far in the future.
For now, the ansible still remains a work of fiction, but it is important to keep an open mind, mathematically and conceptually: as the interplay between our current understanding of physics and what's possible will always keep the field of physics reinvigorating.

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