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Title: Wormhole  
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Singapore Interior #300 from the photo archives of Jason Deckard, 2005

**In physics, a wormhole, also known as an *Einstein-Rosen Bridge* (and less commonly as an *Einstein-Rosen-Podolsky Bridge* or *Einstein-Podolsky-Rosen Bridge*), is a hypothetical topological feature of space-time that is essentially a “shortcut” through space and time. A wormhole has at least two mouths, which are connected to a single throat. Matter can “travel” from one mouth to the other by passing through the throat.**

The name “wormhole” comes from the following analogy used to explain the phenomenon: imagine that the universe is the skin of an apple, and a worm is traveling over its surface. The distance from one side of the apple to the other is equal to half the apple’s circumference if the worm stays on the apple’s surface, but if it instead burrows a wormhole directly through the apple the distance it has to travel is considerably less.

### **Wormhole types**

Intra-universe wormholes connect one location of a universe to another location of the same universe. A wormhole should be able to connect distant locations in the universe by bending space-time, allowing travel between them that is faster than it would take light to make the journey through normal space. See the image above. Inter-universe wormholes connect one universe with another [1], [2]. This gives rise to the speculation that such wormholes could be used to travel from one parallel universe to another. A wormhole which connects (usually closed) universes is often called a *Schwarzschild wormhole*. Another application of a wormhole might be time travel. In that case it is a shortcut from one point in space and time to another. In string theory a wormhole has been envisioned to connect two D-branes, where the mouths are attached to the branes and are connected by a flux tube [3]. Finally, wormholes are believed to be a part of space-time foam [4]. There are two main types of wormholes: Lorentzian wormholes and Euclidean wormholes. Lorentzian wormholes are mainly studied in semiclassical gravity and Euclidean wormholes are studied in particle physics. Traversable wormholes are a special kind of Lorentzian wormholes, which would allow a human to travel from one side of the wormhole to the other. Serguei V. Krasnikov tossed the term space-time shortcut as a more general term for (traversable) wormholes and propulsion systems like the Alcubierre drive and the Krasnikov tube to indicate hyperfast interstellar travel.

### **Theoretical basis**

It is unknown whether (Lorentzian) wormholes are possible or not within the framework of general relativity. Most known solutions of general relativity that allow for wormholes require the existence of exotic matter, a theoretical substance which has negative energy density. However, it has not been mathematically proven that this is an absolute requirement for wormholes, nor has it been established that exotic matter cannot exist. Recently Amos Ori envisioned a wormhole, which allowed time travel, did not require any exotic matter, and satisfied the weak, dominant, and strong energy conditions [5]. Since there is no established theory of quantum gravity, it is impossible to say with any certainty whether wormholes are possible or not within that theoretical framework.

### **Traversable wormholes**

Lorentzian traversable wormholes would allow travel from one part of the universe to another part of that same universe very quickly or would allow travel from one universe to another universe. Because wormholes not only connect spatial locations they would also allow time travel.

### **Wormholes and faster-than-light space travel**

Often there is confusion about the idea that wormholes allow superluminal (faster-than-light) space travel. In fact there is no real superluminal travel involved. Assume that the wormhole connects two remote locations. While traveling through a wormhole subluminal (slower-than-light) speeds can be used. The time in which the distance was traveled would appear faster than it would take light to make the journey through normal space.

### **Wormholes and time travel**

A wormhole could potentially allow time travel. This could be accomplished by accelerating one end of the wormhole relative to the other, and then sometime later bringing it back; relativistic time dilation would result in less time having passed for the accelerated wormhole mouth compared to the stationary one, meaning that anything which entered the stationary wormhole mouth would exit the accelerated one at a point in time prior to its entry. The path through such a wormhole is called a closed time-like curve, and a wormhole with this property is sometimes referred to as a “timehole.”

It is thought that it may not be possible to convert a wormhole into a time machine in this manner, however; some mathematical models indicate that a feedback loop of virtual particles would circulate through the timehole with ever-increasing intensity, destroying it before any information could be passed through it. This has been called into question by the suggestion that radiation would disperse after traveling through the wormhole, therefore preventing infinite accumulation. There is also the Roman ring, which is a very stable configuration of more than one wormhole. This ring allows a closed time loop with stable wormholes. The debate on this matter is described by Kip S. Thorne in the book *Black Holes and Time Warps* [6], and will likely require a theory of quantum gravity to resolve.

Many physicists, including Stephen Hawking (see Hawking’s Chronology Protection Conjecture), believe that due to the problems a wormhole would theoretically create, including allowing time travel, that something fundamental in the laws of physics would prohibit them. However, this remains speculation, and the notion that nature would censor inconvenient objects has already failed in the case of the cosmic censorship principle.

### **Schwarzschild wormholes**

Wormholes known as Schwarzschild wormholes are theoretical bridges between areas of space that are thought to be found in the center of a black hole and white hole, joining two universes. They exist in solutions to Einstein’s equations, and are thought to be

extremely unstable, and would instantly fall apart once created. Some speculation exists that quasars are actually white holes instead of supermassive black holes.

It is impossible for a traveler to go through this type of wormhole because they can only go through a horizon in one direction. If the traveler is formed of non-exotic matter once they reach the center of the Schwarzschild wormhole then, they can't leave the other side, and they can't leave through where they came since the side they came in though was a black hole, meaning nothing can escape it once inside the Schwarzschild radius.

### **Wormholes in fiction**

Wormholes are also a feature of science fiction.

They are a centerpiece of Carl Sagan's novel *Contact*, for which Kip Thorne advised Sagan on the possibilities of wormholes.

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The setting of the television series *Star Trek: Deep Space Nine* is a space station, *Deep Space Nine*, located near the Bajoran wormhole. Wormholes are also the principal means of space travel in the *Stargate* movie and the spin-off television series, *Stargate SG-1* and *Stargate Atlantis*. The central plot device of the programs is a transportation network consisting of the ring-shaped devices known as Stargates, which generate wormholes that allow one-way matter transmission between gates when the correct spatial coordinates are "dialed." The television series *Farscape* features an American astronaut who accidentally gets shot through a wormhole and ends up in a distant part of the universe, and also features the use of wormholes to reach other universes (or "unrealized realities") and as weapons of mass destruction.

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In the FOX/Sci-Fi series *Sliders*, a method is found to create a wormhole that allows travel not between distant points but between different universes; objects or people that travel through the wormhole begin and end in the same location geographically (e.g. if one leaves San Francisco, one will arrive in an alternate San Francisco) and chronologically (if it is 1999 at the origin point, so it is at the destination, at least by the currently-accepted calendar on our Earth.) This series presumes that we exist as part of a multiverse and asks what might have resulted had major or minor events in history occurred differently; it is these choices that give rise to the alternate universes in which the series is set. The same premise is used in the *Star Trek: the Next Generation* episode "Parallels".

In *Star Trek: The Motion Picture*, Willard Decker recalls that "Voyager 6" (a.k.a. V'ger) disappeared into what they used to call a "black hole." At one time, black holes in science fiction were often incorrectly endowed with the traits of wormholes. This has, for the most part disappeared as a black hole isn't really a hole in space but a dense mass and the visible vortex effect often associated with black holes is merely the accretion disk of visible matter being drawn toward it. Decker's line is most likely to inform that it was probably a wormhole that Voyager 6 entered.

In 2000, Arthur C. Clarke and Stephen Baxter co-wrote a science fiction novel, *The Light of Other Days*, which discusses the problems that arise when a wormhole is used for faster than light communication.

A related method of faster-than-light travel that often arises in science fiction, especially military science fiction, is a “jump drive” that can propel a spacecraft between two fixed “jump points” connecting solar systems. Connecting solar systems in a network like this results in a fixed “terrain” with choke points that can be useful for constructing plots related to military campaigns. The Alderson points postulated by Larry Niven and Jerry Pournelle in *Mote in God's Eye* and related novels is an especially well thought out example. The development process is described by Niven in *N-Space*, a volume of collected works. David Weber has also used the device in the *Honorverse* and other books and has described a ‘history’ of development and exploitation in several essays in collections of related short stories.

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*The Commonwealth Saga* by Peter F. Hamilton describes how wormhole technology could be used to explore, colonize and connect to other worlds without having to resort to traditional travel via starships. This technology is the basis of the formation of the titular Intersolar Commonwealth, and is used so extensively that it is possible to ride trains between the planets of the Commonwealth.

Richard Kelly’s science-fiction movie, *Donnie Darko*, also explores the possibility of the existence of wormholes in the universe. While in the original theatrical release, the relevance of wormholes to the plot is unclear, in the Director’s Cut, the “book” *The Philosophy of Time Travel* is presented in more depth. In this version, the wormhole is the path connecting the real universe, and the parallel universe, which in the movie lasts from the jet engine crashing into the Darko family home until Halloween when the actual jet loses its engine to the wormhole, at which point the parallel universe collapses.

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Lois McMaster Bujold uses wormholes as a major transportation system in the *Miles Vorkosigan* novels. Control over wormhole routes and jumps even become the basis for war.

*This text is taken from Wikipedia.org.*