Passages through Enclosures and the Spacetime Continuum in English and American Science Fiction

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For Lena and Elisa

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PREFACE

This book comprises a collection of 8 peer-reviewed chapters written by scholars from around the globe who came together in their shared interest to offer new and innovative approaches to the analysis of science fiction, focusing on passages across enclosures and the spacetime continuum in this genre. Though the subject of supernatural passages across enclosures, time and space is rather common in science fiction literature, there are no comprehensive studies dedicated to it. This is the first collection focused on the concept of passages in English and American science fiction; the concept of passages is intended here in its widest sense, which reflects the rich variety of uses and interpretations of this concept in the science fiction, starting from the passages to another time or universe to mental journeys, passages to a higher plane of freedom and development of the human species.

The rich variety of analytical tools offered in the book makes it attractive both for academic researchers and fans of science fiction, who are interested in understanding the philosophical and scientific mechanisms behind this very popular concept of passages in works by Isaac Asimov, Philip K. Dick, Carl Sagan, Suzanne Collins, Ted Chiang, Murray Leinster, Olaf Stapledon, and other English and American science fiction writers.

More and more scholars agree that science fiction is one of the few literary genres very closely concerned with the analysis and improvement of society. From this point of view, the variety of new perspectives offered in this book on passages, their use in science fiction and their relation to the real world can promote understanding, cooperation, peaceful coexistence and religious tolerance in contemporary society. Using contemporary research methods, including mixed methods research, the authors offer insights into the ways in which science fiction, its analysis and perception are continuously changing and evolving to face constant challenges of modern society.

CHAPTER I

PASSAGES THROUGH SPACETIME: SCIENCE AND FICTION

BOYARKINA IREN

Outline

This chapter offers a brief overview of the main stages of development of scientific ideas about passages through the spacetime continuum, be it passages connecting different points in space or time in the same world / universe or passages between different worlds and universes. Though at the moment humanity lacks the necessary coherent scientific theories and technology for the construction and exploitation of these passages, hard science fiction writers are exploring this topic very actively and enthusiastically, given its potential importance for the human species in the future. The chapter focuses both on passages through the spacetime continuum in science and in science fiction.

Introduction

Nowadays, many people that have no relation to the world of science, consider science fiction to be superficial fantasies of science fiction writers that are only suitable for trapping the immature minds of teenagers. In reality, a good science fiction work is often based on solid scientific theories or some promising hypotheses that have not been definitely dismantled by scientific experiments. Very often science fiction, especially hard science fiction, is written by professional scientists (suffice it to mention Isaac Asimov, Sir Arthur C. Clarke, Stephen Baxter, Carl Sagan, etc.) who wished and still wish to popularize their ideas about science and society. In fact, science fiction is one of the few literary genres very closely concerned with society and its development and improvement. (Boyarkina 2016). Science fiction is important because it can be viewed as a scientific research laboratory that studies the viability of various scientific, social, philosophical and other ideas.

This book focuses on passages through the spacetime continuum and enclosures in science fiction. Though at the moment humanity lacks the necessary coherent scientific theories and technology for the construction and exploitation of these passages, hard science fiction writers are exploring this topic very actively and enthusiastically, given its potential importance for humanity in the future. Some of the potential uses of the passages through the spacetime continuum are space travel and space exploration, as well as escape from our planet to safer worlds. For example, the activity of the sun, such as superflares, can be threatening to humanity, since "recently, scientists from Harvard University presented plausible proof of existing connections between these superflares and life extinction on Earth". (Boyarkina 2019, 234). Also, the Solar system will cease to be a safe habitat for humanity after 2.5 - 5.5 billion years due to the explosion of the Sun. The collision of our galaxy with the Andromeda galaxy is another potential fatal danger to humanity. Indeed,

> Modern science has demonstrated that our Universe in general, and Solar system in particular, are not such safe places to live in as we are used to thinking. Deadly solar radiation, supernova explosions, comets, asteroids, changes of planet orbits, solar superflares – the list of fatal dangers has impressively extended, providing science fiction writers with almost unlimited possibilities for apocalyptic fiction. (Boyarkina 2019, 224)

However,

> Even if the human species manages to cleverly prevent these various catastrophes and transcends to a higher level of existence it still has to face the inevitable (as seen at the moment by the Standard Cosmological model) disintegration of the baryon (visible) matter in the universe, i.e. the death of the universe, caused by its accelerating expansion. The accelerated expansion of the universe is caused by the antigravitational qualities of the recently discovered dark energy, whose density is constant. Thus, in the end, intelligent life in the universe will have to face the death of the universe […], caused by dark energy. Modern science cannot offer any solutions to this problem; hypothetically, some solutions can be found beyond the Standard Cosmological model. (Boyarkina 2019, 126)

No wonder some scientists consider an escape to other worlds to be the only salvation possible. Given vast cosmic distances and the brevity of human life, the demand to reduce the time of travel is understandable and the use of various "supernatural" passages in the spacetime continuum (like black holes, wormholes, etc.) is also being considered, though very hypothetically at this stage. According to Don Nardo, another potential use of studying black holes, wormholes, is as follows:

> the more people learn about these cosmic oddities, the more they will be able to reveal the hidden secrets of the universe. Moreover, learning as much as possible about the properties of black holes could conceivably prove beneficial to humanity. Someday it may be possible to harness and utilize some of the vast energies produced by these objects. (Nardo 2004, 44)

However, while physicists and mathematicians are carrying out various experiments and performing necessary calculations, being very careful with their final conclusions and predictions, science fiction writers are making widespread use of various supernatural passages in their fiction, as this book is going to demonstrate.

Other Worlds and Passages through Spacetime: from Antiquity to our Days

Let us start with a brief overview of the main stages of development of scientific ideas about passages through the spacetime continuum, be it passages connecting different points in space or time in the same world / universe or passages between different worlds and universes.

The existence of other worlds has been hypothesized by thinkers, philosophers and scientists since the times of antiquity; this idea we can encounter already in Buddha, Democritus, St. Augustine, Nicholas de Cusa, Giordano Bruno, Kant, Bernard Le Bovier de Fontenelle, etc. (Steven 1984)

Also, the concept of passages between these different worlds and through various enclosures is not new and dates back at least to the myths of Ancient Greece and the Bible, with its enclosures of Eden, Hell, Paradise, to name just a few examples. Another famous work of literature featuring various passages through enclosures and spacetime is *The Divine Comedy* by Dante Alighieri, where Virgil travels through time and space to visit Purgatory, Hell, Paradise, etc., where he encountered the souls of sinners and righteous people. In fact, both *the Bible* and *The Divine Comedy* are of fundamental importance for the genre of science fiction. They constitute the ultimate horizon for the genre of science fiction, as Darko Suvin observes.

Many works of literature feature supernatural passages to our world, for example, *The Divine Comedy*, various myths and innumerable religious writings. They depict immortal souls and all emphasize that the souls belong to other worlds, not to ours. Hence, the idea that souls, spirits and ghosts come to our 4-dimensional world from the worlds with various numbers of dimensions is not new and has been for centuries developed by many thinkers and writers.

The existence of these hypothetical elusive parallel worlds has also produced endless religious speculations. Mystics and spiritualists have wondered whether the souls of departed loved ones passed to another dimension(s), or to the worlds/universes with a various number of dimensions. Moreover, recently also some prominent scientists in the field of biology, transplantation, stamina cells and cloning, such as professor Robert Lanza and his colleagues, proposed a similar idea in their books. (Lanza, Berman 2009; Lanza, Berman 2016)

Thus, for centuries, mystics, writers, and philosophers, recently joined also by certain scientists, have been speculating about the existence of other worlds (and universes) undetectable by human senses, yet coexisting with our universe, as well as about the possibility of passages between them. No doubt, all these people have been intrigued by the possibility that these unexplored worlds may even be tantalizingly close, in fact surrounding us and permeating us everywhere we move, yet just beyond our physical grasp and eluding our senses. Such ideas, however plausible they seemed to their authors, ultimately proved useless because there was no practical way in which to mathematically express and eventually test these ideas about other worlds, until the first revolutionary breakthrough in the development of the idea of higher-dimensional spaces and the theoretical possibility of passages between them took place on June 10, 1864, when a new type of geometry was developed.

The theory of higher dimensions was presented by Georg Riemann in his celebrated lecture at the University of Gottingen. Riemann demonstrated the properties of higher-dimensional space and his profoundly important essay "On the Hypotheses Which Lie at the Foundation of Geometry" shattered the foundations of classical Greek (Euclidian) geometry, in which all geometric figures are two or three dimensional. Riemann demonstrated that these (higher-dimensional) universes are completely self-consistent and obey their own inner logic. Following the logics of the theory of higher dimensions, our universe might not be alone, but would be one of many possible parallel worlds, some of them might be inhabited by intelligent beings that are completely unaware of the existence of other universes and civilizations.

Since this book focuses on passages through spacetime, it should be emphasized that Riemann was also one of the first scientists to discuss (though at the level of mathematics only) multiply connected spaces, or wormholes. Indeed, Riemann's cuts can be viewed as an example of a wormhole with zero length connecting two spaces. Although there is no proof that Riemann entertained a possibility to use his cuts for traveling to different worlds and universes, a mathematician and writer Lewis Carroll (Charles Dodgson) very vividly demonstrated how Riemann's cuts can be used as supernatural passages by the protagonists of *Alice Through the Looking-Glass* (1871). The mirrors in this book can be considered wormholes / Riemann's cuts with zero length connecting our real world to the alternative world behind the glass.

Clearly, Riemann did much more than lay the foundation of the mathematics of hyperspace (also this term has been very enthusiastically used by science fiction writers ever since, for example, by Isaac Asimov, Arthur C. Clarke, etc.). The German scientist anticipated some of the major themes in modern physics. As Kaku correctly observes,

1. Riemann used higher-dimensional space to simplify the laws of nature; that is, to him, electricity and magnetism as well as gravity were just effects caused by the crumpling or warping of hyperspace.
2. He anticipated the concept of wormholes. Riemann's cuts are the simplest examples of multiply connected spaces.
3. He expressed gravity as a field. The metric tensor, because it describes the force of gravity (via curvature) at every point in space, is precisely Faraday's field concept when applied to gravity. (Kaku 1994, 43)

Riemann's heritage is of great importance for this book for several reasons. First, he introduced the concept of higher-dimensional space, a hypothetical possibility of the existence of other worlds with a varying number of dimensions. Second, he mathematically postulated the possibility of passages between these worlds, called Riemann's cuts, or zero length wormholes. Also, Riemann's study of gravity and warping of hyperspace paved the way for Einstein's relativity, which postulated that the gravity of extremely massive objects curves the spacetime continuum around them into tunnels that hypothetically might serve as passages between two different points in time or space in the same universe or might connect different universes.

Since gravity as the force curving the spacetime continuum around very massive objects is important for this book, we should remember that like Newton, also Riemann "stood on the shoulders of giants" in his study of gravity, his research was grounded in the Newtonian laws of gravity, who in his turn used the works on gravity by Johan Kepler and Tycho Brahe.

Unfortunately, at that time Riemann lacked the field equations that electricity, magnetism and gravity obey, which appeared later. Hence, he could not finish his work on force fields. Riemann did not know precisely how the universe would be crumpled in order to yield the force of gravity (and the curvature of space time is crucial for the creation of passages in spacetime). The scientist had been working on the field equations for electricity and magnetism for some time, but he died before he could finish the project; these crucial developments would be left to Maxwell and Einstein.

Nevertheless, Riemannian revolutionary geometry not only laid the foundation for Einstein's relativity but anticipated other major developments in physics as well and inspired numerous works of science fiction. As Kaku observes,

> Within 6 decades of Riemann's lecture, Einstein would use four-dimensional Riemannian geometry to explain the creation of the universe and its evolution. And 130 years after his lecture, physicists would use ten-dimensional geometry to attempt to unite all the laws of the physical universe. The core of Riemann's work was the realization that physical laws simplify in higher-dimensional space. (Kaku 1994, 30-31)

Indeed, nowadays scientists use ten and twelve dimensions in the attempt to create a unified field theory. However, it should be pointed out that the number of dimensions can differ not only between different worlds but within the same world due to the phenomenon known as compactification of dimensions. Some scientists believe that due to certain evolution peculiarities, additional dimensions can appear or disappear (become compactified). For example, the notion of dimension compactification is also present in the Big Bang theory. At the moment of singularity and explosion, the number of dimensions was much more than the current 4 dimensions. According to scientists, the expansion of the universe and lowering of the temperature, as well as the spontaneous symmetry breaking caused the compactification of the initial dimensions to 4. (Boyarkin 2011, 97)

Riemannian geometry greatly influenced not only the development of the sciences but also the future of the arts and literature in general and sf literature in particular, giving artists and writers the possibility to play with the idea of strange worlds with varying numbers of realities and dimensions. Soon, Einstein introduced time as the fourth dimension in his relativity theory, and the idea of the fourth dimension penetrated the arts, philosophy, and literature; it appeared in the works of H.G. Wells, Olaf Stapledon, Oscar Wilde, James Joyce, and Fyodor Dostoyevsky.

As soon as Einstein published his special (1905) and in 1915 - general relativity he started looking for solutions to his field equations that mathematically connected space, matter, and time. Einstein showed that space is curved by a high concentration of mass (or energy, which is mass equivalent). When the mass is extremely large, such a curvature becomes a tunnel, later called a «wormhole». Thus, the theory of gravity by Einstein (relativity) paved the way and laid the physical foundations for passages to other worlds, although such tunnels through the spacetime continuum were unlikely to exist in reality. Hence, Einstein's relativity became the milestone for the concept of passages in the spacetime continuum, both in science and in science fiction literature. It is important to emphasize that the concept of a wormhole is connected to the concept of a black hole, a massive object able to curve the spacetime continuum into a tunnel. Theoretically, the existence of massive objects like black holes was already predicted (independently) by John Michell, "all light emitted from such a body [black star] would be made to return towards it, by its own proper gravity" (Michell 1784, 42) and Pierre-Simon Laplace:

> The gravitation attraction of a star with a diameter 250 times that of the Sun and comparable in density to the earth would be so great no light could escape from its surface. The largest bodies in the universe may thus be invisible by reason of their magnitude. (Laplace 1796, 305)

Contrary to common belief, wormholes are not mere commonplace inventions of science fiction writers' imaginations, impressive and spectacular as they are, but were discovered mathematically in 1916 as a singularity in a solution to Einstein's field equation. Since then, there have been a number of crucial points in the history of wormhole physics.

It was the German astronomer Karl Schwarzschild, who found the first exact solution of Einstein's field equations. However, this solution contained a singularity and hence, predicted the existence of "black holes", massive bodies hypothesized by Laplace and Michell some centuries earlier. The black hole obtained as the solution by Schwarzschild contains a singularity at its centre. It is a point of infinite density, where time itself comes to an end and the laws of physics (as we know them now) do not work. Hence, the Schwarzschild solution described the changes in the spacetime continuum inflicted by the gravitational field generated by the spherical concentration of mass. Thus, Schwarzschild's result contained a singularity that described for the first time a black hole in space.

However, neither Einstein, nor other scientists were happy with this solution, since usually mathematicians try to avoid singularities in the solutions of equations by choosing parameters accordingly, because singularities violate traditional, generally accepted demands imposed on solutions, such as unambiguity, finiteness, etc. Thus, Einstein decided to look for the solutions that do not contain any singularity (as in the case of Schwarzschild's solution). Hence, together with his collaborator Nathen

Rosen, he employed a mathematical method of a co-ordinate transformation and rewrote the solution obtained by Schwarzschild in order to avoid a singularity, the endpoint of space and time. Nevertheless, their solution was also very strange and unexpected: the singularity became a bridge between our Universe and a universe that would have split off from our universe as a result of quantum mechanics, as Everett's interpretation of quantum mechanics predicted. The MWI is studied in more detail in chapter 2. In 1935 Einstein and Rosen published their results and this bridge was named the Einstein-Rosen bridge. Einstein considered this passage, connecting two spacetimes, to be a mere theoretical exercise in geometry. Actually, there is no evidence demonstrating that Einstein really believed in the existence of such a bridge; for him, also singularities did not really exist. According to the scientist, this was just an oddity of the general relativity's mathematics, one of the many possible solutions of its equations. Such passages between different worlds were not new then, suffice it to consider Riemann's cut, Lobachevsky's geometry, etc. And nobody actually believed that they could become passages leading to other universes.

For example, in the case of the Einstein–Rosen bridge, the first obstacle to face is the event horizon: once you get into a black hole you cannot come back out again. To allow the possibility to get out on the other side of the black hole, it has to be hooked up to a white hole. Unlike a black hole that attracts all matter, a white hole expels the matter from inside. Hence, no matter can come into a white hole, so it is a one-way passage only. Besides, an antihorizon must surround such a white hole, allowing one-way traffic out and never in, contrary to what an event horizon does. Antihorizons, being highly unstable, may transform into normal ones immediately after their formation. However, not only is the antihorizon unstable but the whole Einstein–Rosen bridge is highly unstable. To summarize the possibility of humans using it as a passage through spacetime (obviously, from the current scientific point of view, which is not always shared by science fiction writers):

> The connection would only survive for a fraction of a second before pinching off. In fact, so short is the lifetime of the bridge that not even light travels fast enough to get through. So if you were ever to jump into a black hole in the hope of getting across, you would always get caught in the singularity, and having one's body squeezed down to a size much smaller than an atom is never very desirable. All this is assuming you weren't ripped apart by the tidal forces of gravity before you reached the singularity. The black hole would have to be a supermassive one for you to even survive going through the horizon. (Al-Khalili 1999, 196)

Taking all this into consideration, it becomes clear that Einstein–Rosen bridges at present cannot be viewed as safe passages through the spacetime continuum, be it to parallel universes, different time or to remote regions in our universe.

Another important period in wormhole physics was in the 1950s, when John Wheeler and his research group studied wormholes extensively, by a variety of mathematical calculations. It should be emphasized that Wheeler was working on microscopic (quantum) wormholes. Quantum mechanics studies spacetime on the minutest possible scale where everything becomes fuzzy and uncertain, even spacetime becomes frothy and foamy. At this level, strange structures, including quantum wormholes, can form at random. As Thorne recalls about his teacher's work:

> Wheeler identified the Planck length as the characteristic length scale for quantum gravity effects, and he argued that on this length scale space should exhibit quantum foam: a foam of randomly fluctuating curvature and topology, including microscopic wormholes – handles in the structure of space first described classically by Herman Weyl in 1924, and explored in depth by John and his entourage in the 1950s and early 1960s. (Thorne 2008)

Wheeler's research resulted in the assumption that one way of creating a wormhole would be to enlarge such a quantum wormhole. Down at the smallest length scale and trillions of times smaller than atoms (known as the Planck scale) the concept of length loses its meaning. At this level quantum uncertainty rules, all known laws of physics break down and even space and time become nebulous concepts. This is where all possible distortions of spacetime pop in and out of existence in a random and chaotic dance, which is going on all the time everywhere in the Universe. Such processes are referred to as 'quantum fluctuations' and the 'quantum foam'. This is where Wheeler's microscopic wormholes will exist fleetingly before disappearing, and spacetime is said to be 'multiply connected'. The trick would be to somehow capture one of these quantum wormholes and pump it up to many times its original size before it has a chance to disappear again. Though this idea seems strange, one should keep in mind that these conditions already existed at a certain point of evolution of our Universe - in its beginning.

The quintessence of Wheeler's research can be found in the seminal papers on quantum wormholes (Wheeler 1957; Wheeler 1962; Misner & Wheeler 1957). In short, electric charge was claimed to be a manifestation of the topology of a space, which essentially looked like a sheet with a handle. This was given the name 'wormhole' by Wheeler that has been used in physics ever since. In his paper on geometrodynamics, Wheeler tried to understand what shapes spacetime could be twisted into; it was purely theoretical and had nothing to do with the use of wormholes for humans to travel through.

Another important breakthrough in wormhole physics (and in the evolution of science fiction about passages through spacetime) dates back to 1963 when Roy Kerr, a mathematician from New Zealand demonstrated that Einstein's equations actually predicted the existence of a completely new kind of a singularity: a spinning black hole. It took some time to discover that the solution obtained by Kerr is applicable to all spinning stars collapsed to black holes. Taking into consideration that all stars are spinning on their axes, it turns out that Kerr's black holes can be considered more realistic and more widely spread than non-spinning singularities obtained in Schwarzschild's solution. Since a black hole is much more compact than the original star it is formed from, it must spin much faster than the original star. However, the most important peculiarity of Kerr's singularity that particularly inspired science fiction writers and fans is that it is not a zero-sized point, as it is the case with the center of Schwarzschild singularity. Kerr's black hole is ring-shaped with empty space in the center of the ring. All the matter in Kerr's spinning black hole is concentrated along the perimeter of the ring, which has almost zero thickness and nearly infinite density. Depending on its mass and spin, such a ring singularity can have a diameter large enough for humans (and spaceships) to travel through that makes it a rather popular passage through the spacetime continuum in science fiction. However, Kerr's singularity has another important difference compared to Schwarzschild's singularity: the former is surrounded also by a second horizon (Cauchy horizon) that delineates the boundary after which no light from the outside Universe can be detected. Having crossed the boundaries of the outer event horizon, it is impossible to come back anyway, however, the light from the universe can still be seen, though bent and focused by the singularity's gravity. According to the scientists, Kerr's singularity has one more interesting peculiarity:

> as you fall closer towards the Cauchy horizon. Because your time is running more and more slowly, time outside is speeding up until, at the Cauchy horizon, time outside is running infinitely fast and you would literally see the whole future of the Universe flash before you at the instant you pass the horizon. So, just when you would expect to see your whole past flash before your eyes, you see the entire future instead. (Al-Khalili 1999, 201)

It is fascinating to observe how this prediction of the time flow inside and around Kerr's singularity was skillfully and correctly described in one of the most impressive and spectacular works of science fiction of the XXth century- *Star Maker* (1937) by Olaf Stapledon, written well before the discovery of Kerr's singularity.

As was already mentioned, singularities present too many problems for travel in space and time; the main problem with using singularities as passages through spacetime is their instability and the presence of event horizons (sometimes even two of them, as is the case with a Kerr's singularity). The event horizon permits travel only in one direction and it hides a singularity, makes it invisible, so it is even impossible to calculate the correct angle to enter the singularity. The inner horizon, or the Cauchy horizon is where the infinite blueshifted radiation is. Thus, to use these singularities as passages, one should get rid of these horizons, obtaining a naked singularity. Theoretically it is possible and scientists have put forward some suggestions:

> There are a number of ways of (maybe) getting a naked singularity. One is through Hawking radiation, whereby a black hole gradually evaporates until its horizon shrinks away completely, leaving behind the exposed singularity. But this is still highly controversial and many physicists believe that when a black hole evaporates completely nothing is left behind. In any case, this is only likely to happen to very tiny black holes and it is no good waiting around for a rotating supermassive one to evaporate. (Al-Khalili 1999, 203)

Astrophysicists analyzed some computer simulations which demonstrate that a black hole might be stripped of its horizons also in other ways. By spinning a black hole fast enough, it would be possible to extend further out its Cauchy horizon, enabling it to get closer to the outer event horizon. At a certain spinning speed, the two horizons would overlap and cancel each other out, disappearing, according to the mathematical calculations. Thus, a naked singularity would be formed. Nowadays, physicists still do not believe that it is possible for humans to safely traverse even a naked Kerr's black hole in order to get to a distant point in our universe or in another universe. One of the reasons for this is that a passage through a singularity might imply also travel in time (as was demonstrated by Morris, Thorne, and Yurtsever in 1988) and that is not a possibility many physicists are really willing to consider! In 1988 Morris and Thorne published a paper dedicated to wormholes as passages through spacetime: "Wormholes in spacetime and their use for interstellar travel: A tool for teaching general relativity." The authors observe that many objections are given against the use of black holes or Schwarzschild's wormholes as passages for interstellar travel. They emphasize that

> A new class of solutions of Einstein field equations is presented, which describe wormholes that, in principle, could be traversed by human beings. It is essential in these solutions that a wormhole possesses a throat at which there is no horizon; and this property, together with the Einstein field equations, places an extreme constraint on the material that generates the wormhole's spacetime curvature. […] However, it is not possible today to rule out firmly the existence of such material; and quantum field theory gives tantalizing hints that such material might, in fact, be possible. (Morris, Thorne 1988)

In 1988, prestigious *Physical Review Letters* published "Wormholes, Time Machines and Weak Energy Condition" by Nobel Prize winner (2017, shared with Barish and Weiss) physicist Kip Thorne of the California Institute of Technology and his collaborators Morris and Yurtsever. The paper addressed three main issues: whether the laws of physics permit an arbitrary advanced civilization to construct and maintain wormholes for interstellar travel and whether it is possible to convert such wormholes into a time machine. The authors made a rather astonishing and risky suggestion that the creation of a wormhole, as well as its maintenance and conversion into a time machine might be possible under certain conditions, which can be reached by the careful choice of topology of spacetime (i.e. the choice of spacetime intervals ds2.)

Morris, Thorne and Yurtzever proceeded from the assumption that "The Schwarzschild's metric, with an appropriate choice of topology, describes such a wormhole […] which links widely separated regions of the universe." (1988) However, as was said earlier, the Schwarzschild wormhole's horizon prevents two-way travel and is highly unstable. The authors suggested the following solutions for these problems: "To prevent pinch off (singularities) and horizons, one must thread the throat with non-zero stress and energy," in the paper it is referred to as "weak energy condition" or exotic matter. The exotic matter possesses antigravitational properties and can compensate the gravity force inside a wormhole, thus preventing its pinch off. (Morris, Thorne, and Yurtzever 1988)

As it is known, the first experiments related to exotic matter date back to the experiments with the Casimir vacuum in 1948. Morris, Thorne and Yurtzever intended to use the Casimir vacuum for the production of exotic matter, which, according to modern experiments is the cosmic vacuum (dark energy) discovered in 1998 and 1999 (Chernin 2005, 43).

It should be stressed that the amount of the exotic matter obtained in the Casimir vacuum is negligibly small, while, according to Matt Visser, the amount of the exotic matter necessary to stabilize a wormhole of 1 meter in diameter is equal to the mass of Jupiter. It means that the creation and maintenance of a wormhole may require vast amounts of energy beyond what will be technically possible for centuries to come.

Passages in Time: Time Machines

According to Morris, Thorne and Yurtzever (1988), the possibility of time travel is based on the observation that a wormhole connects two regions that exist in different time periods. Thus, the wormhole may connect the present to the past. Since travel through the wormhole is nearly instantaneous, one could use the wormhole to go backward in time.

It should be observed that this was not the only time machine concept proposed for the attention of the scientific community that has been toying with the idea of time travel already for some time. The bold idea about the possibility to travel in time was already in the air at the end of the XIXth century, *The Time Machine* by H.G. Wells (1895) being one of its best manifestations. Only 20 years later relativity provided some theoretical bases that hypothetically allowed time travel. It contains "time loops" or "closed time-like curves" i.e. paths theoretically allowing time travel into the past. Another possibility - a tunnel obtained due to the curvature of spacetime near extremely massive bodies. However, the possibility of time loops and singularities as solutions to Einstein's field equations of general relativity has been known but not really taken seriously as a workable time machine concept but as a peculiar mathematical construct of relativity.

Actually, time machines can be roughly divided into 2 types: wormholes turned into time machines and time machines based on curving spacetime in the neighborhood of any massive object (spinning infinite cylinders, cosmic strings, etc.). Scientific principles that lie at the basis of time travel and main time machine types are described in several textbooks, articles and popular science editions (Davies 2002; Kaku 2008; Thorne 1994; Nahin 1998). In some of them the dates and description of working principles vary slightly but the list can be as follows:

1. According to Einstein, a flying rocket is a time machine heading to the future (1905).
2. Hungarian scholar Lanczos proposed the exact solution of Einstein's equation of gravitation with rotating matter (functions as a time machine) in 1923. His paper was reprinted in 1997 (Lanczos 1997).
3. A similar solution (independently) was suggested by a Dutch scholar and pilot Willem Jacob Van Stockum, in which an infinitely long and rapidly rotating cylinder functions as a time machine.

4. In 1948 (1949) Kurt Gödel found a solution to Einstein's equation that describes a rotating universe containing time loops which is stationary, i.e. does not expand or contract. In this universe, it is possible to travel backward in time by simply leaving Earth and then returning to it.
5. In 1974 Frank Tipler suggested a solution to Einstein's field equation that implied the creation of a time machine in a finite-sized region of space by using exotic material as a part of the machine. Also Morris, Thorn, and Yurtsever suggested in 1988 that any traversable wormhole (which can be converted into a time machine) must be threaded with exotic material. In the case of Tipler's time machine, the spacetime is warped by a massive cylinder spinning in space. In order to travel to the past, it is necessary to leave Earth in a spaceship, get close to the cylinder, orbit it several times and return to Earth, thus returning back in time.
6. Later it was suggested to substitute the massive rotating cylinder in Tipler's time machine with an infinitely long, dense spinning cosmic string (of exotic matter).
7. In 1991 Richard Gott suggested that instead of one spinning cosmic string, the same effect of curving spacetime and obtaining a time loop would be achieved by two strings moving at high speed past each other.

It is clear that the existence of such massive spinning objects capable of curving spacetime enough to allow time travel is rather questionable (at the moment). However, if the same function of spacetime warping can be performed by other massive spinning bodies, then time travel gets one small step closer. Some scientists believe that time travel may even be achieved not only by orbiting an infinite spinning cylinder or cosmic string, but by orbiting round a spinning neutron star or black hole, provided they were spinning fast enough. Moreover, such neutron stars (pulsars) that spin close to the required rate have already been found; they are called millisecond pulsars because their rate of spin is once every few milliseconds (a millisecond being one thousandth of a second).

As was said, the second group of time machines includes wormholes. Kip Thorne and his colleagues were even able to show

> how a wormhole that was not a time machine—in the sense that if you were to go through it you would emerge at the other end at a later time with the same amount of time having elapsed for you inside the wormhole as had gone by on the outside — could be turned into a time machine.

(1) Make a wormhole (by inflating one out of the quantum foam, or creating one from scratch by warping spacetime).
(2) Stabilize the wormhole (by keeping it open with exotic matter or cosmic string).
(3) Electrically charge one of the wormhole mouths (so that it can be moved about with an electric field) and load it onto a rocket.
(4) Induce a time difference between the mouths (by flying off at close to the speed of light with one of the mouths).
(5) Turn the wormhole into a time machine (by bringing the mouths closer together again). (Al-Khalili 1999, 227)

The main theoretical principles and conditions of time travel are known, while the technical means to ensure these conditions are missing at this stage of development of humankind. However, it is a natural course of events, from theoretical speculations to the factual realization of scientific projects. Suffice it to mention that travel in space or under water, (also considered as supernatural passages a long time ago), first appeared as bold fantasies in scientific romances, then as projects, calculations of engineers and then, finally, became reality. The same goes also for black holes. At the end of the XVIIIth century Laplace and Michell hypothesized the existence of highly massive bodies which gravity prevented even light from escaping their boundaries. At the beginning of the 20th century the existence of these heavenly bodies became more real, when a singularity (a black hole) turned out to be a solution to Einstein's field equations, yet they still seemed to be a rather hypothetical phenomenon, nothing more than a mathematical construct. However, the situation changed drastically after only a hundred years, when not only the existence of black holes become a reality but even a first image of a black hole (or rather, its halo) was obtained by the international network of radio telescopes called the Event Horizon Telescope (EHT) in April 2019. As was said, the gravity of a black hole prevents any matter, even light from escaping its boundaries, so it is not possible to take a picture of it. However,

> the hot disk of material that encircles it shines bright. Against a bright backdrop, such as this disk, a black hole appears to cast a shadow. The stunning new image shows the shadow of the supermassive black hole in the center of Messier 87 (M87), an elliptical galaxy some 55 million light-years from Earth. This black hole is 6.5 billion times the mass of the Sun. Catching its shadow involved eight ground-based radio telescopes around the globe, operating together as if they were one telescope the size of our entire planet. (Landau 2019)

Hence, in about two hundred years a black hole changed its status from a hypothetical object and protagonist of science fiction literature (called 'roman scientifique' in those days) to the status of a real physical object with certain physical characteristics. It is highly likely that the same will happen with wormholes, time travel and other supernatural passages considered in this book.

Of course, scientists have been skeptical about the very possibility of time travel. Stephen Hawking, the author of "A Brief History of Time" (2011) even introduced "Chronology Protection Conjecture" on time travel to the past. Soon, however, he became less skeptical. Science fiction writers, on the contrary, have been highly enthusiastic about time travel and widely explored it in their works. Actually, it was their optimism and enthusiasm that made scientists envy and finally Kip Thorne declared:

> Time travel was once solely the province of science fiction writers. Serious scientists avoided it like the plague—even when writing fiction under pseudonyms or reading it in privacy. How times have changed! One now finds scholarly analyses of time travel in serious scientific journals, written by eminent theoretical physicists...Why the change? Because we physicists have realized that the nature of time is too important an issue to be left solely in the hands of science fiction writers. (Thorne qtd in Nahin 1998, Introduction)

Like many other scientists, Thorne emphasizes the importance of understanding the true nature of time and the possibility to travel in time:

> If we could understand time deeply, then that understanding would produce breakthroughs in our comprehension of the universe. If the fundamental laws of physics permit time travel, even just on subatomic scales, then our present understanding of quantum mechanics is flawed in ways that would explain how information gets lost down black holes – and ways that may have profoundly affected the birth of the universe." (Thorne qtd in Nahin 1998, Introduction)

The words of Thorne about time travel vividly demonstrate that science and science fiction are closely connected, they find inspiration in each other and inspire each other, while looking for the ultimate truth about the nature of life and universe: "Smart physicists seek insight everywhere, including from smart science fiction writers who long ago started probing seriously the logical consequences that would ensue if the laws of physics permitted time travel". (Thorne qtd in Nahin 1998, Introduction)

Indeed, good science fiction and science interact closely and develop in a kind of symbiosis:

> Many significant works of science fiction can be viewed as a kind of a scientific research laboratory in which the important trends in the development of the society [and science] are studied, analyzed and extrapolated to an imaginary world for further analysis. This imaginary world is a metaphor, a model, which tests the viability of concepts and ideas of a science fiction writer [and a scientist]. (Boyarkina 2018, 101)

Conclusions

Science and good science fiction have the same targets to find the truth about the world around us. Though science fiction cannot provide mathematical calculations, it can produce powerful metaphors that very often lie at the basis of solid scientific theories (suffice it to mention a metaphor of elastic rubber balls for the ideal gas model). Karel Čapek first envisaged an intelligent machine and coined the term “robot” in science fiction; nowadays we observe these machines in reality. Travel to the Moon was first mentioned in science fiction (‘roman scientifique’ at that stage of the development of the genre) and then became a real fact, the same goes for travel to Mars, the submarine, etc. In *The War of the Worlds* Wells introduced a device similar to a laser, constructed by engineers a few decades later; in *Aelita* Alexey Tolstoy depicts an apparatus similar to a television/computer and some decades later it appears in reality. In the 1930s Wells and Stapledon describe atomic weapons and predict their potential danger for the total destruction of the human species, long before first atomic bombs exploded. Actually, the list can be really very long.

For those who are fascinated by the subject of passages in spacetime (wormholes, black holes, etc.), it is possible to suggest some further reading. While physicist Kip Thorne is one of the world’s leading experts on black holes and his books can be recommended on this subject, it is fair to say that the best known expert on wormholes is Matt Visser, who has written the first textbook devoted to the subject. Visser has also compiled a whole taxonomy of wormholes. He has shown that wormholes come in different phyla and species; the phylum of interest here is known as Lorentzian wormholes based on the way spacetime is warped to give rise to the wormhole. Here is a short passage from the beginning of Visser’s book *Lorentzian Wormholes: from Einstein to Hawking:*

> Even though wormhole physics is speculative, the fundamentals underlying physical theories, those of general relativity and quantum, are both well tested and generally accepted. If we succeed in painting ourselves into a corner surrounded by disastrous inconsistencies and imponderables, the

hope is that the type of disaster encountered will be interesting and informative. (Visser 1996)

In conclusion, I would like to emphasize that Visser's words about well tested and generally accepted fundamentals underlying physical theories relative to wormholes are also applicable to time travel and black holes, all of them considered here as (supernatural) passages through the spacetime continuum depicted in British and American science fiction literature.

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CHAPTER II

HUGH EVERETT'S MANY-WORLDS INTERPRETATION OF QUANTUM MECHANICS IN SCIENCE FICTION

ALEXEY DODSWORTH MAGNAVITA DE CARVALHO

Outline

The existence of a multiverse made up of multiple perhaps infinite alternates has been seriously considered by physicists since 1957, when Hugh Everett III proposed the *Relative State Formulation* theory also known as the theory of *Universal Wave Function*. Years later, Bryce DeWitt renamed and popularized Everett's theory by calling it *Many-Worlds Interpretation of Quantum Mechanics*. In short, such an interpretation states that it does not make any sense to describe our universe as *the best and only story* as proposed by the German philosopher Wilhelm Leibniz, since everything that can happen will happen or has already happened in some alternate universe. Contemporary physicists like David Deutsch and philosophers like David Lewis advocate that there are other universes where counterparts do exist. This chapter intends to explain the Many-Worlds Interpretation in more accessible words by demonstrating how this theory has been explored in several works of science fiction in contrast to traditional deterministic based plots.