Assignment #2
Process Description

How Time Travelling *Theoretically* Works

Lecture 002 - Tutorial 005

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Process

Over the years, the concept of time travelling has become a mainstay in pop culture. From movies to books, there is no escaping the intrigue that time travel inspires in people. However, how much of time travelling is based on science and how much is based on fictional writing? In reality, science suggests that not only is time travelling possible, but time travelling is constantly taking place. Time travel can be divided into two categories: forward and reverse. Forward and reverse time travel are intrinsically linked; for reverse time travel to work, forward time travel must first take place. Before reverse time travelling can be examined, forward time travelling must be understood.

Time was once thought to be absolute and to flow at a constant rate for all observers (known as Newtonian time).[1] Time is now understood to be malleable and dependent on various factors such as speed and mass proximity.[2] The passage of time is like a river: time can flow quickly or slowly depending on the location. In other words, the passage of time is not constant and hence can be controlled. In general relativity, all four dimensions in spacetime (x, y, z and time) curve under the presence of matter.[2] The curvature of spacetime due to the presence of matter explains the phenomenon of gravity (as seen in Figure 1). Hence, the presence of mass and the presence of gravitational fields are synonymous. As spacetime curves around matter, the net path taken increases. In essence, going from one point to another takes more time as the gravitational fields are increased. For example, satellites' clocks run slower than those found on Earth due to the lower gravity in space. The relative time increase due to gravitational fields is known as gravitational time dilation.

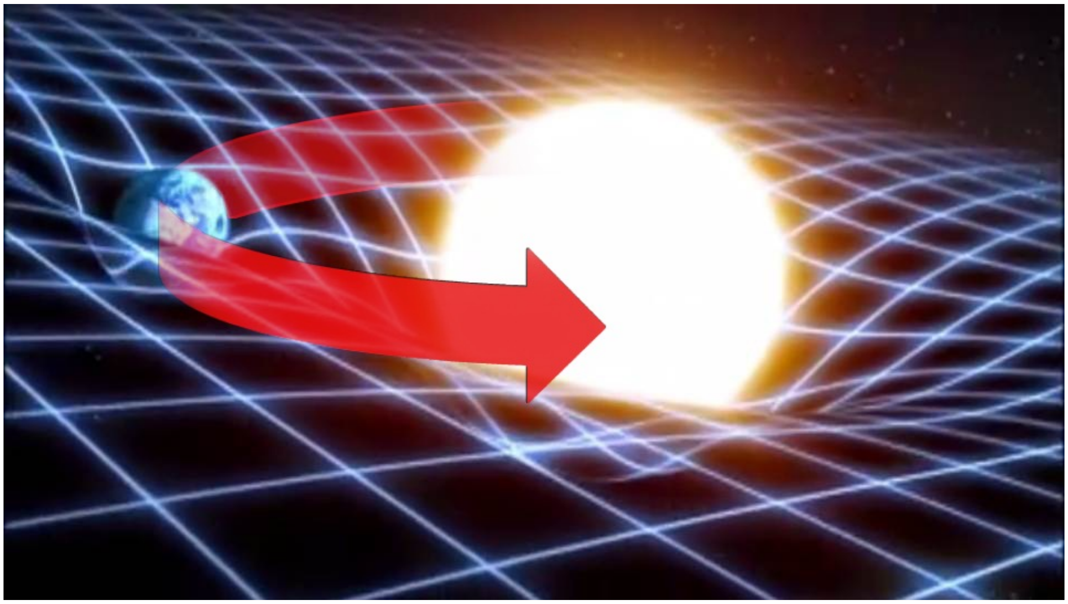

Figure 1. Curvature of spacetime causing gravity.[10]

Time dilation due to spacetime curvature is the founding principle of forward time travelling. To travel forward in time, an individual must occupy a region of space that contains stronger gravitational fields than those found on Earth. However, only an immensely large amount of mass can increase the strength of the gravitational fields to noticeably accelerate time. Over a year span on the sun's surface, an individual will have only travelled 66 seconds into the future (relative to Earth).[3] To travel a significant amount of time forward, an individual will need to closely pass by a mass on the scale of a black hole (as seen in Figure 2). Once such a destination is found, a spaceship can be placed on a trajectory so that the spaceship slingshots around the massive body and returns to Earth. How far forward in time the ship will travel will depend on how close the spaceship approaches the massive body and/or how much time the spaceship spends circling the massive body.

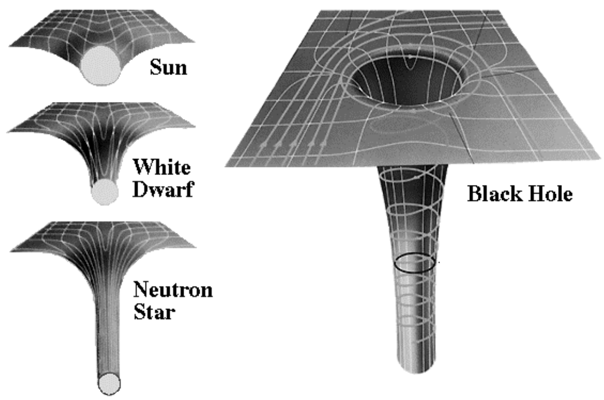

Figure 2. Spacetime curvature of massive bodies.[11]

To travel backwards in time, more complex theoretical science will be needed. There is no possible way under the currently understood laws of physics to reverse the flow of time. As a particle reaches the speed of light, time almost slows to a standstill, but never goes in reverse. Consequently, a method of transportation to the past is needed: a wormhole. As predicted by general relativity, wormholes (also known as Einstein-Rosen bridges) are shortcuts between two points in spacetime (as seen in Figure 3). Wormholes can be thought of as portals: enter one portal and exit the other. However, wormholes are only predicted to stably exist in nature with a diameter of about 10^{-35} m (about one trillion trillionth of the radius of an electron).[4, 5] Wormholes large enough to fit people can be made stable using exotic matter with negative mass and negative pressure. While such mass has not been proven to exist, negative mass does not violate any of the laws of physics.[6]

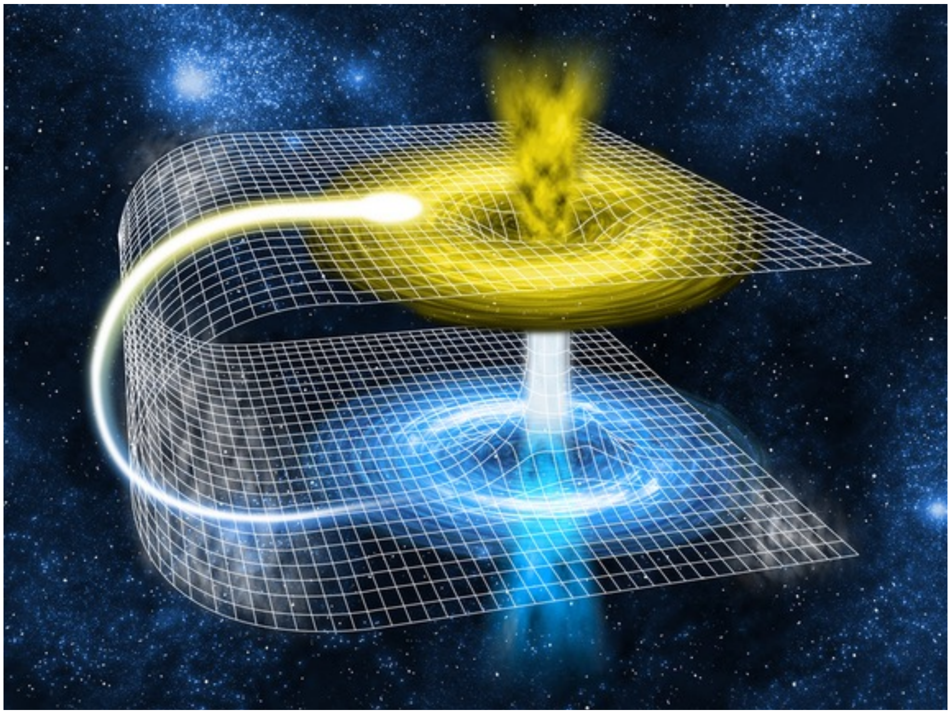

Figure 3. Wormhole connecting two points in spacetime.[4]

With a sufficiently large wormhole, how can an individual reverse time travel? One end of a wormhole, or portal, would be accelerated using an advanced propulsion system. The portal would be placed on a forward time travelling path around a massive body (as seen in Figure 4). In essence, the accelerated end of the wormhole will travel forward faster in time relative to the stationary end.[7] Once the accelerated end returns, the two ends will have experienced two different amounts of time. However, the two ends will be linked to the same passage of time. In other words, if end A has existed for 5 years and end B has existed for 15 years, entering end A will cause the individual to travel back to the time when end B had only existed for 5 years. The major drawback (and keeping in line with causality) is that the farthest point time can be travelled back to is the point when the wormhole entered the gravitational field.[7] Using the previous example, entering end B would cause the individual to travel 10 years into the future. Hence, if the wormholes could be controlled, the two ends could be used to build a time machine with two entrances: one into the future and one into the past.

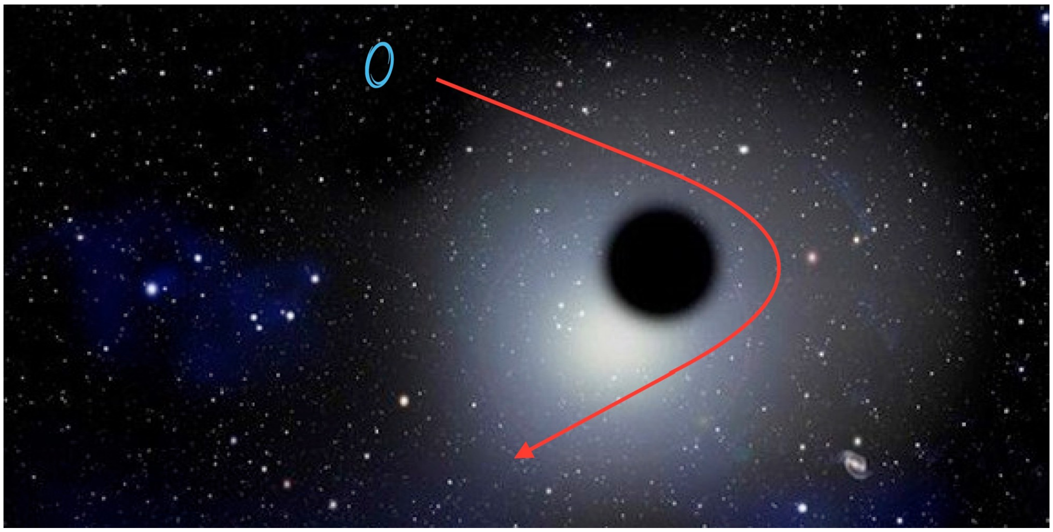

Figure 4. Wormhole trajectory around a black hole.[8, 9]

The current laws of nature predict that time travel in some form is possible. Forward time travelling is actually occurring everywhere; the effect of time dilation is substantial enough that clocks in GPS satellites must account for the effect. However, reverse time travel requires the use of science that is currently theoretical. While reverse time travel is still far off, discussions about the appropriate use of time travel are necessary. As society inches towards an interstellar future, the role that time dilation will play must be considered. Will terminal patients be given a ride forward? Can loved ones who have passed away be returned from the grave? What constitutes ethical usage of time travel? Such discussions will not only affect and shape our future, but may also change our past.

Appendix I: References

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