

# Simplifying the Concept of Special and General Relativity in Relation to Light and Time

By: Skyler Werner

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Frank LaBanca, Ed.D.  
Science Department Chair  
Oxford High School  
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## Abstract

The purpose of this project is to synthesize and simplify the theories of special and general relativity and their relation to motion, light, and time. The project will provide visuals and descriptions in layman's terms utilizing the mathematical framework that hypothetically defines the structure of the universe and the activity and forces of the cosmos. Everything in the universe consists of matter that is held together by different forces. These forms of energy have individual set of principles which describe how they behave according to nature. These laws of the mechanics of the cosmos are complex, yet some concepts that are difficult to grasp can be simplified for better comprehension.

General relativity and the principles of quantum mechanics are two theories that describe the forces of the universe. The general theory of relativity characterizes the technicalities of matter on the largest proportions; it describes forces such as gravity in relation to objects on the cosmic scale. Quantum mechanics, however, describe how substances work on the atomic level. These two principles are accurate, but inconsistent when compared. The laws that describe the forces in general relativity are no longer true when applied to molecular objects, and vice versa. General relativity illustrates the framework and creation of the universe and the important role gravity takes in every matter such as the shape of space, properties of light, and activity of time. Quantum mechanics define the counterparts that complete the whole picture; every electrical impulse behind a tiny particle that makes up the earth and the space around it give scientists a better understanding of the phenomena that occur on a day to day basis. The concept of these controversial theories can be simplified by reference to light and time to present a mathematically elegant explanation of the universe.

## Introduction

Everything in the universe consists of matter that is held together by different forces. These forms of energy have individual set of principles which describe how they behave according to nature. Quantum mechanics describe how things work on the atomic level; general relativity distinguishes the function of super massive objects or the workings of the universe in general. These laws and theories apply the boundary for the activity of everything from a microscopic particle to celestial objects that constitute the mechanics of our universe.

### The Origin of the Theory of Gravity

Isaac Newton's law of universal gravitation states that every massive particle in the universe attracts every other massive particle with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them (Hawking). Newton's law of gravitation was accurate and worked on the small scale; however, when applied to situations of cosmic proportions, the formula did not fit. This led Albert Einstein to formulate a revised theory of gravitation that could apply accurately to large scale masses that could also be compatible with the universe as a whole. Einstein discovered the flaw in Newton's idea of gravity when thinking of a hypothetical instance that would offset the orbit of Earth. Newton had believed that the force of gravity was instantaneous, meaning that the attraction holding the Earth in the sun's orbit is immediate phenomenon; the force could travel over long distances quickly. However, Einstein hypothesized that if a cataclysmic occurrence were to take place, such as the sun disappearing, according to Newton's theory, the earth would immediately be set off its original course of orbit due to the disappearance of the attraction. In reality, it would take quantifiable time for the absence of the sun to effect the Earth's orbit (Hawking).

## Light as the Motion Barrier

Einstein was able to assume that gravity was not instantaneous due to his discovery of the speed of light. In the late 1800's, Scottish physicist James Maxwell made a mathematical framework on electromagnetic fields (Singh). He studied the behavior of electricity in relation to magnetic forces by noting the magnetic field that was created by lightning. Maxwell searched for the connection between electricity and magnetism, and finally, with four simple equations, he unified both into a term we know today as electromagnetism. He observed that the wave pulses of all the electromagnetic disturbances traveled at the same rate. This is when Maxwell realized that this fixed and unchanging speed of the electromagnetic waves included visible light. It was with this breakthrough that Einstein recognized the speed of light was the universal constant; it neither sped up nor slowed down, and the speed of light always traveled at the speed of light in a vacuum. Unlike the motion of all other molecules or particles, all observers agree that light travels at a constant rate of 299,792,458 m /s (Singh). This means that as we look outside the window and watch lightning strike, the source of energy may not even exist by the time the light reaches our eyes. This conflict led to some head-scratching in the early 1900's; scientists had to keep in mind that all the stars and cosmos they were seeing may no longer exist depending on how far away the object was.

Einstein realized that the speed of light in a vacuum was a universal constant, finite speed and acted as the boundary of the motion of particles. Unlike other particles in motion, light instantaneously reaches the maximum speed because the waves are made up of mass-less photons whose energy is infinite once started. Light is the only kind of particle that can reach this barrier of speed because according to Einstein's theory,  $E = mc^2$ , energy and mass are equal, and the greater an object or particle accelerates, the greater its mass becomes. In result, the greater

the mass is, the greater amount of energy is needed to accelerate the object. The amount of energy it takes to speed an object with mass to near-light speeds is infinite. If people someday acquire enough energy to move objects at such high speeds, the theory of general relativity states that when an object is at or close to the speed of light, time moves slower and shortens in length relative to the observer's perspective from Earth. This phenomenon known as time dilation and length contraction can occur at low speeds too; however, the difference in time and appearance of an object is so slight that it makes no perceptible difference to the observer. The location of the observer and how he or she perceives time is perhaps the most important concept to grasp when discussing motion; time is relative to the observer.

#### Motion is Relative

A string theorist, Brian Greene, stated that there "is no absolute notion of motion" (Elegant Universe, 29). Because there is no absolute rest, we therefore cannot possibly compare speed, or motion for that matter, to anything without stating the relative comparison. In the early 1900's, Einstein put into question whether or not an absolute rest exists. The concept of motion is relative; one cannot claim to be in a state of rest without determining the constant to which a person or an object is being compared. For example, saying that a car is moving at 20 miles per hour can mean many different things. An accurate statement would be that the car is moving 20 miles per hour past the stationary bench on the side of the road. However, inside of the car, the people are not moving relative to the interior of the car and therefore can be defined as at rest relative to the vehicle. This means that everything in the universe is in motion, whether it be accelerated or constant.

## The Relativity of Motion: Special Relativity

In 1905, Einstein formulated his special theory of relativity which uses the four dimensional space-time interval and explains how time all about inertial frame of reference. This means that time depends on the movement of the observer and where they are located relative to the other person. In physicist Simon Singh's book, *Big Bang*, he mentions that "our familiar notion of time is fundamentally wrong. Scientists and non-scientists had always pictured time as the progression of some kind of universal clock that ticked relentlessly, a cosmic heartbeat". It is essential to throw away all ideas about time being a constant; time is all about relativity.

## General Relativity

Einstein's general theory of relativity describes gravity as a warping of space-time by the mass and energy of an object, rather than the attraction based on mass and distance as Newton had anticipated. Therefore, instead of imagining the planets tied together by a rubber band in the cosmos, one should imagine space to act as a fabric, such as a trampoline, that is flexible and holds all the planets or bodies on its tense surface. These planets or bodies, such as stars, have enough mass that they make an indent in the surface of the "fabric." Then, when some indents are larger than others, objects literally ride the curve of space, orbiting within the groove of space-time.

## The Picture of Our Universe

Isaac Newton made the observation that based on his theory of gravity, all the stars should attract to one another, so they would eventually "fall together". This would only be the case if space was finite, though, but if there were an infinite number of stars over infinite space, then there would not be a center area for the stars to fall to. The idea of a static universe or

"Einstein's universe" is one which demands that space is not expanding nor contracting but rather is dynamically stable.

When Einstein began searching for a way to formulate the theory he envisioned- a static universe with a gravitational equilibrium- he realized that such a universe would become unstable if any event occurred to offset the balance of mass. This would result in cataclysmic caving in of the universe. According to Einstein's new theory of gravity, everything in space was attracted to one other. The pull between every object would cause it to move slowly together; which would ultimately end with the universe collapsing upon itself. However, Einstein soon realized that there had to be some explanation for the unseen force holding the seams of the universe together (Singh, 67-69).

This cosmological constant is known as anti gravity, the force that makes gravity ineffective in some objects. This anti gravity was the repulsive force throughout the universe that kept it from collapsing, and still Einstein's theory of general relativity was applicable though the existence of an anti-gravity force was present. Einstein said the cosmological constant was "only necessary only for the purpose of making a quasi-static distribution of matter" (Singh, 69). That means that the presence of anti gravity allowed the eternal universe many scientists envisioned.

#### The Unification of General Relativity and Quantum Mechanics

The superstring theory is known as the "theory of everything," or the theory that unifies the conflicting laws of quantum mechanics and general relativity. Super massive objects such as galaxies, planets, and space itself abide by different laws and behave in different manners than microscopic objects such as atoms behave (Elegant Universe, 3-4). The string theory portrays the cosmos are made up of literal strings of energy that act as the stabilizing force that creates the "smooth" universe Einstein envisioned.

## Conclusion

To simplify the theories of special and general relativity and their relation to motion, light, and time is impossible to do; however, presenting the terms using an understandable approach makes the concepts easier to understand. This project provides descriptions in layman's terms utilizing the mathematical framework that hypothetically defines the structure of the universe and the activity and forces of the cosmos.

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General and special relativity and quantum mechanics are the laws and theories apply the boundary for the activity of everything from a microscopic particle to celestial objects that constitute the mechanics of our universe. Compatibility seems to be the main issue of the theories created by scientists over the years. Isaac Newton's law of gravitation was accurate and effective on the small scale; however, when applied to situations of cosmic proportions, the formula did not fit (Elegant Universe, 3-4). This led Albert Einstein to formulate a revised theory of gravitation that could apply accurately to large scale masses that could also be compatible with the universe as a whole.

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miraculous breakthrough that Einstein recognized the speed of light was the universal constant; it neither sped up nor slowed down. Unlike the motion of all other molecules or particles, all observers agree that light travels at a constant rate of 299,792,458 m/s. Light is the only kind of particle that can reach this barrier of speed because according to Einstein's theory,  $E = mc^2$ , energy and mass are equal, and the greater an object or particle accelerates, the greater its mass becomes. In result, the greater the mass, the greater amount of energy is needed to accelerate the object. The amount of energy it takes to speed an object with mass to near-light speeds is infinite. If people someday acquire enough energy to move objects at such high speeds, the theory of general relativity states that when an object is at or close to the speed of light, time moves slower and shortens in length relative to the observer's perspective from Earth. This phenomenon known as time dilation and length contraction occurs at all speeds; however, the difference in time and appearance of an object is so slight that it makes no perceptible difference to the observer. The location of the observer and how he or she perceives time is perhaps the most important concept to grasp when discussing motion; time is relative to the observer.

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