The birth of science as we know it arguably began with Isaac Newton's formulation of the laws of gravitation and motion. It is no exaggeration to say that physics was reborn in the early 20th-century with the twin revolutions of quantum mechanics and the theory of relativity - Paul Davies, English Physicist, writer, and broadcaster (Davies 3).

For billions of years, the solar system is being held together by the force of gravity. Everything from minuscule dust particles to gargantuan planets revolve around the G-Type main-sequence star. Until the early 20th century, scientists abroad accepted the Newtonian Laws as the best interpretation of gravitational force. Then, theoretical physicist Albert Einstein proposed his theory of general relativity in 1916, which revolutionized the concepts of gravitation. The introduction of the new scientific commodity arrived as a sequel of special relativity, which did not address systems that were accelerating or when a gravitational field was present. Though there are other theories today, general relativity is frequently referred as the simplest way to explain the definition of gravity and how it affects our universe.

What is General Relativity?

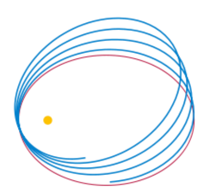
Specifically, general relativity is a combination of Newtonian Laws and Special Relativity that instates gravity as a curvature of space-time. To understand the full image, space can be viewed as a massive rubber plane. Mass bodies resting on this plane sink inwards dragging the rubber. In reality, mass objects create “ripples in space time” that result from the sinking motion of the brane, or the four dimensional universe. Consequently, the ripples acts as an unbalanced force, and objects affected are contained with gravity.

A crucial concept in general relativity is that gravity is not a force, but considered as an “effect.” The effect is caused by the implication of a mass body on the plane of space-time, which are believed to create "ripples," which act as a gravitational effect. Einstein stated that these ripples do not travel in straight lines, but in geodesics. A geodesic can be explained as "great circles" ("Introduction to General Relativity" 10). It does not travel in a constant speed and describes the orbital motion of planets orbiting the sun, or any other star. Einstein stated that all free-moving particles with no external force move in geodesic patterns, without a steady speed or path.

In this situation, Einstein included his ideas on time dilation. The closer an object is to the epicenter of a gravitational field, the slower time flows, and vice versa. Tests have been conducted in space to show this increase and decrease of time. For example, an astronaut returning from the International Space Station after one year would have aged 0.014 seconds less than he would have on Earth (Toothman 1). Though this may seem miniscule and differentiate by only milliseconds, it is a major difference judging that our technology is not capable of reaching the speed of light. Another possibility of time dilation is high speeds, such as near the speed of light. Travelling at excessive speeds may transport your physical being faster, but the time around will slow down. Back on Earth, tests done at Harvard have shown that there were microsecond differences in time when measured from a basement and a church tower ("Thorne 36). This proved Einstein's time dilation concept.

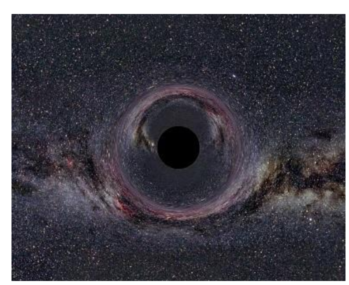
Examples in the Universe

In space today, there are multiple examples of the effects of General Relativity. Firstly, general relativity states that planets move on an eclipse, which has its own revolution around a center of mass (Wudka 1). For example, the picture to the right dictates the difference between Newtonian Laws (Red) and Einstein's relativity (Blue). The planet's orbit around the yellow star moves up by a minute difference every year, as dictated by the blue lines on the picture. Until the



20th century, astronomers assumed that the orbits of planets remained in the same plane. The best example of this motion is the orientation of Mercury's orbit. The position of the perihelion (closest to the sun) revolves around the planet's center of mass. Moreover, the planet's orbital plane increases minutely by an extra 43 seconds of arc per century (one arc is 1/3600 of an angular degree). The precession of the perihelion was first identified as a gravitational anomaly in 1859 by Urbain Le Verrier, but was explained by Einstein's relativity. Mercury's orientation can be explained by Einstein's geodesic precession as well. This concept states that the axis direction of a gyroscope in four dimensional space-time will change with the direction of light received from distant stars. Both concepts can show how, Mercury's orientation is a great example of General Relativity.

In addition, Einstein states that light propagation should change in a gravitational field. In other words, gravitational and light waves should not be constant. In general relativity, the effect and magnitude of waves can be predicted. He stated relationships such as the more mass or higher the gravitational field, the stronger the waves emitted. Conversely, the less mass, the less gravitational field, and less waves. With this concept, Einstein included gravitational lensing, when the effect of gravity is so strong that it "bends" the light behind it in a circular shape. This distorting is experienced around massive gravity fields such as black holes and supergiant stars (when drawn or captured, they all are shown with gravitational lensing). Faster spinning objects warp more space-time, therefore making an image more gravitationally lensed. To understand the effects of gravitational lensing better, picture a clip art image inserted into a document. When you chose the setting "tight" the words wrap around the image and adjust based on the image's position. Similarly,



light wraps around large mass objects such as black holes and adjust based on the position of the object's gravitational field.

Furthermore, general relativity can be used to explain gravitational redshifts in space. Also called an Einstein Shift, it is an occurrence when strong electromagnetic radiation emitting from a gravitational field source is decreased in frequency, or "redshifted" ("Gravitational Redshift" 1). This restates the concept of time dilation, as when the wave moves farther from the source, the effect is decreased. For this effect to be witnessed, the waves must be travelling - towards a gravitational field with a higher pull than the source. Otherwise, a gravitational "blue shift" will occur. To understand better, picture the sound of an ambulance racing past blaring the loud sirens. As the vehicle moves farther away, the sound seems different and does not seem to be "stretched." This same effect can occur when a moving vehicle honks its horn. The noise emitted seems to stretch and exist even after the source has stopped. Overall, redshifts are the stretching of waves emitted from a strong gravitational field.

Additionally, Einstein instated the term "gravitational wave." He stated that these waves carry energy that come from a gravitational field. He coined this term based on the common term, light. In theory, light is the waves emitted from an electromagnetic field. Einstein stated that gravitational waves are ripples caused from the curvature of space-time. Like light waves, gravity has an amplitude, frequency, wavelength, and speed. Amplitude is the fraction of stretching and squeezing. Frequency is the rate at which the wave oscillates (swing back and forth). Wavelength is the distance between each maximum height (like the crests of an ocean wave). Finally, speed is the time it takes for each wave to stretch and squeeze. Einstein theorized that gravitational waves travel at the speed of light. Most commonly, gravitational waves are created by two objects orbiting each other. Overall, gravitational waves are energy released from a gravitational field.

Lastly, general relativity allowed scientists to predict the mysterious black holes hiding in the depths of the universe. Whenever the relationship between an object's mass to its radius becomes surreally large, a black hole is on the verge of formation ("General Relativity" 12). Numerous supergiant stars in interstellar space have masses that are up to 77 times the Sun and are frequently candidates for black holes. Eventually, all stars end their billion-year evolution process, after burning all the fuel with no energy to continue nuclear fission. At this point, the only stage left is a black hole. Moreover, a black hole is a large amount of mass concentrated in a small amount of space. This creates the extreme warping of all surroundings, a pull so strong that even light cannot escape. In summation, a black hole can be predicted when an object's mass to radius ratio becomes abnormally large.

NASA Gravity Probe B

Recently, evidence of general relativity has been shown through NASA's Gravity Probe B, which was sent into Earth's orbit in 2007. The purpose of the mission was to measure the Geodesic Effect, the dip created by large mass bodies in space. The satellite could measure this through interesting gadgets on deck. It had four gyroscopes (for verification of data) that could measure angle of spin differences to an accuracy of 1% ("Einstein was right, probe shows" 4). Using this technology, the satellite watched for "frame dragging," the amount a spinning object pulls space as it rotates (Amos 3). This effect caused changes of 0.041 arc seconds per year (Amos 4). Returning to the geodesic effect, Earth drags space-time very slightly while rotating and causes a dip, which is how the moon orbits. The satellite measures this by first aligning its four gyroscopes with a guide star. Over one year, the gyroscopes are measured for changes in the angle of spin caused by the geodesic effect. Here, the Geodesic Effect measured made the spin axis angle to revert by 6.6 arc seconds per year. This data was verified by all four gyroscopes on board. In the end, the Geodesic Effect was conformed, and the Earth is now known to cause a dip in space-time, causing drag and warp effects as it rotates. In 2010, the satellite was scrapped, as its mission was complete (Perrotto 2).

In the future, this information can help scientists understand how general relativity can explain higher gravitational anomalies created by binary black hole systems. There are plans of sending a satellite to test the equivalence principle stated in general relativity.

Newtonian Laws VS General Relativity

General relativity revolutionizes concepts used in the Newtonian Laws of Gravity. Firstly, Newton's Laws are inaccurate at the presence of an extremely strong gravitational field. The gravitational waves mentioned above cease to exist in Newtonian principles as they don't travel at an infinite speed (Newton's Laws state that physical interactions propagate, to stretch, at an infinite speed). Furthermore, Newton's Laws are incorrect when speeds are close to light, as time will dramatically slow down around the object so that everything will have aged billions of years while it (the object) would have aged a second ("Introduction to General Relativity" 1); particles moving at the speed of light would be inconsistent with the behaviors attributed by Newtonian Laws. Overall, most conditions fit the Newtonian Laws, as the speed of light is normally unseen in the world.

Special Relativity VS General Relativity

Einstein proposed his theory of general relativity to remove the limitation of accelerating objects in special relativity and "generalize" it with Newtonian Laws. With 1905 special relativity, no outside forces could be present, including gravity for any moving particle. The theory disregards the concept of gravitational waves when large mass bodies are accelerating

(Gibbs 1). In addition, special relativity only has one dimension, imagining space as a flat plane without a four-dimensional structure. The theory is only applied in a localized area of space-time. Currently, general relativity is used in the situation of a strong magnetic field. Conversely, a weak field requires the use of special relativity. The wave propagation mentioned above was identified through special relativity and was incorporated into general relativity to unify electromagnetism. After ten years of effort, Einstein introduced the general relativity theory to amalgamate the concepts stated in Newton's Laws and special relativity.

Quantum Physics VS General Relativity

Quantum Mechanics is another excellent method to explain the universe. The theory states that there is a subatomic realm called the *Quantum Realm* where the interactions of particles occur in wave-like patterns that are unpredictable. They explain the smallest levels of matter including atoms, quarks, and particle force carriers. Conversely, general relativity involves serious predictions where everything is explained. An object's mass can be determined using its geodesic effect, and the formation of a black hole can be predicted using an object's ratio between radius and mass. In addition, General Relativity substantially explains gravity, the weakest of the four forces in nature. Quantum theory summarizes the behaviors of the remaining three forces, Strong Nuclear, Weak Nuclear, and Electromagnetism. In the last thirty years of Albert Einstein's life, he focused on unifying the two theories, to explain all four forces of nature. Recently, scientists may have succeeded in achieving his goal.

The Theory of Everything

In the last 65 years, the concept of string theory has evolved and currently best supports a theory of everything. The concept states that there are tiny bits of vibrating strings that exist hundreds of times smaller than atoms, which give particles their unique qualities. The strings can be compared to vibrations that occur as a cello is being played; each bow stoke emits a different resonance, giving tone and pitch to the music. String theory has yet to be tested, as it involves unrealistic situations such as up to eleven dimensions in space. In the past, the theory has had a rocky outlook moving high in the scientific realm of popularity and dropping suddenly again as explanations are harder to devise. The notable theoretical physicists of the day including Stephen Hawking and Brian Greene have yet to provide evidence for the captivating uncovering of miniscule strings existing beyond the microbial size of atoms. Until then, string theory has achieved Einstein's vow of unification.

GPS Systems

Currently general relativity helps us predict how slow a GPS satellite's atomic clock will tick from space. These satellites orbit at an altitude of 20,000 kilometers and at a velocity of 14,000 kilometers. The theory states that time will flow faster away from a larger mass body. Consequently, time flows 45 microseconds faster in orbit than on the surface of Earth. To even the effects of general relativity, engineers launching the satellites purposely set the clock at a slower ticking rate than at sea level, so that it adjusts for the differences in space. The accuracy of a GPS needs to be between 20-30 nanoseconds (Pogge 2). In addition to giving a slower ticking rate before launch, engineers have also included an onboard computer that calculates the change in time and adjusts to match the rate on Earth. This provides for the accuracy needed for customers on the surface. Overall, general relativity can help us predict the differences in an atomic clock on the surface to that of in space.

Conclusion

General relativity is frequently referred as the simplest way to explain the definition of gravity and how it affects our universe. To begin, the theory instates gravity as a curvature of four dimensional space time. Mass bodies sink in the brane, creating gravitational waves, and warping their surroundings. The waves act as unbalanced forces and “hook” objects into its pull. There are multiple examples of General Relativity being used in the universe. The orientation of the planet Mercury is a great example as it incorporates Einstein’s principle that the orbital plane of an object is not constant, and that the precession of the perihelion causes the position of the perihelion to move around the center of mass. Furthermore, Einstein states his principles of Gravitational Lensing, that large gravitational fields cause light behind to bend around them. In addition, the concept of redshifts, when the wavelength of gravity emitted from a source is stretched as it moves farther away from the field is an addition to the theory. Thirdly, the concept of Gravitational Waves, waves that carry energy emitting from a gravitational field was introduced. In addition, black holes can be predicted through the ideas involved in General Relativity. Lastly, the recent NASA Gravity Probe B confirmed the Geodesic Effect and frame dragging mentioned in General Relativity. In the future, the information can help us explain higher gravitational anomalies created by binary black hole systems. Overall, general relativity is the best theory to explain gravity and an excellent combination of Newtonian principles and special relativity. It has been proven to function on Earth, in space, and will be essential in the exploration of the vast universe. The theory will continue helping scientists and civilians well into the future.

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