4-2018

Gravity Then and Now

Paul Ingraham
Germanna Community College

Gravity Then and Now

Paul Ingraham

Germanna Community College

English 210 / F01, Advanced Composition

March 21, 2018

Abstract

This paper discusses the theory of gravity from the time it was discovered by Sir Isaac Newton to present time with the discovery of gravitational waves by Albert Einstein, and the detection of gravitational waves. Stephen Hawking's and Leonard Mlodinow's recent book, *The Grand Design*, provides support for Edward Witten's M-theory. Gravity was the first of the four fundamental forces to be discovered, and that last to be detected. Einstein proposed that gravity was not only a force, but also could be characterized as a wave on the space-time continuum.

Keywords: Gravity, Gravitational Waves, Isaac Newton, Edward Witten, Stephen Hawking, M-theory

Gravity Then and Now

Before the theory of gravity was discovered by Isaac Newton, Johannes Kepler proposed that we can predict the movement of celestial bodies about the sun. Just as then, we can expect to fall to ground when we trip, and not up into the sky. Galileo Galilei demonstrated that objects of different weights fell to the ground at the same rate (Hawking & Mlodinow, 2012, pp. 16-18). But why? Today, everyone knows about classical gravity, but aside from the scientifically inclined, many people do not associate gravity as the weakest of the four fundamental forces. Gravity is derived from the Latin, gravitas or weight (Lewis, 1915). Without gravity, a ball thrown across a football field would travel until it reached a receiver or hit a wall. Without gravity, if a person jumped up, they could stay there. Just as importantly, Newton provided a mathematical basis for predicting the effects of gravity in his Laws of Motion (Newton). The basic equation of the force of gravity between two objects equals a constant number multiplied by the mass of one object times the mass of the second object divided by the square of the distance between the two objects. Written algebraically, the force of gravity is:

$$F= (G * m1 * m2) / (r * r)$$

where: F is the force of gravity in Newtons,

G is the Universal Gravitational Constant in Newtons times the square of kilograms per meter,

m1 is the mass of an object in kilograms,

m2 is the mass of another object in kilograms, and

r is the distance in meters between m1 and m2.

These equations were for the intellectuals, while the population was accepting that the earth revolved around the sun, and the moon about the earth. We take this for granted today, but until

Newton figured out that larger masses have larger gravitational force to keep smaller masses close, such as our earth winning the tug-of-war with people pulling with their own puny gravitational force. A person falls to earth because the earth has a much larger mass than anyone person. A space station astronaut's distance is too great from the earth, then the gravitational force of attraction decreases with the inverse square of the distance, and the astronauts floats in space. Based on Newton's equations, for very large values of r, the gravitational force between two objects approaches zero. Why do our cells not collapse onto each other? Gravity is significant for very large masses near small masses. However, in the case of molecules and atoms, gravity is insignificant as individual atoms of molecules are very far apart from each other, and the masses are very small. Other fundamental forces hold molecules together, and gravity plays a minuscule role. As people began to think about traveling into space, and what would life be like on the moon, Newton's equations helps us understand that we can jump higher on the moon, as its gravity is smaller than the earth's. We are still m1, but our m2 moon mass pulling us is much smaller than the earth, resulting in a smaller gravity. This also explains why there is very little atmosphere around the moon: there is not enough gravity to keep very small masses from escaping, and oxygen molecules are very small compared to people and the moon. Today, this one observation supports Hawking's statement, “If the total energy of the universe must always remain zero, and it costs energy to create a body, how can a whole universe be created from nothing? That is why there must be a law like gravity. (Hawking and Mlodinow, p. 144)”

Astronomers now have an explanation of why planets rotated around the sun, and why the moon moves around the earth. Gravity does not hold molecules or a nucleus together. These are electromagnetic and strong forces respectively. The concept of force introduced by Newton was essential in providing scientists a model for viewing other physical phenomena as unseen forces. Coulomb's Law of electrical attraction and repulsion of charges has the same structure as Newton's Third Law of motion. One need only substitute charges q1 and q2 for the masses m1 and m2, and substitute Coulomb's Constant for the Universal Gravitational Constant (Nave, 2016).

Newton, independent of Gottfried Wilhelm Leibniz, also invented the mathematics of differential calculus based on changes in position (ds/dt), velocity (dv/dt) and acceleration (da/dt) with time. Descartes introduced the inverse of differentiation or the integration symbol, and the mathematics of electromagnetism was simplified. Vector mathematics advanced as scientists could easily express magnitude and direction in one form. Classical physics relating to large bodies with mass in motion could now be more rapidly represented and calculated. Before calculus, approximation math methods resulted in poor experimental results, and theories could not be proven without errors. The inaptly name weak force is what fascinated Albert Einstein and Stephen Hawking and made them household names. Einstein extended Newton's gravity to propose gravitational waves unifying Maxwell's electromagnetic equations with Newtons Third Law of Gravity. Einstein needed to extend Newton's classical gravity to his theory of relativity, or the new field of quantum mechanics. After the discovery of strong and weak forces, Hawking looked at subatomic particles to describe formation of the universe, based on the life of quarks. Without gravitational waves, there would be no ripples in the space-time continuum. (Achenbach, 2016)

But how much of this science is necessary in everyday life? In 2016, gravitational waves have recently been observed for the first time. "The black holes that LIGO *[Laser Interferometer Gravitational-Wave Observatory]* observed created a storm in which the flow of time speeded, then slowed, then speeded... A storm with space bending this way, and then that. (Achenbach)" With gravity being the weakest force, something really big happening was needed to be observed.

Now that gravity and gravitational waves are now proven to exist, Hawking and Mlodinow are promoting M-theory ahead of string theory (Greene, n.d.). In their recent book, Hawking and Mlodinow view Edward Witten's M-theory as the unifying theory that Einstein was seeking. M-theory is unproven, but once corroborated, Hawking and Mlodinow maintain that science can explain the birth and existence of the universe. (Hawking & Mlodinow, 2012) Why is M-theory needed? String theory and superstring theory continue to be explored but are getting increasing more complicated. Similar to Newton's Laws of Motion, Maxwell's equations, Einstein's theory of General Relativity, and Hawking's Big Bang Theory, scientists are seeking a simpler concept that explains the birth of the universe, the destruction of black holes and subatomic particles in one idea without many exceptions and special conditions (Delta Institute of Theoretical Physics, 2016). An example of the complexity of string theory is the concept of supersymetry which relies on the existence of supergravity. Supergravity relates that "gravity particles are the same as matter *[mass]* particles." One loose way of relating supergravity to supersymmetry in string theory (Vassilevich, 2006) is to liken the Einstein relation of the mass (m) of a particle being converted in energy (E), in the famous equation E equals m times the square of the speed of light (C). It bears mentioning that the energy in our universe is conserved. For any events in the universe, energy may be converted to mass which has an equivalent based on Einstein's equation. Any inefficiency, such as in heating our homes, is the result of losing heat to the outside world, but energy is conserved in our big bubble of a universe.

Gravity is important in Hawking's research as galaxies are large masses that attract each other, with our universe continuing to expand since the Big Bang. Gravitational waves are important because Hawking also wants to advance the understanding of the smallest particles where classical mechanics was demonstrated as related to quantum mechanics by Einstein. The larger problem of abandoning string theory is that it has not as yet been disproven. M-theory simply offers a blanket to include and cover string theory (Wolf, 2016). Unlike Einstein's General Relativity, M-theory offers no new model, idea or mathematics. Like Einstein, and with the recent experiments at LIGO, Hawking, Mlodinow and Witten are including gravity, and gravitational waves as fitting into the idea of M-theory.

One reason to consider gaining a better understanding of gravitational waves is that space travel is now being developed my many companies. And perhaps the fastest way to travel in space is along a warp in the space-time continuum. Perhaps Hawking's and Mlodinow's book is a good start in getting introduced modern physics to include gravity (McKie, 2010). If we travel by way of a gravitational wave, we can traverse distances along the warped space time continuum. It would have to be a really large and stable wave, something akin to surfing along Hawaii's coast. There is some humor evident. Hawking and Mlodinow characterize Richard Feynman as " a colorful character who worked at the California Institute of Technology and played the bongo drums at a strip joint down the road. (p. 2)" Later they state, "The quantum theory of the electromagnetic field, called quantum electrodynamics, or QED for short, was developed in the 1940s by Richard Feynman and others, and has become a model for all quantum field theories. (p. 79)" Quantum theory is important to understanding gravitational waves. The universe is constantly changing, and being able to consider the motion of subatomic particles such as quarks and bosons is necessary to unravel the science and mathematics of space-time. The universe very dynamic in cosmological time. This is mainly the result of particle and large body interactions that obey the four fundamental forces. With gravity and gravitational waves, the large and small masses of varying energies in the universe interact with their distant neighbors. Today, everyone knows about the tremendous power of the gravitational field caused by black holes.

Gravity is still the weakest of the four fundamental forces, but it has great reach. Our sun is over 93 million miles away, and it holds the earth in orbit. No other fundamental force can do that. Gravity is stable in local cosmological distances, but gravity is unstable in space-time where everything from very light particles, such as light, and some very heavy objects, such as comets and asteroids travels great r distances to occasionally reach earth. Charged particles and molecules can only give off and attract electrons and protons at very short distances of chemical and atomic scales. When very faraway from earth, black holes interact, energy is conserved, but gravitational waves are produced that we can now detect. We can now dream of multiverses being created by gravitational forces, and travel beyond our space, into different universes.

Hawking passed away on March 14, 2018 at the age of 76. Just as Einstein attracted the greatest scientists and mathematicians of his time, Hawking has engaged and encouraged Witten, Mlodinow and Hertog, among many others. Hawking has left us one more scientific paper to anticipate. As with his most recent work, Hawking collaborated with the eminent theoretical physicist, Thomas Hertog. This paper is in pre-publication and must be shared with the world, just as Hawking's dissertation was made available for free on the internet. This paper promises us a way that we can detect and prove there is a multi-verse (Wall, 2018). A multi-verse formed by gravity. It took over 100 years for the world to prove Einstein's idea of gravitational waves. Perhaps Hawking has jumped ahead again, and is proposing something beyond M-theory. We have not begun to figure out how to prove that yet. People around the world should hurry up and read the paper when it comes out, and figure out what mathematics, theory and experiments are needed to prove the multi-verse. There is much to be done. No doubt, this will be a large experiment whether we are looking at particles such as quarks, fermions and bosons, or supermassive black holes colliding or collapsing. Hawking must be remembered as one of the greatest scientists ever, next to Newton and Einstein with a vision to ride a great gravitational wave.

References

Achenbach, J. (2016, February 11). A brief history of gravity, gravitational waves and LIGO. *Washington Post*. Retrieved February 21, 2018 from https://www.washingtonpost.com/news/speaking-of-science/wp/2016/02/11/a-brief-history-of-gravity/?utm_term=.d2865d6634ed.

Arithmetica Universalis: Sive De Compositione Et Resolutione Arithmetica Liber. (2016, August 31). Retrieved March 12, 2018, from http://lawlibrary.wm.edu/wythepedia/index.php/Arithmetica_Universalis.

Delta Institute of Theoretical Physics. (2016, November 8). "New Theory Might Explain Dark Matter." University of Amsterdam. Phys.org. Retrieved February 25, 2018 from https://phys.org/news/2016-11-theory-gravity-dark.html.

Garner, D. (2010, September 07). Many kinds of universes, and none require God. *New York Times.* Retrieved February 18, 2018 from http://www.nytimes.com/2010/09/08/books/08book.html.

Greene, B. (n.d.). The Elegant Universe Teacher's Guide - PBS. Public Broadcasting Service. Retrieved February 21, 2018, from https://www-tc.pbs.org/wgbh/nova/education/activities/pdf/3012_elegant.pdf.

Hawking, S., & Mlodinow, L. (2012). *The grand design*. New York: Bantam Books Trade Paperbacks.

Lewis, C. T. & Kingery, H.M. (1915). *An Elementary Latin Dictionary*. New York: American Book Company. Reprint.

McKie, R. (2010, September 11). The Grand Design by Stephen Hawking & Leonard Mlodinow | Book review. *The Guardian.* Guardian Media Group. Retrieved February 19, 2018 from https://www.theguardian.com/science/2010/sep/12/the-grand-design-stephen-hawking.

Nave, Carl R. (2016). Fundamental Forces. *HyperPhysics.* Georgia State University. Retrieved February 19, 2018 from http://hyperphysics.phy-astr.gsu.edu/hbase/Forces/funfor.html.

Newton, I. & Motte, A (Trans.). (2006, January 23). Newton's Principia: the Mathematical Principles of Natural Philosophy: Newton, Isaac, Sir, 1642-1727, Free Download & Streaming. *Internet Archive*, New-York: Published by Daniel Adee. Retrieved March 21, 2018 from books.ebooklibrary.org/members.5/oca/n/newtonspmathema00newtrich.pdf.

Wall, M. (2018, March 19). Stephen Hawkings Final Paper Proposes Way to Detect the Multiverse. *Space.com*, Accessed March 21, 2018. www.space.com/40025-stephen-hawking-final-paper-multiverse.html.

Wolf, P. (2016). Witten on 2+1 Dimensional Gravity. Columbia University. Retrieved February 22, 2018 from http://www.math.columbia.edu/~woit/wordpress/?p=555.

Vassilevich, D. V. (2006). Constraints, gauge symmetries, and noncommutative gravity in two dimensions. *Theoretical & Mathematical Physics*, *148*(1), 928-940. doi:10.1007/s11232-006-0089-2.

Annotated Bibliography

Achenbach, J. (2016, February 11). A brief history of gravity, gravitational waves and LIGO. *New York Times.* Retrieved February 21, 2018 from https://www.washingtonpost.com/news/speaking-of-science/wp/2016/02/11/a-brief-history-of-gravity/?utm_term=.d2865d6634ed

Gravity is invisible. The scientific detection of a faraway collision of two black holes confirms the existence of Einstein's gravitational waves. "It's all geometry."

Arithmetica Universalis: Sive De Compositione Et Resolutione Arithmetica Liber. (2016, August 31). Retrieved March 12, 2018, from http://lawlibrary.wm.edu/wythepedia/index.php/Arithmetica_Universalis

Isaac Newton introduces principles of algebra and geometry which are later used in mathematically demonstrating the effect of gravity on people and objects on earth, and for providing a mathematical basis for his Laws of Motion in *Philosophiae Naturalis Principia Mathematica.*

Delta Institute of Theoretical Physics. (2016, November 8). New Theory Might Explain Dark Matter. University of Amersterdam. *Phys.org.* Retrieved February 25, 2018 from https://phys.org/news/2016-11-theory-gravity-dark.html

Eric Verlinde proposes a new theory of gravity (emergent gravity) that may not need the concept of dark matter.

Garner, D. (2010, September 07). Many kinds of universes, and none require God. *New York Times.* Retrieved February 18, 2018 from http://www.nytimes.com/2010/09/08/books/08book.html

This book review was written just days after the text (*The Grand Design*) was released to the public. The first few paragraphs provide the reviewers history of Hawking as a showman and ultimately as an atheist. The reviewer notes that the book is written in colloquial and imprecise language, giving the reviewer the impression that Hawking and Mlodinow treat Feynman dismissively, and propone M theory and multiple universes. In the reader's view, the authors think that ordinary people are limited by their historical perspective of the world we live in. This limitation therefore, does not allow the commoner to consider the coexistence of multiple universes. In closing the reviewer suggests that religion and science are two separable and separate things. This article is brief and likely not very helpful in understanding the book as it portrays the book in an unflattering manner.

Greene, B. (n.d.). The Elegant Universe Teacher's Guide - PBS. Public Broadcasting Service. Retrieved February 21, 2018 from https://www-tc.pbs.org/wgbh/nova/education/activities/pdf/3012_elegant.pdf

Provides some definitions and information on String Theory, a precursor to M-theory. General relativity is based on space-time. Quantum mechanics is physics as a very small scale. General relativity and quantum mechanics do not explain the big bang and black holes. String theory attempts to bridge relativity and quantum, but the secret is in gravitational waves.

Hawking, S., & Mlodinow, L. (2012). *The grand design*. New York: Bantam Books Trade Paperbacks.

This is the main text under research. The book consists of 8 chapters within a body 177 pages to include numerous figures. Anecdotal figures and comments are interspersed with scientific and classical studies, such as philosophy throughout the book. In recounting the

history of science, Plato and Newton are recognized in the first instances along with M-theory in the same paragraph on pages 7 and 8. Thales' prediction of an eclipse, and Galileo's and others deductions on planetary movement are precursors to Newton's mathematical descriptions of force, mass, velocity, acceleration and gravity. The principles of scientific determinism are used to describe the universe, using mathematics, and ideas that form models to describe scientific ideas such as quarks. J.J. Thompson's experiments with cathode ray tubes is credited following Newton, Laplace and Descartes mathematics of physics. "*[T]*he big bang theory" (p. 51) is an example of a model. Models are subjective, whereas the authors are striving for scientific determinism. M-theory is a model. It is unproven and a concept based in the unified theory suggested by Einstein. The idea that models are subjective includes the premise that "a good model… is elegant." (p. 51) This idea of proving a model is extended to Newton's theory that light behaves as a particle, but as Einstein explained mathematically, in some cases light behaves as a wave, not a particle. Einstein proved that light can act as both a particle and a wave. Einstein extended Newton's mathematics of mass, gravity and velocity to instances when particles behave as waves. This is the idea of duality, and as both ideas are supported by observations, these ideas are part of M-theory. (Ch. 3, p. 58) Having introduced Newtonian mechanics supported by Newton's observations and mathematical treatment was later supported by Laplace and Descartes. Hawking and Mlodinow close with Newton's Law of Conservation of Energy. The energy in the universe remains constant. (Ch. 8, p. 180) Gravitational forces are important, as energy must be applied to separate the moon from the earth. "Because there is a law like gravity, the universe can and will create itself from nothing…" (p. 180)

Lewis, C. T. & Kingery, H.M. (1915). *An Elementary Latin Dictionary*. New York: American Book Company. Reprint.

English-to-Latin and Latin-to-English dictionary. Useful in verifying translations of Latin into English. Latin was used by Old European scholars such as Isaac Newton with perhaps most notably his *Philosophiae Naturalis Principia Mathematica* (*Mathematical Principles of Natural Philosophy* and *Arithmetica Universalis: Sive De Compositione Et Resolutione Arithmetica Liber (Universal Arithmetic: Or From Composition and Resolution Arithmetic Book.*

McKie, R. (2010, September 11). The Grand Design by Stephen Hawking & Leonard Mlodinow | Book review. *The Guardian.* Guardian Media Group. Retrieved February 19, 2018 from https://www.theguardian.com/science/2010/sep/12/the-grand-design-stephen-hawking

This book review suggests that prior reviews and articles regarding *The Grand Design* are wrongly focused on religion vs. science for the creation and existence of the universe. This review is written several weeks after the book's publication, and mentions the furor with some of the first reported tenet of science that portend there is not religion. The review considers this a false perception of the of the book. In this review, the book contains 11 dimensions of space-time (i.e., not many multiples, as stated by Garner's review. But then as in Garner's article, there are many multiples of universes as a result of these 11 dimensions... suggesting M theory.

Nave, Carl R. (2016). Fundamental Forces. *HyperPhysics.* Georgia State University. Retrieved February 19, 2018 from http://hyperphysics.phy-astr.gsu.edu/hbase/Forces/funfor.html.

Provides diagrams and definitions of the four fundamental forces. In order of strength: strong, electromagnetic, weak and gravity. Strong forces hold a nucleus together, and include gluons and pi nucleons. The range of strong forces is extremely small, around 10E-15 meters which is about the size of a nucleus. Electromagnetic forces technically have an infinite range but can be isolated by non-conducting materials. Electromagnetic forces have a strength far below, i.e., 1/137th of Strong forces. Weak forces hold a single proton together, and have a strength of one millionth of a strong force. When a weak force fails or decays, a neutrino is produced by the disintegration of a proton, giving off some energy, and the much smaller electron. Therefore, the decay of a proton results in an electron and a neutrinos flying off. Gravity is the weakest of the fundamental forces.

Newton, I. & Motte, A (Trans.). (23 Jan. 2006). Newton's Principia: the Mathematical Principles of Natural Philosophy: Newton, Isaac, Sir, 1642-1727, Free Download & Streaming. *Internet Archive.* New-York: Published by Daniel Adee. Retrieved March 21, 2018 from books.ebooklibrary.org/members.5/oca/n/newtonspmathema00newtrich.pdf.

After a Latin poem by Edmund Halley, Newton introduces his Laws of Motion and supporting mathematics. Prior to that, from the translation, the first mention of gravity is as follows:

> Gravity is [a force] of this kind, by which bodies tend towards the centre of the earth ; the magnetic force, by which iron seeks a loadstone; and that force, whatever it may be, by which the planets are drawn perpetually from rectilinear motion, and are forced to revolve along curved lines.

Vassilevich, D. V. (2006). Constraints, gauge symmetries, and noncommutative gravity in two dimensions. *Theoretical & Mathematical Physics*, *148*(1), 928-940. doi:10.1007/s11232-006-0089-2

Space-time theories define conditions that allow for analyses of the two-dimensional string gravity (also known as the Witten black hole).

Wall, Michael. (2018, March 19). Stephen Hawkings Final Paper Proposes Way to Detect the Multiverse. *Space.com*, Accessed March 21, 2018. www.space.com/40025-stephen-hawking-final-paper-multiverse.html.

Recent web article on the passing of Hawking.

Wolf, P. (2016). Witten on 2+1 Dimensional Gravity. Columbia University. Retrieved February 22, 2018 from http://www.math.columbia.edu/~woit/wordpress/?p=555.

Witten is a mathematician and proposes the study of black holes by a series of equations forming a computer model to help scientists understanding black holes an gravity. Quantum gravity is related to two dimensional (flat) conformal field theory. Witten does not use string theory but a quantum field theory. Witten stated that perhaps what he had to say could be embedded in string theory, and that the recent papers by other scientists showing that one can't get pure supergravity by taking a limit of string theory did not apply in three dimensions. Expressing gravity in terms of gauge theory variables and hoping to quantify in these variables instead of using strings, is one of the central ideas.