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From Atoms to Strings

ABSTRACT

Humans have quested for knowledge since the beginning of history. One of humanities greatest goals is to unravel the mysteries of the universe. Democritus opened this door with his proposition that everything was created of atoms. From this, notable physicists such as J.J. Thompson and Ernest Rutherford have proved that there is an atom and in it are subatomic particles. Along with James Chadwick they have shown not only an atom, but there are particles that create it: the electron, proton, and neutron. In human history, having one answer is never an absolute. From these discoveries there has been the search for even smaller particles. Wolfgang Pauli, like Democritus, opened another door. He showed that there could be an even smaller particle called the neutrino that coexists with these other particles. In this new line of subatomic physics many discoveries have been made. CERN was created and so were other institutions dedicated to this line of work. As the 20 century ends, the greatest controversy since the atom has arose, this is String Theory. Still after almost half a century of research it is unknown to whether this theory is an absolute. As time continues, perhaps another theory will postulate or maybe String Theory is finally the solution that the scientific world has looked for.

From Atoms to Strings

Since the beginning of time, humans have tried to discover everything that the universe is made up of. Starting thousands of years ago, Democritus claimed that there was something small that existed called an atom that made up everything. Three key components of the atom: the electron, proton, and neutron, formed the understanding that Democritus was right and there was this thing called an atom. Since its discovery, physics has been tested as many controversial underlying ideas about the universe have arrived. There have been flawed ideas, but the human desire of knowledge has physicists dedicating theirs lives to unraveling the mysteries of the universe. Since the discovery of the atom, atomic theory was born which led to a whole new branch of understanding. With more and more particles discovered, the controversial question of the 21st century came with the idea that from all of these subatomic particles, they could be broken down one step further into what is now known as String Theory.

Since the beginning of Greek history, philosophers tried to unravel what created the universe. From this idea of thought a famous philosopher, Democritus, assumed that there were small particles of matter that created everything. In this time era there was no scientific way to prove he was right or wrong, however this notion was debated for thousands of year. In the late 1700s, one such scientist who opposed this notion was Antoine Lavoiser who stated that elements were the smallest possible particle and could not be broken down anymore. Then in the early 1800s, a physicist, John Dalton, sided with Democritus claiming that everything could be broken down into atoms. However, there was still no proof to show that either of these two physicists was correct in their hypotheses. Because of John Dalton's claim, though, he was considered the father of atomic theory who started the revolution in science to search for all of these particles in the universe. These two disputing claims started a large search to discover if there was such a thing as an atom.

Half a century later, George Johnstone Stoney researched elements and found that they produce electricity. He named this electricity an "electron" which is where the name today comes from for the particle. J.J. Thompson then tested Stoney's theory of an electron. To do this, J.J. Thompson used a cathode ray tube experiment to prove the existence of an electron. Cathode ray tubes were a newer discovery and Thompson used this to send a ray of particles through the tube. On each side of the tube were magnetically charged plates. Since opposites attract and likes repel, the ray bent towards the positive plate proving that there were electro-negative particles. The result of this experiment proved that elements were made of negative and positive particles. With this discovery, Thompson confirms that there are smaller particles that make up an element.

This theory held for years, but scientists hypothesized that maybe the elements are empty spaces that are held together by these positive and negative charges. In 1899, Ernest Rutherford discovers the Alpha particle, which is a positively charged particle. Rutherford then told scientists to help him devise an experiment where he could test to see if an Alpha particle could be shot through gold foil. He assumed that the trajectory of the alpha particles could be tested from this experiment. To his surprise, this famous gold foil experiment showed that some of the Alpha particles deflected off of the gold foil instead of going straight through. Rutherford discovered that there was a dense center of mass in the middle of the atom and named this the nucleus. Rutherford also discovered that this central nucleus was positively charged and from that he named this positive charge a proton. To finish Rutherford's model of the atom, James

Chadwick confirmed the nucleus that Rutherford mentioned and found that not only was there a proton, but also a neutron in the center. With these two discoveries and also that of J.J. Thompson's, an accepted model of the atom was formed.

An atom is not the only particle that breaks up into smaller particles. During the years that Rutherford was working on his experiment, another physicist was researching the particles that make up light. Albert Einstein, one of the most notable scientists, discovered that subatomic particles exist in light. He named this particle a photon and from it future physicists have discovered more about particles. This is a highly important discovery to note because it added a lot to the understanding of how subatomic particles act. Then Einstein measured the energy of light and came up with the formula that he is most remembered for, E=mc^2. Louis de Broglie discovered that electrons shared both properties of particles and waves, and supported Einstein's discovery. This concluded that electrons shared similar properties to all other particles and meant that its energy could be calculated. With this, mostly all of the basic ideas of the atom and its subatomic particles were realized which led to physicists looking more into all of the other particles that could exist.

From all of the general knowledge about the atom, physicists transitioned into looking at all particles. Niels Bohr created this new field of physics known as atomic physics. Bohr had developed an explanation for the atomic structure and showed the basic regularities that existed within the periodic table. The structure he created is known as the Bohr Model. This model had improved on Rutherford's previous model. Ernest Rutherford proved that electrons were attracted by a positively charged nucleus; however, he just assumed these electrons were floating around. Niels Bohr hypothesized that these electrons are attracted, but they are attracted in a specific way. He created the Bohr Model to show that electrons were attracted in energy orbitals around the nucleus. This model is sometimes referred to as the “planetary model” because it resembles how the planets go around the sun. This model has become the standard model that people are taught today to represent atoms.

Scientists were still not convinced that the atom ended with just an electron, proton, and neutron. One scientist, Wolfgang Pauli, hypothesized a new particle that accounted for the fact that energy and momentum were not being conserved in some elements, specifically nitrogen. From this experiment he set the foundation for the discovery of the neutrino. Pauli’s ideas lay dormant for decades until two scientists, Clyde Cowan and Frederick Reines, started to experiment with energy conservation based off of Pauli’s work. What they discovered was a new particle called a neutrino. This neutrino has a neutral ½ spin that solved the problem of energy conservation in beta decay. In atomic theory, every particle has an antiparticle that allows for the conservation of energy. What they observed was that since a neutrino was produced with an electron in beta decay that there was some conserved number that characterized these particles called a lepton number. This followed the laws of conservation with particles since beta decay and an electron produced an antineutrino. There is an in depth explanation for the findings of these scientists by S.M. Bilenky called “Neutrinos”[6]. The neutrino Cowan and Reines had discovered is now known as the electron neutrino.

With the discovery of one neutrino, scientists assumed that there were other particles in the neutrinos that had similar properties. CERN or the European Organization of Nuclear Research, sought to discover other types of neutrinos in the universe. The second type of neutrino that they had discovered was the muon neutrino or mu neutrino. It was discovered by Leon Lederman and has no net electric charge. Roughly half a century later, scientists were able to find a third neutrino which they named the tau neutrino. Like other neutrinos it has no net electric charge. The name mu stands for the second generation of lepton particles, whereas tau stands for third generation lepton particles. Since the discovery of the tau neutrino in 2000, no other neutrinos have been observed.

Apart from the neutrino, there is one other field of atomic theory that is highly controversial and researched by many scientists in the 21st century and that is string theory. String theory is a lot newer, starting with a proposed idea in 1968. It is the newest theory of the universe that goes against Einstein and his work. Einstein created special relativity that gives absolutes for gravity and space, whereas string theory works towards linking the uncertainties in the world and could be considered the link to understanding everything. Unlike any previous type of subatomic model, string theory has the idea that there is one foundation that creates everything and that is an oscillating string. The atomic models that have been described in the past believed that subatomic particles of atoms were 0-dimensional. This meant that they were dots that could not be broken down any further. However, as scientists keep unraveling the mysteries of the universe they have considered the possibility that all particles are creating by high oscillating strings that exist in 1-dimension. With all of the research being done string theory has become the most likely candidate for explaining the coexistence of gravity and fundamental forces.

String theory was never thought about until Gabriele Veneziano was measuring the amplitudes of hadrons. This does not sound like the string theory people recognize today, and actually, the idea of string theory was more focused on hadrons than being a solution to everything. String theory was originally a solution to Gabriele Veneziano's work with hadrons. This solution was given by Leonard Susskind, Yoichiro Nambu and Holger Neilsen who said that the solution to these amplitudes was found in quantum mechanical 1-dimensional strings.

Then scientists even postulated that string theory had to have 26 dimensions. At this time there was a very rough image of string theory as people were unsure exactly of the extent of its accuracy.

String theory was at a standstill in the scientific community as no one wanted to completely endorse it because it was new and theoretical. There were two major physicists that created the string theory revolution and made it practical for research today, John Schwarz and Michael Green. In 1974, John Schwarz and Michael Green first discovered that string theory contains gravitons and proposed that string theory could unify quantum mechanics and special relativity. These two physicists later postulated superstring theory and named the first two parts of it Type I and Type II. Type II was further broken down into two parts, IIA and IIB. In 1984, CERN discovers W and Z bosons which support the Stand Model and String Theory. Ed Witten then proves that all of the anomalies that occurred in Type IIB superstring theory would cancel out which showed that IIB was a reasonable theory. A few years after Schwarz and Green proposed Type I, they showed that all of the anomalies in this theory could cancel out making it reasonable as well. As a decade passed two other superstring theories, HE and HO were added to total 5 different string theories. HE and HO are parts of the heterotic superstring theory. Ed Witten made created the second superstring theory revolution in 1995 when he proposed that all of these different types of theories are different realizations of the same fundamental theory, 11D M Theory. All five of these theories were conjectured that they all related by similar dualities. With new dualities branching across string theory, there have been other postulated theories about the universe that relate to string theory. Theoretical physics is still an ongoing field of study that is being researched every day. There are research institutions such as the Institute for Advanced Study at Princeton, NJ and the Perimeter Institute for Theoretical Physics in Canada that are solely dedicated to this type of research. As new theories arise, scientists will constantly be discovering everything that makes up the universe.

The research done on string theory has been contested over the years by colleagues. Physics have said that this research has been pointless because it is all theoretical. Until recently, string theory could not even be physically tested. Besides CERN, there are barely any research facilities that can actually support physical research for atomic particles. Peter Woit has been a large opponent to string theory who claims its main shortcoming is, “the lack of directly testable experimental predictions that would signal ‘string theory’” (Woit). CERN has made tests, but they are not as accurate as people would like. Scientists dispute these claims because everything is based off of theory. With no practical evidence, string theory will always be a contested field in science.

Today, physicists have even more of an understanding than ever before. Someone as far back in history had an idea. This idea has led to countless years of research and thousands of ideas and theories being contested. With the discovery of the atom, subatomic physics was made possible. This branch of physics has become one of the most prominent branches today as scientists discover all of the particles in existence. From the beginning with the electron, to the proton, neutron, neutrino and now the bosons in string theory; scientists keep coming one step closer to discovering what everything is made up of. With string theory as the most current idea, the scientific world has been searching for its answer of whether there is one key link behind all of physics. Whether it was the atom, or the neutrino, or even string theory, physicists have struggled to unravel the deeper mysteries of the universe and will continue to do so in centuries to come.

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