Travis Alvarado
10/20/07

Anti-Matter

According to the “Standard Model”, which is the current theory of the creation of the universe that is most widely accepted among physicists, immediately following the big bang (the explosion from a single point that jumpstarted the universe 14 billion years ago), there was symmetry about the evolving universe. Whenever a particle of matter came into existence, so did a particle of antimatter. Antimatter is essentially similar to matter. Each subatomic particle like protons, electrons, and neutrons but also photons (particles of light) and neutrinos (small neutrally charged particles) and other basic units of matter, have a corresponding opposite antiparticle with the equivalent mass and spin. The fundamental difference is that elementary charge is exactly opposite. Theoretically, an antiproton (the particle that mirrors a proton) can be the nucleus of an “anti atom” that has a positron (the particle that mirrors an electron) existing in orbit of the positron. The anti atom can have antineutrons (the particle that mirrors a neutron) in the nucleus as well. We can now start making a periodic table. If enough antiprotons, positrons and antineutrons combine under the right conditions, an anti-oxygen atom can be made. If an anti-oxygen mixes with two anti-hydrogens, they should form “anti water”. It will have the same properties as water (i.e. it will have the same boiling point of 100 degrees, freezing point of 32 degrees, structure, viscosity, etc.). The same can be said for stars, planets, people, and so on. An antimatter galaxy is theoretically possible, and should exist.

When quarks where shown to exist, around the mid 1990’s, antiquarks were theorized soon after. A quark is a constituent of a proton just like a proton is a constituent of an atom and atoms are constituents of molecules. Caltech Professor Gell-Mann associated what he called strangeness to a quark as well as naming a top and bottom quark. Quarks were attributed to experiments that had been done in the 1960s and 1970s. A proton is made of two up quarks and one down quark and a neutron is made of one up and two down quarks. Since matter and antimatter are almost identical, it is logical for an antineutron to be made of antiquarks in a structure similar to a regular neutron. An antineutron has one up antiquark and two down antiquarks. Quarks and antiquarks can build short living exotic particles such as pions; also, within protons, quarks and antiquarks continuously appear and cancel out in the space in between the up and down quarks. The structures of matter and antimatter are identical.

The existence of antimatter solved an asymmetry that had confused scientists for ages: why are positively charged subatomic particles relatively heavy (i.e. the proton with an atomic weight of one) and the negatively charged subatomic particles light (an electron weighs about one two-thousandths of a proton). Now a heavy particle can be negative and vice versa. Both particles can have either charge. Slightly after the Big Bang, both matter and antimatter began to be produced. Antimatter most likely annihilated itself with the available matter and busted into energy early in the lifetime of the universe. Then, something happened that scientists are still unable to explain. During the production of matter and antimatter immediately after the big bang, antimatter began losing the battle. Matter dominated the celestial sky. Matter and antimatter should be in equal amounts in our universe, but so far, no evidence is present that suggests there are anti galaxies matching ours or very much antimatter at all. How this situation came about is described by the process of baryogenisis. The postulations say that during matter and antimatter production, a CP-violation occurred (which stands for charge conjugation and parity). This doesn’t tell us much about what happened specifically, but it is the extent of our knowledge of why antimatter seems to be in small amounts.

Antimatter was first surmised by A. Schuster in 1898, but most credit is given to Dirac who predicted it by means of negative solutions to his equations of quantum physics. But it was first experimentally proven to exist by Carl D. Anderson. The most notable characteristic of antimatter is its ability to combine with matter and release 100% efficiently converted high energy photons called gamma rays from matter. Nuclear fusion of hydrogen, which accomplishes the same task of converting matter to energy, converts with about 7% efficiency. And after the matter - antimatter reaction both materials completely vanish, called annihilation. Once we have to power harness this energy and make reactions economically feasible, matter-antimatter reactions could have many applications in fuel, power (electricity), or weaponry.

The first experimental proof of antimatter appeared in a cloud chamber of water vapor. A good analogy as to what goes on in this chamber is like running your finger over a foggy window. The path of your finger is evident by the condensation that is left behind. Similarly, a cloud chamber can show the path of subatomic particles. Carl Anderson was doing research in Caltech, when he asked to use a new high powered magnet, normally used for aeronautical purposes, for his studies. In a cloud chamber among a magnetic field, positive particles curve upward and negative particles curve downward. Also, heavy particles, protons or neutrons, leave a thicker trail in the cloud chamber, similar to pressing one's finger on the glass harder. Alternatively, light particles leave thin trails. After a few experiments, Anderson took notice of trails that curved upward but were laid in a thin path. Many scientists argued over the origin of this anomalous outcome. Some said the particles enter from an opposite direction (down instead of up), which would explain the outcome. However, Anderson wanted to disprove this idea so he placed an aluminum barrier in the chamber. This showed that the particles entered from the expected direction. His professor didn't agree with him until this was done. This lead Anderson to believe that they were most likely positively charged electrons. A picture of his cloud chamber experiment began to be passed around the scientific community and an editor of one of the scientific journals covering the story suggested the name positron. This all occurred while Anderson was unaware of Dirac's breakthrough equitations that actually predicted this particle. After all was said and done, Anderson revised his paper, which did not mention a positive electron due to his professor and Anderson disagreeing, to say that the picture was most likely a positively charged particle that must be significantly smaller than a proton. He proposed that these particles were made by cosmic rays.

After its postulation, expression in mathematical equations, and creation in a lab, antimatter was still a mysterious substance. Some of the discrepancies between matter and antimatter being mostly symmetrical but having some anomalous characteristics left many physicists baffled. Primarily, whenever antimatter was shown to exist mathematically, the equations would only pertain to a “second quantization” which generally means: we couldn’t describe antimatter in classical terms but only in the language of quantum mechanics. We lacked the mathematical skill to describe it classically until the development of “isodual mathematics”. This new category of math allowed some variables to be redefined to allow antimatter to be expressed adequately. We believe there is little antimatter naturally in the cosmos because we have not detected it yet. We believe. Directly, we have probed the stars for signs of antimatter, but in reality, we would not know if we were looking at it. The electromagnetic radiation from normal stars is essentially identical to the radiation that would theoretically come from a star composed of antimatter. The direction of the magnetic poles is reversed, but this is no different from looking a star that is facing the other direction. What leads physicists to believe that little antimatter exists is the lack of gamma radiation that would be emitted when some of the antimatter would contact matter. Gamma radiation is a type of electromagnetic radiation exactly like light, radio waves, x-rays, microwaves; however, gamma rays have incredible high frequency that has the potential to cause damage. Antimatter is produced naturally however. When cosmic rays (which are high energy particles that consist of mostly protons, a few pares of 2 proton, 2 neutron particles, and rarely an electron that traverse through space mostly due to nuclear reactions within stars) contact matter, trace amounts of antimatter are produced. These small quantities don’t last long because they react with matter quickly. In principle, if radiation contains enough energy to account for the rest mass of the particle and antiparticle times the speed of light squared, which is the reverse reaction of fusion or matter - antimatter annihilation, and encounters the right material, like an atomic nucleus, a pair of particle and antiparticle will be created.

This reaction creates matter (and antimatter) from energy, or what it looks like, nothing. Imagine watching light turn into a rock or some object.

There are more problems with antigravity that we can't explain. For all Dirac's equations, there are negative values. This was how antimatter was predicted, but this also requires the existence of antigravity. For antimatter to gravitate toward itself when large amounts are present requires the largest field of force that would bring electrons, who repulse each other due to their similar (now positive) charge (opposites attract), together. In a word gravity but it works for antimatter. This would mean that antimatter and matter should repel each other when in each other's gravity field (which is, in principle, everywhere). However, relating to General Relativity, this is impossible. It does not allow this type of gravity. General Relativity has been the foundation upon which quantum physics (the most experimentally proven and consistent system of theories in the history of science) has been built upon. To disprove a component of it would cause alarm. Scientists are unsure of how this will be resolved. On a side note, if antigravity is shown to exist, casual time travel is predicted to be a possibility.

In the last decade, the isodual mathematics mentioned earlier has revolutionized theories about antimatter. In 1993 it was first applied to antimatter, and since then isodual mathematics has been applied to many advanced mathematical systems of space. Isodual mathematics has been found to predict a unique type of photon emission by antimatter. Previously, photons were thought to be their own antiparticles, and consequently they are indecipherable from an emission source of matter or antimatter. However, the unique photon, called an isodual photon, would show scientists if it was emitted from a source of antimatter. In the coming years, we can expect a machine that will be able to detect antimatter directly! More far fetched predictions made by isodual mechanics are that antimatter has negative mass and negative energy. This would mean that antimatter would be attracted to matter while matter would repel from antimatter. Since antimatter has negative energy, it will actually be repelled, but it will move in the opposite direction, witch is attraction. This system exerts acceleration, just like gravity, and if the two particles are of equal mass, they should accelerate continuously without additional energy input into the system. Rocket propulsion could be entertained, but these characteristics of antimatter are still only hypothetical. Another result of the negative qualities is antimatter would then exist in negative time, moving backwards from future to present. More generally, antimatter would exist in a basically separate space-time.

If it were available in proportion to any other material on earth, it is the most valuable material on earth. It is valuable for many reasons. First, because of its scarcity, however much one hypothetically has, it is the only available antimatter on earth. Second, it would be valuable for scientific study. The incredibly small particles of antimatter available to study today, along with the short increments of time they exist, determent the advancement in understanding antimatter. With a larger amount, we would be able to study antimatter more easily. As mentioned before, antimatter could be useful in power supply. If earth were to acquire at most a ton of antimatter, it would be an endless resource. The entire planet would be able to be powered. It would also have applications to destructive purposes. A military power could easily design a matter – antimatter reaction bomb, an antimatter bomb. One gram of antimatter, when annihilated with one gram of matter, has the explosive force of 43 kilotons of TNT. With a relatively small amount of antimatter, an entire country could be destroyed in the blink of an eye (with minimal global pollution effects like that of current nuclear bombs). We are currently capable of producing antimatter, and we are. But the process is immensely expensive and so little antimatter is being made, much too little to be useful for any of these categories. A physicist from CERN (the world leader in antimatter production) was quoted as saying, “If we were to accumulate all the antimatter produced by CERN in its history, and then annihilate it with matter, it would only produce enough energy to light a light bulb for a few minutes”. Whether or not we will ever be able to harvest antimatter efficiently is speculation.

Antimatter is another example of how science fiction became factual. Much is left to be discovered about antimatter, and research of it is one of the leading tasks being done by quantum physicists today.

Alfven, Hannes. Worlds - Antiworlds. San Francisco: W. H. Freeman and Company, 1966.

Barbour, Julian. The End of Time. New York: Oxford UP, 1999.

Duquesne, Maurice. Matter and Antimatter. New York: Harper and Brothers, 1960.

Fraser, Gordon. Antimatter. Cambridge, UK: Cambridge UP, 2000.

Santilli, Ruggero M. Isodual Theory of Antimatter. Vol. 151. Netherlands: Springer, 2006.