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Project:

Exploring the Subject Of Dark Matter and Dark Energy

By

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The Unseen Universe

We look around us. What do we see? Books, people, buildings, food, cars, computers, animals, plants, planes, clouds, and stars…All of these things we can see. Our whole lives are mostly spent on what we can see with our eyes, but what about those things that we cannot see? What about those things that are not immediately recognizable, those things that pass by without anyone noticing them? The most obvious example that comes to mind is the air we breathe. Very few people take a lot of time to think about the air, yet without it we would not be living here as we are. In a broad statement, it can be said that the things that we cannot see have the greatest effect on what we can see. And so here in this work, phenomena that are not widely known will be set forth and explored. Those phenomena are known as dark matter and dark energy.

Surely the connotation is heavy, but what do these phrases actually mean? Many have heard these terms, mostly spoken of in mysterious tones, but no one really knows the content of what these terms hold. Sadly enough, though, this information largely is not to be found. There is evidence, and also a plethora of theories, that try to shed light on this matter, but as of yet, nothing concrete has been set forth. Despite this lack of knowledge, though, many steps have indeed been taken to come to grips with this strange phenomenon.

The Wilkinson Microwave Anisotropy Probe (WMAP), which was launched in 2001, describes the composition of the universe as roughly being seventy percent dark energy, twenty-five percent dark matter, and a mere five percent atoms, the stuff we see on a day to day basis. This figure differs from the data taken for the composition when the universe was still young which indicates that the composition was sixty-three percent dark matter, twelve percent atoms, fifteen percent photons, and ten percent neutrinos. These compositions are given in Figures 1 and 2.

Figure 1

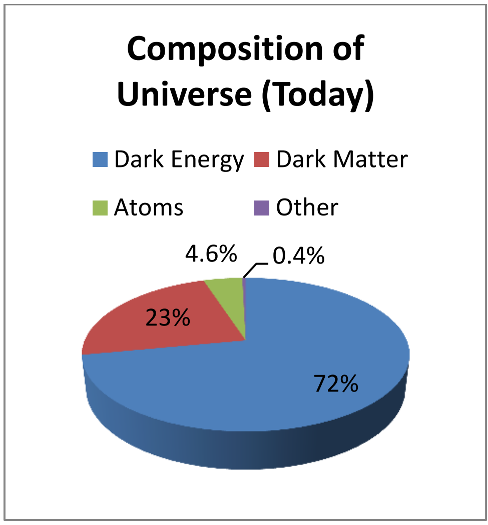
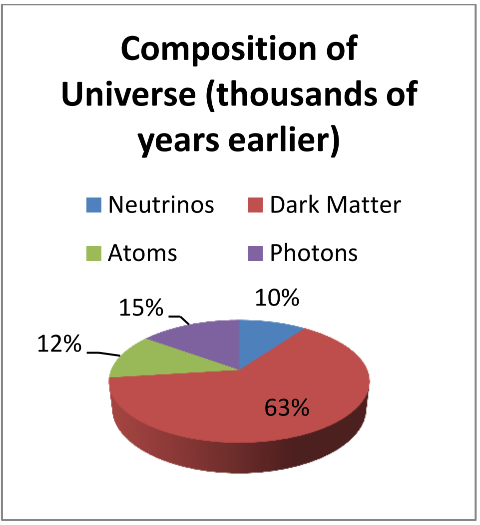


Figure 2



As you can see from the figures the estimated percent of dark matter has significantly decreased over the years while the amount of dark energy has done just the opposite and has increased dramatically. Why is this? As has been stated, we are actually not sure, but let us dig a little bit deeper into this issue.

To start, a little history has to be learned. For centuries, beginning with the ancient Greeks, men have wondered about their universe. Men have studied it, theorized about it, made expressions about it, and just about everything else they could think of to learn more about this world. But one of the biggest questions on their minds, when studying the heavens, was, “How big is the universe? Is it finite or infinite? How do we even find out?” For the longest time, no headway was made on these questions, but in the early nineteenth century the search for answers began to pick up in earnest due to the observations of several men, the most prominent being Sir Isaac Newton and Albert Einstein. But before we come to their discoveries, let us first acquire an idea as to what they were working with, and that search begins with the idea of gravity.

Several men have had a huge impact on this subject, but of course the main ones were the two mentioned above. Newton was the first man to coin the term “gravity” and used this idea to describe many different aspects of physics. It was Newton that discovered the gravitational attraction between all objects concerning mass. He explained the force between two objects with this equation: $F = \frac{Gm_1m_2}{r^2}$. Where G is the gravitational constant, m_1 is the mass of one object, m_2 the mass of the second object, and r is the center to center distance between the two objects. Newton theorized that every particle within an object felt the gravitational attraction of every other particle in another object and that this force acted as if all the matter of an object was at its very core. This is where we get the traditional definition of gravity as,” the force by which a planet or other body tends to draw objects toward its center.”(*Webster’s Dictionary*)

On the other hand, Einstein expanded on the idea of gravity and applied it on a larger scale. He formed the idea of general relativity, which states that gravity is a result of space-time being warped by planets and other bodies of mass. It was Einstein’s idea that space-time acted as a blanket. When it is stretched taunt and objects are placed on it, the objects “bend” the blanket. This makes all other smaller bodies nearby attracted to the larger object and it is this ‘attraction’ that we define as gravity. This idea led to the belief that the universe would eventually collapse back on itself due to all the objects in the universe exerting an attractive force on each other. It was only a matter of time before a “big crunch”.

But then, in the 1920s, Edwin Hubble made a brilliant discovery. While studying a class of stars called Cepheids, he found that the redshift, which is the shift in the wavelength of light, of the stars was proportional to their distance from Earth. This led to the conclusion that, at a greater distance, objects were accelerating at a faster rate. Hubble used this theory to construct this equation: $v = H_0D$. Where v is the velocity at which the mass is receeding from the Earth, D

is the distance from the Earth, and H_0 is the Hubble Constant. Looking at this equation it can easily be summarized that at a greater distance the velocity is greater. This seemingly simple epiphany, though, leads to the understanding that the universe is actually expanding at an accelerating rate. This does not mean that the actual galaxies or solar systems are expanding but simply that “galaxies keep growing farther apart from each other.” (*Garfinkle and Garfinkle, 178*) But our question is why is this happening? Scientists have come to the conclusion that at one point the universe was contained within a very small point of mass. This small point, for reasons unknown, then exploded and it is this explosion that we call the “Big Bang”. The previous idea of the expansion of the universe flows very well from this theory. But then we hit a wall. If the expansion of the universe was caused by a ‘big bang’, then would it not make sense that the universe would in fact be slowing down due to the force of gravity? Would it not follow that the momentum of the expansion would eventually fade away? It would. However, that is not the case. It is this idea that has stumped scientists. What is making the universe accelerate the way that it is? The only solution that has been hinted at is the idea of dark matter and dark energy.

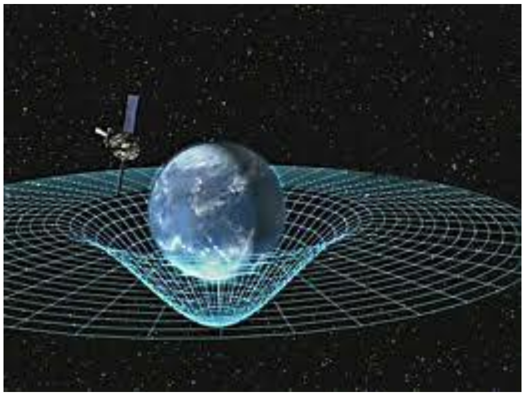
Let us begin with an explanation of what dark matter is. As you know, we do not understand dark matter’s full implications and characteristics, but it is possible to work with a functional definition, meaning we will only define it as to what it actually does rather than what it is. At the very base, dark matter is believed to be the reason why galaxies rotate the way that they do. As we know, galaxies are made up of millions, possibly billions, of stars. Each star has the energy to break off from the others, but because of the gravitational pull all the stars exert on each other, the stars stay in a rough orbit around some center. But scientists have been able to calculate the combined densities of stars within a universe and have found that the visible stars would not create a strong enough gravitational pull on each other to keep everything together. This leads to the assumption that there must be something else out there that is creating the gravitational attraction needed to keep galaxies together. This assumption led to the idea of dark matter, matter that exists out there that cannot be seen but creates a large gravitational pull.

But what exactly is dark matter? The simple answer is that we just do not know, but it would be beneficial to see what possibilities are out there, starting with black holes. As we understand them, black holes are actually collapsed stars. A star begins in the early stages as a large cloud of gas. If the cloud has enough density, it will collapse back onto itself and form a new star called a protostar. From this point the particle could go in many different directions all depending on the mass of the protostar and its chemical composition. If the mass is relatively small the protostar will turn into what is known as a ‘brown dwarf,’ a star that is basically a large planet giving off little light. Otherwise, if the mass is large and the star becomes hot enough, then it will result in a hydrogen burning star. This occurs through what is known as nuclear fusion, the process of the nuclei of lighter elements merging so as to form heavier elements. As nuclear fusion continues, the elements become more and more dense. If the star is massive enough, this process will continue until the star collapses due to its own gravitational force. When this happens, an explosion occurs which we call a super nova. Again depending on its mass, this super nova can result in two different things: a neutron star or a black hole. A neutron star results from the spinning off of different particles from a super nova and has an incredible density due to the fact that, through the super nova, most of the electrons and protons were destroyed, as its name hints at. By having no particles with charge on them, though, the material can be packed into a small space with an immense density. Due to the conservation of motion, as the material continues to collapse, which increases its density, the object will begin to spin at a higher and higher rate.

Eventually, again depending on the initial mass, the object will not be able to resist its own gravitational force, which results in a further collapse. This collapse can possibly lead to the core of the star disappearing altogether, which results in a black hole. All of these different objects; brown dwarfs, neutron stars, black holes, and huge planets; have been classified by cosmologists as massive compact halo objects (MACHOs) due to their characteristic of residing in the halos of galaxies. All of these objects at one point in time were suspects to the mystery of dark matter.

Back to black holes, though, within the sphere of Newtonian physics, which stated that gravity only affects objects with mass, the effects of the black hole did not make sense because it was found that not only did black holes affect objects with gravity, but they also had a huge effect on light, which is massless. Here we come back around to Einstein’s theory of relativity. Einstein concluded that, instead of gravity simply being a force between two objects, gravity was a result of the orientation of objects as they relate to space-time. From this we can see why even light, when it comes near to a black hole is bent, or attracted, towards the black hole. This idea of space-time is represented in Figure 3.

Figure 3

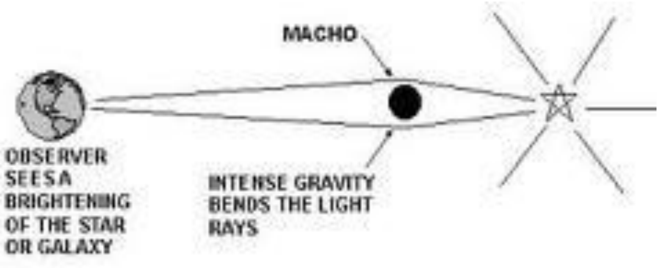


Here the plane represents space-time. As we can see, this plane is being bent by the presence of the Earth. This bending of space-time creates what we know as gravity. Any light that passes by along this plane will then experience a bend in its direction due to gravity.

But this idea of light being bent does not just apply to black holes. Any massive object will create such an intense gravitational “dent” in space-time that any light particle that is passing by will be bent towards that object. This occurrence can actually be used in such a way as to identify MACHOs by using what is called gravitational lensing.

Gravitational lensing is used to identify MACHOs in much the same way that the lens of glasses or even the lenses in our eyes work, except with one major difference. Instead of using the lens to identify an object, as in the case with glasses, gravitational lensing uses an object to identify the lens. It works like this: every star emits light. This light will always travel in a straight line as long as it does not encounter any gravitational pulls. So when we see a star from earth we are seeing the light rays as they are traveling directly from the star. But when the light from the star encounters a dip in the plane of space-time, the dip “focuses” the light of the star in such a way that it seems as if the star brightens for a brief moment. Of course we know that this dip is created by a massive object. This idea is represented in Figure 4.

Figure 4



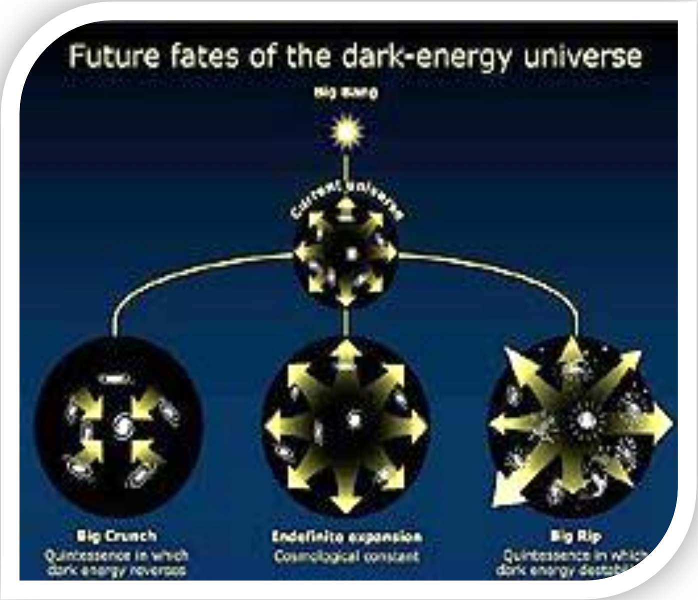
Gravitational Lensing--how MACHOs focus light

Dark matter does not emit any light of its own, so by using gravitational lensing a person can “see” dark matter by watching when a star momentarily brightens then fades again, indicating that a MACHO passed in front of the star’s light.

However, there are several flaws with this theory. We are not always able to tell if indeed a MACHO all of a sudden passed in front of a star, or the star merely brightened and faded on its on as many stars are prone to do due to the changes in pressures when burning its fuel. Also this theory does not hold a lot of water because if this were true then this should occur with high frequency due to the supposed large quantity of dark matter, but we find that this is not the case, gravitational lensing only happening once in a while. Although this theory has its pros, overall it is not a surefire way to detect dark matter. So now, even though we still do not know exactly what dark matter is, we do have a good idea as to how it works and the search to identify it still continues this day by many scientists.

So now let us turn our attention to another subject. If our universe is filled with only the objects that we have already talked about, then what does the future of this universe look like? Several different ideas have been proposed. Beginning with Newton’s law of gravity we are led to assume, that since all mass in the universe is attracted to all other kinds of mass, that eventually the universe will begin to collapse and will fall back on itself. Einstein believed that we lived in a universe much like a sphere. He theorized all about a “static” universe, a universe that was neither contracting nor expanding, but where it was possible to travel in one direction and eventually end up right where you started. This idea, though, is hard to grasp; for it seems as if Einstein was formulating a finite universe. And at that point many people begin to

Figure 5



ask: if the universe is finite, what would happen if you went passed the edge? That question can lead any person staggering from the effort to find an answer, but it is actually this idea that Einstein based all his formulas about the universe on and even made him give up on his cosmological constant for a time (we will get to that later). Another theory is that the universe may continue to expand at an accelerated rate where eventually everything is “ripped apart” in some way that we do not yet know. Then the last theory is that, even though the universe is expanding, it is doing so at a slower and slower rate so that eventually it will level off and cease to expand. It is this theory that has led many to formulate the idea of the “big bang.” By measuring the current expansion rate you can postulate that if everything is spreading away from each other at a constant rate, then if you trace this expansion back you would come to a single point in space where everything first began to spread out from each other. This has been called the Big Bang theory and has a good amount of evidence and many supporters. (A few of the theories on the fate of the universe are shown in Figure 5)

So what makes the difference in all these scenarios? Well, we have come down to one thing, it really all depends on the exact nature of what has come to be called dark energy. Again we will have to make do with a functional definition, as we do not really know what it is, but first let us explore where this need for dark energy came from.

As has been stated, Einstein theorized that the universe was static, or nonmoving, but so as to align with Newton’s idea of gravity he added that there must be some kind of force counteracting the gravitational pull of all the mass. This force was labeled in his formulas as the cosmological constant. Later, after Hubble’s discovery that the universe was actually expanding, Einstein ended up throwing away this cosmological constant. But many scientists believe that he did so too soon. Studies have shown, amazingly, that the mathematical value of the cosmological constant may be consistent with the rate at which the universe is expanding. Einstein discovered dark energy way before it was even thought of, only he did not know it.

But where does this seemingly random energy come from? If you think back to the beginning and the compositions of the universe, you will remember that the percentage of dark energy has dramatically increased over the years. Coupling this with the fact that we know that the universe is expanding, scientists have wondered if maybe dark energy is an actual property of the universe. We tend to think that space is a whole bunch of nothing, but what if space actual had energy in its very nature. This would make sense because as the universe expanded more and more, then the fraction of dark energy would continue to increase while matter and other sort of things would continually decrease in their percentage. Other theories are that dark energy may be some type of new fluid that only consists in space or maybe that our current theories of gravity have some aspect of them that are incorrect. We are not really sure what dark energy is, but scientists are hopeful that with more and better data we will be able to discern what this force labeled dark energy really is.

These two phenomena, dark matter and dark energy, make up the majority of our present universe. Yes, for the moment, there is still a lot to be learned about these two subjects and how they affect our universe, yet progress has indeed been made. For the longest time they were unseen and completely unknown, but with present technologies we have stumbled upon some monumental findings. Scientists are sure that; with continued documentation, experimentation, and progress in technology; at some point it will be inevitable that someone will make a discovery, a discovery that will rock the cosmological world. At some point the dam will burst; we are just on the brink.

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