February 2. 2006
Marlin H. Anderson, Jr.

INTRODUCTION

In his opening comments last spring, Frank Nash stated that the first paper of a new member of the Athenaeum Society was usually autobiographical. This was followed by a paper about their profession with later papers being about their interests. I have not given much of my history in earlier papers and so I would like to say a little bit about who I am and what has sparked my interests as an introduction to this current effort.

I was born in Montgomery Alabama as the fifth of seven children. My early years were spent in Millbrook and later Coosada, communities just north of Montgomery. My family did not have electricity or indoor plumbing in Millbrook. Kerosene lamps were used for lighting, a pitcher pump on the back porch for water and an outhouse for those private bodily functions. The outhouse was a "two-holer". What the second hole was for, I do not know. I don't recall ever sharing the outhouse with anyone, nor did I ever see others share it. It was never a place for long visits. In the winter it was cold and in the summer it was hot and invested with flies and other flying pests. Alabama has some pretty big horse flies. Our refrigerator was truly an "ice box" with the ice man visiting three days a week. I was fascinated by the scissor like tongs he used to carry a block ice with the use of only one hand. What held the ice in place when he was holding it with only one handle?

I have always been curious as to how things worked. This curiosity was not limited to mechanical things. It also included living things and I had a sister who did what she could to increase my knowledge. One Sunday while my mother was preparing dinner, this sister was kind enough to dissect an oyster to show me that the oyster had green blood. This insured that she had my share of fried oyster at the meal. I have since learned that a chromium containing molecule carries oxygen in shell fish while an iron compound serves that purpose in mammals, but I still don't eat oysters.

We had indoor plumbing and electricity by the time we moved to Coosada, but there was no air conditioning and no TV; therefore during the summer, we spent most of our waking hours out of doors. One clear summer night another of my siblings pointed out the Milky Way to me and told me how vast it was with nothing but a lot of dark space in between stars and planets. About this time I was also beginning to contemplate my mortality and trying to understand the meaning of eternity. Putting together the vast darkness of space and the vastness of time scared me to death. What does forever mean? I was still saying at bedtime the prayer many of us learned: "Now I lay me down to sleep, I pray the Lord my soul to keep. If I should die before I wake, I pray the Lord my soul to take." Well, I was not ready for anybody to take my soul so I tried to stay awake. Once sleep came, I had many vivid nightmares. Many may remember the World War II poster with the caption, "Uncle Sam wants you"? For me he was coming and my soul was in jeopardy. I eventually developed another prayer that did not include the dreaded phrase and was ridded of nightmares. I should also say that I have long since come to terms with my mortality, but that experience left me with a desire to know more about the universe in which we live.

After high school, I spent approximately five years in the Air Force before going to college and graduate school where I majored in physics. Solid state physics was my area of concentration with optics and optical instruments being used in my research and I gained an appreciation for the power of such instruments. Until the fourteenth or fifteenth century, the eye was our only optical instrument. Since that time, many instruments have been developed that allow us to look with greater clarity both outward, telescopes, and inward, microscopes. This brings me to the title of this paper: "We See, or Do We" where I will look at advancements in looking outward and how it has changed our cosmology.

WE SEE OR DO WE

Throughout recorded history, man has tried to understand his universe and his place in it. Until recently, man has been earth bound with all his earlier knowledge of the universe being based upon what could be seen with the naked eye. That is light from heavenly objects was seen and this light allowed him to construct a picture of the universe. Thus, it was natural for early civilizations to think of the earth as the center of the universe with everything else revolving around it. Have you ever stood on a high hill or a tower where you had a good view of the horizon in all directions? What did you see? Did it look like you were at the center of a big disk with a dome of sky above you?

The first know model of the universe was just this, a flat disk shaped earth covered by a semicircular dome. The sun and moon plied their paths across the sky just below this dome. The dome was opaque, but full of pinholes. The pinholes, which we call stars, allowed man to see the fire surrounding the outside of the dome. That is, our world was surrounded by fire. Fire above and fire below, some might say it was a "Hell" of an idea.
Other early Greek models were based on this disk shaped earth covered by a crystal dome, in other words, a covered cake plate. Another model had the earth and its dome surrounded by water, water above and water below. You might recall this from a reading of Genesis.

Around 500 B.C., the Greeks discovered that the earth was a sphere and the model became one with the earth as the center of the universe and the other heavenly bodies were located on concentric crystal spheres that rotated about the center. Aristotle had developed a model explaining the known facts around 350 BC that required 55 crystal spheres revolving around the earth in order to explain the motion of the heavenly bodies. Because of the harmony in these spheres, the idea of "the music of the spheres" was developed, and this idea crept into one of the hymns many of us sing. Again, the model fit observations and existing knowledge. Around 140 AD, Ptolemy, a Greek astronomer in Alexandria Egypt, improved Aristotle's model by adding epicycles to explain the retrograde motion of the planets. If one observes the motion of a planet over an extended period of time, the planet appears to move from east to west relative to the fixed stars most of the time. Periodically, it will turn and go backwards (retrograde) before continuing its regular motion. Ptolemy's was the accepted model of our universe for more than 1300 years.

Nicolas Copernicus had published after his death a book that suggested that a Helios or sun centered system was more plausible since it required fewer assumptions. Most scholars of the day and the Catholic Church still held to the Ptolemaic system. Galileo aimed his telescope at Jupiter and, low and behold, found that Jupiter had four satellites or moons. With this he declared that Copernicus' sun centered solar system must be right. He quickly found why Copernicus, a Catholic priest, had his work published after his death. The Church's view was that an earth centered system was Biblical and Galileo's view was heresy. He was forced to recant and spend the rest of his life in near house arrest, unable to teach or expound on his work. Slowly the Copernican system was adopted due to the work of people like Tycho Brahe, Johannes Kepler, Christiaan Huygen and Isaac Newton.

Brahe made exacting plots of the visible planets paths across the night sky for a period of 20 years. This allowed Kepler to develop empirical laws of planetary motion. Huygens improved the telescope by the grinding of more precise lenses and discovered a moon of Saturn along with expanding the Knowledge of Saturns rings. Using Newton's gravitational laws one was able to explain why the planets followed Kepler's laws. With time, our universe became the Milky Way. Before continuing, we need to say a little about light.

Empedocles, a Greek philosopher of the fifth century BC, believed that all matter was composed of four elements: fire, air, water and earth. This idea was adopted by Plato and Aristotle and dominated Western thought in one form or another until the eighteenth century. The reason for his four element theory was to argue a modification of the belief that all things that appear to exist are merely part of a single eternal reality.

Empedocles believed that light traveled with a finite velocity, not through any experimental evidence, but simply through reasoning. Others felt that light moved instantaneously from one point to another and rude experiments proved it to their satisfaction.

Aristotle writes in "De sensu" :-

"Empedocles says that the light from the Sun arrives first in the intervening space before it comes to the eye, or reaches the Earth. This might plausibly seem to be the case. For whatever is moved through space, is moved from one place to another; hence, there must be a corresponding interval of time also in which it is moved from the one place to the other. But any given time is divisible into parts; so that we should assume a time when the sun's ray was not as yet seen, but was still traveling in the middle space."

Many of Empedocles' ideas have turned out to be correct. In addition to his belief in the finite velocity of light, he developed a crude evolutionary theory based on the survival of the fittest. He developed a form of the law of conservation of energy and had a theory of constant proportions in chemical reactions. Although his ideas had little influence on the development of modern science, it can be said in the light of our current scientific knowledge that his insight into the world around him was incredible. But I digress.

Empedocles believed that Aphrodite made the human eye out of his four elements and lit a fire in the eye which shone out from the eye making sight possible. He realized that if that were true one would be able to see at night. This complicated things but he solved the problem by postulating an interaction between rays from the eyes and rays from a source such as the sun.

Lucretius did not see eye-to-eye with Empedocles and wrote in "On the nature of the Universe" (55 BC):-

"The light and heat of the sun; these are composed of minute atoms which, when they are shoved off, lose no time in shooting right across the interspace of air in the direction imparted by the shove."

We might say it differently but Lucretius was quite accurate. His views were not accepted, however, by many of his peers.

The understanding of the nature of light continued to improve in the East during what we know as the dark ages but little was learned in Europe until the thirteenth century with developments by Roger Bacon, William Snell and several others. There was still disagreement about whether the speed of light was finite or infinite and whether it was a wave or small particles.

In the seventeenth century, Newton sent a beam of sun light through a prism and found that what is now called "white light" is composed of all of the colors of the rainbow. The separation into bands of color is due to refraction or the change in the speed of light as it moves from a less dense to a denser medium or vice-versa. Newton was a proponent of the corpuscular or particle nature while Huygen and Hooke supported the wave theory. The disagreement between Newton and Hooke was so heated that Newton waited until after Hooke's death to publish his treatise "Optick" where he developed his theory of color. His theory would require light to travel faster in the more dense media than in the less dense one. Once it was learned that light actually travels slower in more dense media, in agreement with wave theory, the wave theory became the accepted one.

James Clerk Maxwell developed a set of differential equation in the late eighteen hundreds that described light as a transverse wave with electrical and mechanical components being at right angles to each other, what we now know as electromagnetic radiation. It was also learned that, when excited, different elements give off distinct spectral lines. That is discrete wavelengths with very narrow band width or a distinct set of colored lines.

We now know that visible light makes up only a very tiny portion of the electromagnetic spectrum. The Diameter of a human hair is approximately 90 times the wavelength of yellow light at the mid-point of the visible spectrum. This electromagnetic spectrum ranges from tenths of nanometers to several meters. One finds that the smaller the wavelength, the greater the energy per quanta. The most energetic or ones with the smallest wavelenghts we know as gamma rays while the low energy long wavelength ones we know as radio waves. In between, we find X-rays, ultra-violet, visible, infrared and microwaves. You might say, we don't see all that much of what is happening around us.

In 1895 Max Plank developed a theoretical expression for "black body" radiation that required light to be emitted in discrete packets or quanta, much like a particle. This was the birth of quantum mechanics and a new way of viewing the nature of light. We now say that light has a dual nature. In some case it behaves as a particle and in others as a wave. Developing a theory that would reconcile the dual nature of light would be sure to win you a Nobel Prize.

Now back to the development of cosmology. With improvements in lens making and the invention of the reflecting telescope by Newton, we were able to see further and more clearly the universe around us. We saw that what appeared to be hazy stars with the naked eye were in fact clusters of stars surrounded by what looked like clouds of dust. These were given the name nebula. A good example would the Orion Nebula, the center star like object in the sword of the hunter. The Milky Way was still felt to contain our entire universe.

Newton had used the prism to expose the visible spectrum in sun light and with improvements in spectroscopy; Joseph von Fraunhofer found dark lines or gaps in the sun's spectrum. He cataloged the more prominent lines. Meanwhile, Kirkoff and Brunsen found, that when heated, all elements emit discrete spectral line such as the two yellow lines of sodium that give rise to the color of sodium vapor lights or the red, blue, green and violet lines emitted from hydrogen atoms. They realized that the Fraunhofer lines were produced by absorptions of light characteristic of the elements in the outer layers of the sun and thus we could know the composition of the light source without visiting it to get a sample. Further improvements in spectroscopy allowed us to learn even more about the relative abundance of elements and more about their energy states.

When looking into the night sky we see that some stars appear to be bluish in color, while others have a more yellow hue and still others appear to be reddish. We now know that these colors represent different phases in the lifecycle of a star. More will be said about this a little later. First I would like to say a little something about distances.

Astronomers began determining the distance between stars by comparing nearby stars of similar brightness and type and using simple geometry. Cepheid Variables, one of a class of stars called Red Giants, were used to measure the distance to more distant stars after it was learned that the period of variation was proportional to the luminosity of a given star. Thus by measuring the apparent brightness and the period of the variable star, one could determine its distance from us.

Edwin Hubble in 1920 noticed that the Fraunhofer lines from distant stars were shifted toward the red end of the spectrum indicating that the stars were moving away from us. This effect is analogous to the variation in pitch one hears when a train is approaching or moving away from us. As the train approaches, the whistle has a higher pitch (shorter wavelength) than it does when it is moving away. The wavelength of light is increased as the light source moves away from us with the increase in wavelength being proportional to the velocity of the moving source. Using the red shift of Cepheid Variables, Hubble determined the size of the Milky Way to be 300,000 light years in diameter. We now know that his measurement was high and the Milky Way is only a mere 100,000 or so light years across.

Hubble was also the father of modern cosmology, since his discovery proved that many nebulae thought to be in the Milky Way were actually galaxies. Again using Cepheid Variables, he showed that the Andromeda Galaxy was approximately 1,000,000 light years from the Earth. Again he was a little off and today we think the distance is more like 2.9 million light years. His work showed that many galaxies were much more distant and in fact, the more distant the galaxy, the faster it was moving away from us. That is, our universe is not stagnant, but is expanding at an extremely rapid pace. This discovery led to Einstein saying that the inclusion of a factor in his General Theory of Relativity to make the universe static was the biggest mistake of his life.

When I entered graduate school in the 1960's there was debate over whether the universe will expand forever or will eventually slow and stop before contracting and if it does contract, will it be something like a bouncing ball or oscillating spring? That is, will it contract to a point, stop, turn and expand again? The mass of the universe would determine which of these models would be correct. It was known that not enough visible matter existed to make the universe continue its expansion and so the search for dark matter began. Gravitational effects indicate that only about 4% of the cosmos is seen directly with 23% being in the form of dark matter and 73% as a mysterious substance called dark energy. Again we don't see that much with the eye.

While some astronomers were beginning to construct instruments to look in the microwave and radio region of the electromagnetic spectrum for the low energy dark matter, two researchers at Bell Labs, Robert Wilson and Arno Penzias, were using their microwave antenna in an attempt to receive reflections from Earth satellites. Everywhere they pointed their instrument they found a low hum or static. Inspecting the bell of the instrument, they found pigeon droppings from pigeons that roosted there. They captured and moved the pigeons thirty miles away, but the pigeons returned. There was no other option but to kill the pigeons. The pigeons were sacrificed unnecessarily since the static remained. The low hum was cosmic microwave radiation of uniform strength that was being received from all directions. The shape of the spectrum was indeed like that of a black body (perfect radiator) with a temperature of 3 degrees Kelvin, supporting the Big Bang theory of creation rather than the steady state hypothesis.

Before discussing the "Big Bang" theory, a little must be said about the lifecycle of stars. Gravity causes particles in the dust and gas clouds of nebulae to contract into masses rich in hydrogen since hydrogen is the most abundant element out there. The more mass that is drawn in, the higher is the gravitational force. If the mass is on the order of the mass of our sun, at some point the pressure and temperature in the core becomes high enough to cause the fusion of hydrogen atoms to form helium, a controlled hydrogen bomb. The release of energy exerts an outward pressure with the emission of light and a star is born. Our sun is relatively small compared to other stars. We should be glad that this is the case. It has been burning its hydrogen for approximately 4.5 billion years and will continue this process for an additional 4-5 billion years. Once its hydrogen is consumed, the gravitational contraction will again resume until the temperature and pressure at the core becomes great enough that the fusion of helium begins. Helium will fuse to form carbon and our sun will expand rapidly forming a Red Giant in a relatively short time, less than a million years. When this happens, the outer surface of our sun will encompass all of the inner planets, Mercury, Venus, Earth and Mars. At that point, Earth may be a "hell of a place". It will be hot enough. Once the helium is expended, our sun will cool to a White Dwarf and eventually die, becoming a black dwarf. That is, it will no longer be visible and, if you will, it will be a cold day in hell.

A star having ten times the mass of our sun will go through a similar cycle, but the hydrogen-burning phase would last only a few million years and the helium-burning phase would last for a very brief period of time, followed by a tremendous explosion in which helium and carbon would fuse to form the heavier elements of the periodic table. This explosion gives rise to what is called a supernova. The Crab Nebula is the remnant of such an explosion that was observed by the Chinese in 1054 A.D. Supernova in other galaxies can be brighter than the entire galaxy for a brief period of time. The cores of these massive stars condense to become black holes.

A black hole is a mass so large that, according to Einstein, the curvature of space is so great that nothing can escape from it; not even light. These star remnants continue to draw matter into them. As the matter accelerates in approaching what is called the horizon, it gives off electromagnetic radiation in the x-ray region of the spectrum. The event horizon is the boundary between being able to escape the black hole and being captured by it. That is, if you were in a spaceship coasting toward the black hole, outside the horizon you could escape by firing your rockets but once you cross the horizon, you are doomed. No matter how big your rocket or how much power it has you are headed for the black hole. As you approach the horizon you would see the horizon moving toward you and at the horizon, it would be moving toward you at the speed of light while at a distance the position of the horizon would seem fixed. If this sounds strange, it is. It is a bit like "Alice in Through the Looking Glass": she has to run as fast as she can just to stay in one place. There is some evidence that the center of our Milky Way Galaxy contains a black hole. We Return now to the "Big Bang".

The "Big Bang" theory is based upon Einstein's theory of General Relativity, which states that space is not flat but is curved with the curvature of space increasing as the mass in a given region increases. The "Big Bang" theory is based on the assumption that all of the mass in our universe was concentrated at a point having zero volume with infinite mass and temperature just prior to a tremendous explosion. Mathematically, this point is known as a singularity since it cannot be described in mathematical terms. In fact, on a time scale, we can get only within 10^{-43} seconds of the initiation of the explosion. At this point, our universe would have been pure energy at extremely high temperature; no particles would have existed. Moving outward in time, there would have been the formation of some structure by one-millionth of a second with the beginning of the formation of many black holes.

One might ask, how did the universe continue to expand if very early in its existence it consisted of many black holes? Steven Hawkings came up with this concept and using quantum mechanics developed a way for mass to tunnel out of black holes and thereby causing the black holes to dissipate relatively quickly.

As the universe continued its expansion, first, sub-nuclear particles were formed, then neutrons, protons and electrons. This was all in a vast soup of ionized particles with no attachment of electrons to nuclei. With continued expansion and cooling, electrons were captured by protons and hydrogen atoms were formed. In this capture, the energy given up by the electrons was given off as light and the universe began to shine just as it shines today in gas clouds within nebula. Some neutrons combined with hydrogen to form deuterium and tritium and some hydrogen atoms combined to form helium. This became the soup from which the first stars were born. As it continued its expansion, stars began grouping together forming galaxies. Some stars were extremely large, having very short life leading to the production of the other elements we find here on Earth. In fact, our sun is what is known as a second generation sun since much of its material was gathered from the remnants of these exploding stars, making it rich in such elements as iron and silicone. These elements were also swept up to form the inner planets.

We now have telescopes that gather radiation from all regions of the electromagnetic spectrum. The Chandra telescope operates in the x-ray region, the Spitizer in the infrared, the Compton in the gamma-ray region and the Hubble in the visible portion of the spectrum. These instruments have helped up better understand our universe and also have helped to test the "Big Bang" theory. To date, the theory has met all tests. Some still have trouble accepting it but to me, it is fascinating to consider how it all came into being. I can now look at the night sky in awe and speculate about our place in the vastness of this universe that is more than 13.7 billion years.

In college, I dated a girl who was studying to be an elementary teacher. One day I met her coming out of the library. She had a Dr. Seuss book that she said I had to read. It was the greatest book she had ever read. Here you might question my choice of girlfriends and my willingness to read a child's book. The book was "Horton Hears a Who". Horton is an elephant who hears a who living on a dust particle in Whoville. Horton is asked to save Whoville from a catastrophe about to happen. One might speculate that we are Whos living in our own Whoville on a dust particle in some other creature's vast universe. It is just a thought.