A Christian Physicist Examines the Big Bang Theory

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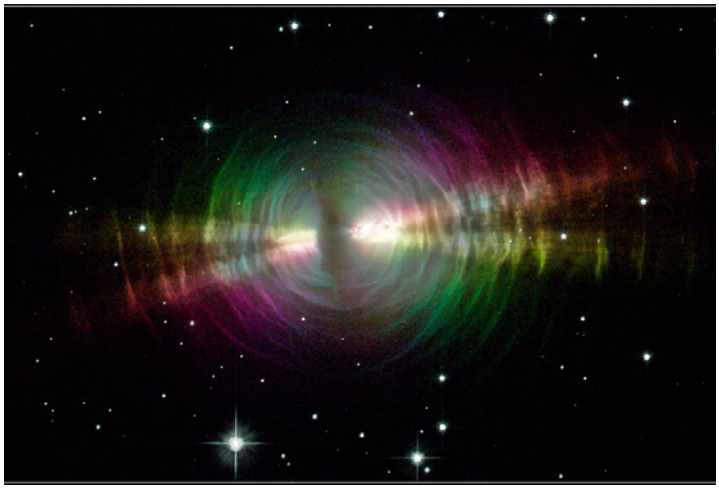

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Dedication

I dedicate this work to my physics professor, William Graziano, who first showed me that the universe is orderly and comprehensible, and stirred a passion in me to pursue the very limits of it.

Cover picture of the Egg Nebula, taken by Hubble Space Telescope, courtesy NASA, copyright free

Introduction

This booklet is a follow-up to the similar previous booklet, *A Christian Physicist Examines the Age of the Earth*. In that booklet I discussed reasons for the controversy over this issue and how these can be resolved. I also drew from a number of fields of science, ranging from the earth's geology to cosmology, to show that the scientific evidence clearly favors an age of 4.6 billion years for the Earth and about 14 billion years for the universe. I know that the Big Bang Theory of cosmology is not so readily accepted in some Christian groups, precisely because it points to an older universe. But I appealed to reason and the apparent agreement with the scriptures [1] when considering the evidence. However, in an attempt to preserve a continuity of discussion, that booklet only briefly covers some of the scientific evidence supporting the Big Bang theory, and the following discussion of scriptural references did not emphasize any relevance to the Big Bang. There was much more to write on these, but it did not seem to fit well with the discussion on the age of the Earth. However, since I asked the reader to reason with me, it didn't seem quite fair on my part to cut short the explanations. Thus I now offer a bit more for the reader interested in this issue.

Lately, there has been a widespread popular interest in finding out what modern science can tell us about origins, from the birth of our universe to the origin of life on planet Earth. Correspondingly, there are quite a number of popular books discussing the Big Bang theory of cosmology and implications for religious faith, some claiming support for the Bible [2,3], others by renowned scientists with varying personal philosophies of a non-Christian perspective [4,5,6]. In one of the most well known of the latter, Nobel Laureate Stephen Hawking conjectures an unknown physics phenomenon, admittedly in an attempt to remove the need for a Creator [6]. Indeed, it remains difficult to avoid the implications of the Big Bang theory, namely that there was a beginning to this universe having a cause beyond the universe itself. I would like to address readers struggling to make sense of both the Big Bang theory and its relevance to biblical faith. Here you will find a summary of the evidence from the perspective of a Christian whose training is in the field of experimental high energy physics. As such, I fully expect the Christian faith to stand up to the toughest questions I can ask of it, including how it relates to modern science. If you ask tough questions too, I trust you'll enjoy this account.

If people tell me that you don't need all of the science to be a good Christian with a strong faith, I fully agree. But science serves to enrich our lives and our faith. God has revealed truth to us through His Holy Word, the Bible, and through the physical laws and principles governing our universe. I would not have chosen a vocation pursuing physics knowledge if I truly felt it had nothing to offer of lasting value. I had a deep conviction that my physics training could serve a good purpose, as long as I was committed to following and serving God with all my heart. In fact, it is my hope and prayer that this booklet serves His purposes. Perhaps you can be a better judge of that than I can. It is my hope and prayer that the remarkable scientific account our generation has been privileged to see and comprehend will stretch your mind and will enrich your faith as it has mine.

Chapter 1
The Big Bang Controversy

Not long ago, a popular bumper sticker had the following catchy phrase, "I believe in the Big Bang Theory - God said it, and 'Bang!' it happened." Although one may differ concerning the intent of this message, it seems clear that the original intent was not in support of the "The Big Bang Theory" of cosmology, a commonly accepted theory among scientists concerning the origin and development of the universe. The bumper sticker was merely expressing a widely held skepticism on the part of believers who hold that the Bible gives us the correct account of how it all began, regardless of what the scientific community believes. This skepticism towards science in general appears rather widespread in the Christian churches of America today.

There is even a more common practice, which reveals a deep-seated distrust of science. It began with the Christian fish symbol, frequently seen on the back of cars owned by Christians. This symbol goes all the way back to first century Christians, who used it to identify themselves with a codeword, since the Greek letters in the word fish "ιχθυσ," pronounced "ichthus," also were the first letters of the words *Jesus Christ, God's Son, Savior*. Outspoken supporters of Darwinian evolution recently began placing a symbol on their cars showing a bigger fish sprouting legs, outlined with the word "Darwin", eating the smaller fish symbol. This certainly conveyed the meaning that Darwin's theory is replacing the need for Christian beliefs. In response to this, yet another bumper sticker shows a larger fish, outlined with the word "Truth", eating a smaller "Darwin" fish. All of this punching and counter-punching is revealing the hostility between those who hold to traditional Christian beliefs and those who believe that modern science has rendered the Christian faith merely empty mythology.

The Scriptures

Let us momentarily put aside modern science and look at what the scriptures say about the origins of the universe. The Bible explains that God was intimately involved in the entire process of creation. His purpose and plan are shown to be the driving forces behind the formation of this remarkable universe. However, many details concerning how are not given. The Bible is clearly not intended to be a science textbook. So how should one view the input of modern science? Do most Christians see modern science as contributing something of importance to their understanding of origins? No! The hostility revealed by the bumper stickers does accurately reflect a deep-seated skepticism of the scientific community and of science in general. Consequently, most Christians accept a view of origins without any input from science, particularly since this is seen as sacred ground reserved for the Bible alone to address. Scientific theories which appear to conflict with Biblical teachings are rejected.

And tragically, those outside the Christian faith who recognize the value of science, but see the Christian community rejecting it, see no need to consider the claims of Christian beliefs. Ironically, more than ever before science is confirming the validity of the Bible. While many in the Christian community feel no need for scientific confirmation of their beliefs, it is important for Christians to recognize that science is a strong ally of the faith. The testimony of the heavens is bearing witness to the design of a Creator as stated in Psalm 19:1, **"**The heavens are declaring the glory of God; and their expanse is declaring the work of His hands"[1]. Scientists are recognizing that the universe has a very remarkable design built into it. We shall discuss some

of this design in the next chapter. But where does one look for answers to the questions concerning the ultimate cause and purpose behind it all? People who feel an aversion to religion still have these questions. However, they cannot see themselves finding answers from a faith that rejects science.

My Challenge

I see no need for either group to compromise what they see as revealed truth, whether it is from the Bible or from science. Rather I wish to challenge both groups to consider how both form a remarkable consistency. Clear messages are being given to us both from the Bible and from the physical universe, which speak of God's careful design and His intent to communicate His presence to us. While it may always be possible to propose explanations for the scientific record which deny any involvement of a Creator, it has become increasingly difficult to do this while maintaining intellectual honesty. The evidences for precise design built into the universe at every level have become staggering. The same evidences supporting the Big Bang theory reveal many of these precision designs. Rather than recognizing the consistency between the scientific evidence and the Bible, some scientists have proposed bizarre explanations, such as the proposition that there must have been an infinite number of universes [7], and we happen to live in the one in which a long list of factors are fortuitously just right for our existence. But such explanations are not a very satisfactory response to the evidence. We have only one universe to observe and draw our conclusions from. Rather than appeal to things that can never be verified, let us look to the evidence at hand. The evidence reveals a universe consistent with the account of creation in the Bible, something that can be verified.

When challenging Christians to examine the Big Bang theory, I fully realize that Darwinism is the roadblock many face instead. Proponents of "Creation Science" claim that the Big Bang theory is just another tool of evolutionary scientists to explain away the existence of the universe without God [8]. Because it indicates vast ages for the universe and the earth, it is assumed by many to provide ample time for random natural processes to give rise to the evolution of life. However scientists, even those working in the field of evolutionary biology, have successfully challenged this assumption [9]. Establishing the Big Bang theory of cosmology does not validate Darwin's theory of evolution, since the incredible complexity of life still defies a scientific understanding of its origin. Furthermore, attempts to rule out God as the originator of the incredible features of our universe do not find much support from the scientific evidence. We will see that the evidence actually points to a Creator of unfathomable wisdom, transcendent of the universe itself. And it is the growing strength of the evidence, not prevailing philosophical whims, that also explains the growing acceptance of the Big Bang theory. The Big Bang theory does not leave God out of the picture, since it is merely a scientific account of how our universe has dramatically changed since its infancy. The question of its ultimate cause strongly suggests a Creator with a definite purpose.

What about Problems with the Big Bang Theory?

Skepticism of the Big Bang theory's validity based on scientific grounds is certainly welcome, since it is important to establish how much actual scientific evidence supports a given theory. Questionable data and biased interpretative frameworks are claims made by those choosing to reject theories now commonly accepted by the scientific community [8]. But scientists themselves, for reasons that will be discussed later, have been the strongest critics and have

imposed a very thorough scrutiny of the Big Bang theory. Several valid questions have been raised, some leading to a more careful formulation of the theory and a quest for more accurate astronomical measurements. Others highlight the fact that the theory is incomplete and does not yet explain all details of the history, composition, and structure of our universe. These have been conveyed in popular accounts critical of the Big Bang theory [10], especially since provocative titles tend to sell more books. But many of the criticisms and objections have since been resolved with more accurate data and improved understanding, as we shall see. The Big Bang theory has survived the intense scrutiny and in the process, even more compelling evidence has been found in support of it.

Our Response to the Evidence

As we shall investigate in the next chapter, there is clear evidence that the universe is expanding from a hot, explosive beginning approximately 14 billion years ago. But before we explore this, let us ask ourselves "how should we respond to the evidence?" A healthy respect for the role of science does not require us to choose between it and the Bible. Rejecting the evidence from science may indicate a lack of faith that the God of the Bible could be the same One who wrote the laws governing our universe. I encourage people to consider how God can use the same physical principles, which are used to understand the Big Bang theory, to accomplish His will regarding creation. If the vast age of the universe is the only reason for rejecting the Big Bang theory, then it's time to give it thoughtful reconsideration.

As I wrote in the booklet, *A Christian Physicist Examines the Age of the Earth*, the Bible does not permit a determination of the age of the earth or the universe from its passages without questionable interpretations. However, creation itself does have much to tell us, containing a record of its history all the way back to the moment of creation of the universe. We are now able to examine the remarkable story written in the heavens more clearly than ever before. For the sake of the nonscientist reader, I will attempt to tell the story in the most basic terms possible. It is helpful to summarize the development of our scientific understanding and the interesting accounts behind our most important discoveries. Then we will then explore several of the popular objections and corresponding answers. Finally we will consider how the Big Bang theory relates to the origin accounts of the Bible, since the Bible's authority is used to guide the Christian believer in a search for truth, especially in significant issues such as the creation of the universe.

Why is the Evidence so Important?

Before we begin, let us address why it is so important that empirical evidence is the primary reason for the growing acceptance of the Big Bang theory. The evidence is far more valuable than any interpretative framework or philosophical bias, since the evidence is no respecter of persons. It cannot always be forced to fit one's favorite theory. Wrong interpretations will inevitably encounter inconsistencies that cannot be adequately explained as more evidence mounts or as the evidence is examined more carefully. But in order to allow science to work successfully we must be willing to allow the evidence to guide us, to correct us, and to test our ideas. This is the basis for good science. In *A Christian Physicist Examines the Age of the earth*, I discussed criteria for good science, despite the fact that we cannot completely reproduce the events of the Big Bang in our laboratories on earth. These criteria are important enough to repeat here. I wrote:

> The reliability of the evidence can be determined in a number of ways. First of all, since our universe obeys certain laws and principles, the evidence should be examined in light of these well-established laws and principles. Secondly, when several independent sources are all giving very similar answers, it increases the measure of confidence we have in the results. Good science requires both the measures of self-consistency and consistency with other independent, yet equally valid methods. [11]

While the Big Bang theory has not only survived intense scrutiny, a series of remarkable confirmations have shown it to be one of the greatest scientific accomplishments of recent years, revealing an incredible story of how our universe developed into what we observe today. It has become one of the strongest testimonies to the validity of the biblical account of creation, since it clearly confirms that our universe had a beginning, as described in Genesis 1, in which the cause of it is outside of the physical realm we observe. It is remarkable that the observations have allowed us to trace the record of our universe back to this beginning point.

But does our worldview permit us to examine this evidence thoughtfully? One holding a solid faith in the Bible should have no fear of examining the testimony of the universe, since this too bears witness of God's handiwork. And for the one who appreciates science, but is skeptical of whether it agrees with a Christian worldview, I also urge an open mind. You will find that the evidence provided by the universe doesn't need a lot of speculative interpreting on our part. Leading scientists have simply provided a theoretical framework based on known laws and principles of physics to describe what we observe. The resulting Big Bang theory has provided us some very testable predictions, which agree well with the astronomical evidence collected over the last four decades. Let us now consider the evidence supporting the Big Bang theory.

Chapter 2
The Evidence Continues to Grow

When I was recently asked, "What is the greatest scientific discovery of the 20th century?" I didn't need any time at all to reflect. Without hesitation I replied that the discovery of the Cosmic Microwave Background Radiation, made in 1965, showed us clearly that the universe had a beginning. One of the most fundamental questions of science was settled by one very clear observation made by accident. Two Bell lab scientists, Robert Wilson and Arno Penzias, were testing out a new microwave receiver, when they noted a low temperature background "noise" that persisted despite all efforts to remove possible causes, including the radioactivity in pigeon dung! Not knowing any plausible reasons for the microwave radiation, they began calling scientists who might be able to help. When they relayed their findings to Jim Peebles, an astrophysicist at Princeton University, they finally received their stunning answer. It turned out to be the predicted radiation left over by the initial explosion that began the expansion of the universe itself. The Bell lab microwave receiver was the first telescope capable of analyzing such light waves, allowing an accidental discovery. This fascinating story is told in more detail by Robert Jastrow's book *God and the Astronomers* [12].

What was it about this discovery that convinced scientists that the universe had a very hot, explosive beginning? Did this simply fit a growing paradigm that had already gained a foothold in the scientific community? Hardly! As a mocking gesture, the name "Big Bang" had been given to the theory that predicted such a hot, explosive beginning by astrophysicist Fred Hoyle, who held firmly to his favored "Steady State" theory, in which the universe has no beginning. In fact, a number of scientists had earlier considered the Big Bang model to be philosophically undesirable, since it reveals a beginning which science itself cannot fully explain. Indeed, the Big Bang theory demands a cause from beyond the universe itself, since all matter, space, and even time were created in one spectacular event. As Jastrow writes,

> At this moment it seems as though science will never be able to raise the curtain on the mystery of creation. For the scientist who has lived by his faith in the power of reason, the story ends like a bad dream. He has scaled the mountains of ignorance; he is about to conquer the highest peak; as he pulls himself over the final rock, he is greeted by a band of theologians who have been sitting there for centuries [12].

No, the entire scientific community was not overwhelmingly eager to receive supporting evidence for such a theory. For it demands answers from outside the realm of science. But by 1965, for most scientists the evidence was too glaringly obvious to ignore. It is noteworthy that the scientific community chose to accept what the evidence was clearly revealing, in spite of personal bias against it. Perhaps we can all learn something important from this. But at the start of the 20th century, the view many scientists held concerning cosmology had no basis in scientific evidence. Let us briefly review how these changes came about.

Einstein, Relativity, and his Personal Bias

Resistance to the Big Bang existed even before the theory was formulated. Efforts to avoid the conclusion of the Big Bang, that the universe had a beginning, were already in full swing when

Einstein developed his theory of general relativity, back in 1916. Einstein had been busy working out a new theory of gravity that would render Isaac Newton's theory of universal gravity an incorrect description. This was quite an audacious move on Einstein's part, considering the 250 years of stunning success of Newton's universal gravity in describing orbital motion in our solar system. Astronomical events such as eclipses can be predicted accurately in advance for hundreds of years or pinpointed backwards in ancient times. But Newton's theory of gravity was suspected to be inexact where gravity is very strong, such as very near to our Sun. Irregularities in the orbit of planet Mercury could not be explained by Newtonian gravity.

Contrary to Newton's view of time, Einstein had already shown with his theory of special relativity in 1905 that time could not be considered the same for all observers in the universe. There really isn't any absolute universal clock, since measurements of time depend on an observer's reference frame. Comparing measurements made in one reference frame to those made in another frame moving rapidly relative to the first one reveals differences in the lengths of objects and the times between ticks of a clock. This has been verified to high accuracy by many experiments. Space and time are intertwined in such a way that we refer to both together as space-time. An excellent introduction to relativity limited to algebra can be found in reference [13]. But the theory of special relativity only considers reference frames moving at constant speeds relative to each other, and therefore does not include gravity, where acceleration exists. However, Einstein believed that since Newton's concept of universal time was incorrect, his universal gravity must also be reformulated, since it incorporates the concept of universal time.

After 10 more years of intense work, Einstein finally had a complete theory of relativity, one that included acceleration and gravity, as equivalent concepts. As promised, general relativity only agreed with Newton's universal gravity where gravity is weak, which holds true for the motion of most objects in our solar system. But where gravity is strong or in considering a vaster scale of the universe, the theories prove radically different. General relativity connects the properties of space-time to its proximity to matter. High concentrations of mass warp space-time in such a way as to effectively change the measurement of distances and time for observers at varying proximity to it, even if they are not moving relative to one another. On the large-scale universe, the mass density of the universe determines the overall curvature or warping of space-time.

Einstein, who had remarkable insight into the physical significance of his theory, began to apply the equations of general relativity to the universe itself, and soon found himself facing a dilemma. He recognized that in solving the equations of general relativity, if nothing exists to counteract the attractive force of gravity, then a static universe is not possible. In other words, gravity would serve to either pull the entire universe back together, or to slow it down if it were expanding. Einstein later admitted as "the greatest blunder" of his scientific career, his insertion of a term into the equations that had absolutely no observational basis, a term referred to as the cosmological constant. His reason is clear. The only way to get a static universe solution, in accordance with his philosophical inclination, was to have something counteract gravity. The cosmological constant would serve as this mechanism, even though there was no other reason to invoke it. It represents a pressure derived from the energy of space-time itself. Popular science journals have recently been making bold claims that Einstein has been vindicated; since it now appears that the cosmological constant is actually non-zero [14]. However, this is somewhat misleading, since Einstein's intent was to show that the universe could be static, which eventually proved to be incorrect.

General Relativity: Predictions and Observations

The Russian scientist Alexander Friedman did not see any need for a cosmological constant, and chose to take Einstein's more basic equations of general relativity and solve them for the entire universe. By assuming the universe is relatively uniform (homogeneous and isotropic) the equations can be solved, even without the aid of a computer. Although it now appears that the universe is not very uniform today (we see densely populated regions of galaxies interspersed between large voids), the assumption is still a reasonable one for two reasons. First of all, the concentrations of mass we see today were not so unevenly clustered during much of the initial expansion, as we shall discuss later. Secondly, the growing development of anisotropies in the universe does not significantly alter the overall solutions, which predict a uniformly expanding universe. His solutions were published in 1922 [15]. In contrast to Einstein's static solution, all of his solutions involve a beginning point reached by extrapolating backwards in time. Although his solutions were derived from the more basic equations of general relativity without the cosmological constant, this did not necessarily imply that they were a more correct description of our universe. General relativity itself had not even been confirmed by experiment.

In 1919, astrophysicist Arthur Eddington led a team of scientists to Africa to observe a solar eclipse. Although solar eclipses had been observed many times before this, this occasion was to provide a very important test of general relativity. Einstein realized that for a theory to be successful, it needed experimental verification. He had provided a bold prediction that easily allowed his theory to be confirmed or be proven incorrect. The prediction was that starlight would be bent by strong gravitational fields, such as light from a distant star passing near our Sun. Although the actual angle was very slight, the experimental measurement would reveal whether general relativity or Newtonian gravity was correct. Eddington's team showed convincingly that starlight is indeed bent by gravity, and that general relativity was the correct description of gravity. Additionally, the orbital irregularities of planet Mercury proved to be in excellent agreement with the predictions of general relativity. In the following years, additional tests would continue to confirm the accuracy of general relativity [16]. But while the theory of general relativity was vindicated, the question of whether the universe was static or expanding remained unanswered.

Hubble discovers an Expanding Universe

The Mount Wilson Observatory opened in 1920 with the largest telescope in the world, a huge 100-inch diameter, reflecting mirror. This allowed sufficient resolution to begin identifying individual stars in galaxies beyond our own Milky Way galaxy. Using Cepheid Variable stars, whose brightness varies periodically, Edwin Hubble was able to measure the distances to these galaxies. These are considered standard "candles", with established intrinsic brightness, allowing an observed brightness to be converted into a corresponding distance from us. The distances are immense, beyond what a spaceship traveling at near the speed of light could cover in a million years. Hubble also learned something about the universe. He was able to determine how fast each galaxy moved relative to us, by measuring how much the wavelengths of light were changed according to the Doppler effect. Galaxies moving away from us have their light stretched out to longer wavelengths, while those moving towards us have their light shrunk to shorter wavelengths. He found that the universe is expanding at an incredible rate. His famous law of cosmology was established by 1929, namely, that the further away a galaxy is from us, the faster it is moving away from us [17]. Einstein, convinced of the results, decided his

cosmological constant was the greatest blunder of his scientific career. The simple and elegant form of general relativity appeared to be sufficient to describe the universal expansion.

Certain implications of this result were clear. The universal expansion is not like any ordinary explosion we can observe, where matter is thrust outward in all directions within measurable space and time. This explosion involved the expansion not only of matter, but of space and time as well. It makes no sense to ask what lies outside of the expanding universe, since it includes all of space-time, something we cannot visualize with our 3-dimensional perspective. We can only use analogies to understand it. One very good analogy is the surface of a 3-dimensional sphere. Since you only need 2 coordinates (latitude and longitude) to locate any point on its surface, the surface can be thought of as a 2-dimensional realm. People confined to 2 dimensions would not be able to visualize that their realm is a curved one, but they could certainly determine that by making some measurements over a large enough area of the surface. That is exactly why we needed to make measurements over very large distances to determine if our realm of space is curved, and whether it will continue to expand or slow down and reverse at some point. In either case, extrapolating backwards in time, the realm of the universe shrinks to a point, the beginning point where all space and time begins. A beginning then demands a Beginner, One who is not confined to the universe and the laws that govern it.

The "Steady-State" Universe

But acceptance of this obvious conclusion was not forthcoming. It would require much more evidence to convince the scientists that the universe had a beginning. Although the universal expansion was accepted, cosmology was considered by most to be a non-testable area that was borderline science, mostly metaphysics. Certainly no one could reproduce the events of the early universe in the laboratory. Failing that, what evidences could be found to support any theory of cosmology? Little did anyone realize just how much evidence would be discovered. Prior to World War II, the observed universal expansion and the successful theory of general relativity stood alone as the basis for a scientific view of cosmology. And these alone did not convince everyone that the universe even had a beginning.

Following World War II, scientists began to turn back to basic science research again, since the war effort had diverted the brightest minds to weapons research. Some astrophysicists sought to construct cosmological models, which agreed with the observed expansion of the universe, but did not have a beginning. The "Steady-State" cosmology of Fred Hoyle is the best-known one, recognized largely because of its philosophical appeal to many scientists. To its credit, it also made some clear predictions that allowed it to be tested experimentally. Its premise is that new matter is continually being created as the universe expands so that voids are filled in with the new matter, thereby eventually forming new galaxies. Thus the universe always looks the same, even though it is expanding. It would later become clear that the "Steady-State" model failed to agree with several basic observations. One simple prediction, that there should be many galaxies with vastly older stars than those of our Milky Way galaxy, is clearly wrong. All nearby galaxies appear comparable in age to the Milky Way. However, as we look far out into the distant regions of the universe we see evidence for much younger galaxies. This is exactly what is expected in a universe in which nearly all the galaxies formed at the same time, since looking at distant galaxies is effectively looking backwards in time due to the travel time of light. But there are no hints of any galaxies much older than our own, as is expected from the Steady-State

model. However, scientists remained reluctant to accept that the universe had a definite beginning. That would require much more convincing evidence.

The Cosmic Microwave Background Radiation

Russian-born physicist George Gamov chose to examine what physical implications would result from an earlier, extremely hot and compact universe [18]. Gamov's model predicted in 1948 a radiation pervading all of space that would now be cooled down to a very low temperature following a lengthy expansion. The explanation for this radiation is the premise that all fundamental particles would have existed in very close proximity in the early universe, when extreme temperatures would have caused continued emission and absorption of radiation by the hot, dense mixture of particles. But as the universe expanded and cooled, one very peculiar event would make the universe suddenly transparent to this radiation, allowing it to expand and cool independent of matter in the universe. That event was the point at which the temperature had fallen sufficiently to allow the slower electrons to be captured by protons, forming neutral Hydrogen atoms. A similar process forming neutral Helium atoms would occur as well, a topic we shall return to later. When this happened, the radiation was no longer energetic enough to free the electrons from the protons, thus allowing no more absorption of the radiation. The initially extremely hot "explosion" that sent the universe expanding would eventually cool down as it expanded to a very cold background radiation today. It is called the Cosmic Microwave Background Radiation or CMBR because it has the same wavelengths as the radiation in the microwave ovens we use. Not all scientists were impressed by such a clever idea. As a mocking gesture, Fred Hoyle nicknamed this a "Big Bang" theory, a label that would stick.

This radiation would not look like mere random noise, since it should have a very characteristic distribution of wavelengths described by "blackbody" radiation. While all objects radiate heat in the form of light, most objects are not hot enough to radiate light that our eyes can see. For example, our bodies radiate infrared light, which is invisible to our eyes. In the nighttime sky we see light coming only from the Moon and planets and stars far beyond our Sun. But if we could see microwave light, the entire night sky would be glowing. Blackbody radiation is radiated by an object that absorbs all light incident upon it (rather than reflecting it), then emits the light with a characteristic distribution of wavelengths that depends only on its temperature. Gamov and his colleagues had predicted the CMBR temperature to be only around 5 degrees above absolute zero degrees Kelvin, or -450 °F [19]. At that time it was assumed that this very low temperature background would be beyond the capability of available technology to detect for many decades.

That brings us to the early 1960's, when Bell Laboratories scientists Robert Wilson and Arno Penzias were developing a radio-microwave receiver to study various microwave sources in the Milky Way Galaxy. The cosmological prediction of Gamov was completely unknown to them. In fact, Robert Wilson regarded the "Steady-State" theory of Fred Hoyle as the leading cosmological model [20]. Their interest was more in pinpointing astronomical sources of microwaves, since it was known that the Milky Way Galaxy is a source of longer radio waves. They soon detected a faint microwave source that appeared to be coming from all directions in the sky. This was at first assumed to be noise, either associated with the receiver or with unwanted background sources nearby. One by one, Wilson and Penzias ruled out the possible sources of noise. Even the radioactivity in pigeon dung was ruled out after a careful cleaning of the receiver. The persistence of Wilson and Penzias allowed for an unmistakable identification of the source of the microwave radiation as an astronomical one by 1965 [21]. But first they had

to make some phone calls to ask for ideas from astronomers. They learned from Princeton astronomer Jim Peebles that they were looking at the radiation left over from the hot initial explosion predicted by the Big Bang theory of cosmology. Robert Wilson and Arno Penzias would be awarded the Nobel Prize in 1978 for their remarkable discovery of the Cosmic Microwave Background Radiation.

The CMBR has since then been carefully measured by a number of experiments. The Cosmic Background Explorer or COBE, a satellite launched in 1989, has carefully measured the radiation to have a temperature of 2.726 degrees Kelvin. However, COBE was designed to investigate something much more interesting than the precise average temperature of the radiation. It was recognized that a perfectly uniform temperature from all directions would not be possible in a universe in which matter had clumped together to form galaxies. The fact that galaxies did form implied that even during the very early stages of the universe, when the radiation became transparent to matter, there must have been some unevenness or "ripples" in the radiation. Without regions with slighter hotter temperatures, there would not have been any preferred locations for galaxies to begin forming. These ripples were calculated to be minimally one part in a hundred thousand slightly hotter than the surrounding temperatures. Measuring such precision low temperatures from earth is rendered very difficult due to the heat of the earth's atmosphere. However, COBE could avoid this problem by measuring it in the vacuum of space far above the earth's atmosphere. In 1993 COBE scientists announced the discovery of ripples of a few parts in a hundred thousand [22], showing the radiation has enough unevenness to account for galaxy formation. This has been confirmed by succeeding experiments. The Big Bang theory has withstood the test of a closer examination in convincing fashion.

Abundances of the Elements

An additional test of the Big Bang theory includes the abundance of elements in the universe. We observe that matter in the universe is predominantly Hydrogen atoms. Even though Hydrogen is not the earth's most abundant element by mass, over 99% of our solar system's mass is contained in the Sun, which is 73% Hydrogen, 25% Helium, and around 2% heavier elements by weight. We find this is approximately true of nearly all stars, except for the remnant cores of extinct stars. And since stars form the predominant source of matter in the universe, the universe is thus mostly Hydrogen and only one-quarter Helium. Amazingly, the remarkable events of the early universe explain this ratio quite accurately. Early in the expansion, not even protons and neutrons could form, due to the incredibly hot temperatures and rapid collisions of the fundamental particles from which they are composed. But the cooling induced by the expansion would then allow protons and neutrons to form without being subsequently destroyed. Neutrons are unstable by themselves, decaying after a few minutes into a proton, an electron, and a neutrino (a ghostly particle very weakly interacting with matter). Therefore, if all matter in the early universe consisted only of protons, neutrons, and electrons, the resulting decay of neutrons would have left only Hydrogen atoms after each proton eventually captured an electron.

What took place concurrent with the neutrons gradually decaying away was a continued cooling until a proton could combine with a neutron long enough to form a Deuterium nucleus, which is stable. Indeed, neutrons are quite stable inside certain nuclei. A Deuterium nucleus would then fuse together with another Deuterium to form a Helium nucleus, which is very stable. This process of nuclear fusion is similar to what is generating energy inside our Sun today. It is possible to calculate how much matter should have been converted into Helium, given the

lifetime of the neutron and the time it took for the expanding universe to cool down until it became too cool to fuse protons and neutrons into Helium nuclei. This period ended only three minutes after the initial explosion that began the expansion [5]. Very little elements heavier than Helium should have formed in the Big Bang explosion since even higher temperatures are needed, and the universe was cooling off. Leftover neutrons, not having fused into Helium nuclei, would then have decayed into protons, eventually forming Hydrogen atoms. Only a very small amount of Deuterium would have survived since it is very weakly held together and would have continued to be knocked apart long after it was too cool to fuse into Helium. The resulting expectation is that the matter in the universe should be approximately 75% Hydrogen and 25% Helium, almost exactly what we observe today. This calculation was first carried out in 1948 by Ralph Alpher, a colleague of Gamov [19].

If the universal expansion rate had been slightly greater, not much helium would have been generated since the rapid cooling would have left little time for Helium nuclei to form before it became too cool to induce fusion. In this case nearly all the matter in the universe would have become Hydrogen atoms. If the expansion rate had been slightly less, there would have been sufficient time for most of the protons and neutrons to fuse into heavier elements. Either way, the universe would have been much different than it is today. Remarkably, by using the known expansion rate along with well-established nuclear physics reactions, we find that the universe should be mostly Hydrogen, some Helium, with a small fraction of heavier elements. It has now been established that the 2% heavier elements, of which our earth primarily consists of, has been primarily generated in later fusion processes inside stars, long after the initial explosion of the universe. Our observations match precisely what is predicted. This constitutes a very strong support for the Big Bang theory.

The Big Bang theory has remarkably predicted what we see in the universe today, from the universal expansion to the Cosmic Microwave Background Radiation with its slight “ripples”, to the abundance of elements we observe in the universe. While additional tests continue to be made, the Big Bang theory has become recognized as a highly successful theory with impressive predictive power. It meets the criteria for good science, all the more so because of the scrutiny it has been subjected to and withstood. We now examine in the next chapter how the investigation of supposed problems has only served to further vindicate the theory.

Chapter 3
Problems with the Big Bang Theory?

No important theory is without problems of some kind, simply because of the richness of our universe in which new phenomena continue to challenge our understanding, ensuring that science remains an actively growing and changing enterprise. But that doesn't mean that established laws and principles get thrown out the window. Usually, a more general principle is found which makes the old one just a special case of the new one. That is certainly true of Einstein's theory of relativity, which agrees with Isaac Newton's theory of universal gravity in most cases quite well. It was only when problems were found, giving rise to suspicions that it was an incomplete theory, that a more general theory was sought. That may be the case with the Big Bang theory, since it presently rests on known laws and principles of physics. There may well be new physics that remains to be discovered, which would require the Big Bang theory to be modified. Indeed there already have been numerous apparent problems explaining some of our observations with the Big Bang theory. Some have taken this as an opportunity to denounce the Big Bang theory's validity as a whole [10].

But it must be emphasized, that no other scientific theory has been offered yet which has explained so much of what we observe in the large-scale universe. Also important is that the Big Bang theory was not proposed as a complete explanation of the origins and development of the universe. It arises from applying the same principles we find to hold true in our realm of the universe to the development of the entire universe. The observed problems have actually led to further advances in the Big Bang theory, which helps us understand the very early universe and its subsequent development even better. These problems include the "uniformity" problem, the "flatness" problem, the "missing matter" problem, the "age" problem, and the recently observed accelerating expansion of the universe. There is, of course, also a theological difficulty that some see in the Big Bang theory. But let us defer that discussion to the next chapter. Here, we briefly describe each scientific problem and how each has been resolved and has further strengthened the case for the Big Bang theory.

The "Uniformity" Problem

The "uniformity" problem has to do with the incredible degree of uniformity of the Cosmic Microwave Background Radiation at 2.726 degrees Kelvin [22]. Even though the slight "ripples" have been found to agree with the level needed to explain galaxy formation, there is another problem even more serious. It is known that the universe was expanding at such an incredible rate during its most early period, prior to the radiation being released, that it could not have had any opportunity to come into thermal equilibrium. Not even light could have had time to travel between separated regions of the expanding universe to allow the same uniform temperature to be reached in all parts of the universe. Thus the highly uniform radiation temperature is either simply an extremely arbitrary initial condition of the expansion or some mechanism existed to allow the universe to thermalize prior to the expansion. It is important here to note that scientists by nature do not wish to accept extremely arbitrary initial conditions as an explanation, since that ends the search for any other explanations, of which there may be a good one. A good explanation is also one that may indeed be correct, as borne out by further investigation.

In this case, a good explanation does exist. It is good for several reasons. It resolves not only the "uniformity" problem, but it also the "flatness" problem, which we shall address next. Another argument in its favor is that it agrees with our understanding of the fundamental forces of nature. However, it requires that we go back very close to the start of the universal expansion, to when all of the fundamental particles were swarming in an extremely hot, dense mixture that formed the entire universe. At this earliest time, there were no galaxies, stars, or even protons or neutrons. Everything is broken down into the smallest constituent particles in the universe. The fundamental forces responsible for electromagnetism and the nuclear strong and weak interactions were essentially all identical at this extreme temperature. This expected unification of the fundamental forces of physics is itself a remarkable leap in understanding, since it arose from the study of particles and fields, independent of cosmology. But the only time the fundamental forces in nature were identical was during the moment right after the creation of the universe. We cannot achieve a high enough temperature to simulate these conditions today, and thus it remains somewhat speculative. The time is within an extremely small fraction of a second, approximately 10^{-35} seconds after the start of the universal expansion, which began in an exceedingly hot state. As the universe expands it cools in this brief time, until it is cool enough for the nuclear strong force to become distinct from the other forces. As this transition takes place, an enormous amount of energy is released and a tremendous effect occurs. The energy released serves as a repulsive force, overpowering the gravitational attraction. The universe undergoes an extremely short and rapid expansion called "inflation", analogous to a phase transition when a liquid becomes a gas. This inflationary period was proposed by physicist Alan Guth in 1981 to resolve the uniformity problem [23].

The rapid expansion balloons the universe from an extremely small dot too little for our eyes to see, into a universe roughly 50 orders of magnitude larger within an extremely small fraction of a second. Then the universe continues to expand in a much more milder fashion, although still quite impressively such that the universal expansion is too fast to allow light enough time to travel from one part of it to another quite distant part as it expands. We know that the universe has expanded faster than light can traverse its extent, since we are presently observing events at the "edge" of the visible universe with our most sensitive telescopes. At the "edge" of the visible universe, objects now coming into view have previously been too far removed from us for the light, traveling at the speed of 186,000 miles each second, to have arrived to us since the universe began. This problem has also been referred to as the "horizon" problem, since most of the universe has been beyond the horizon limited by the travel of light [24].

Inflation resolves the "uniformity" or "horizon" problem in the following way. Prior to the inflationary expansion, the universe was extremely tiny, small enough that even in the small fraction of a second prior to inflation, light could easily traverse the universe. Thus thermal equilibrium is reached quite thoroughly before inflation takes place. That equilibrium is then preserved during the rapid inflation of the universe. After the rapid expansion, the uniform temperature everywhere is simply because of the previously very close proximity of everything, when the universe was able to come into equilibrium. Even though vast regions of the universe are now separated beyond what even light could traverse during vast ages of the universe, these regions were already "causally" connected, and thus at very nearly the same temperature. The very rapid inflation of the universe served to smooth out irregularities even more, resulting in a cosmic microwave background radiation today at a very uniform temperature everywhere. But

without any such inflationary period, the universal expansion does not allow the vastly separated regions to ever be "causally" connected by light.

The "Flatness" Problem

Inflation also explains the "flatness" problem, but we first much define what this means. As mentioned previously, the mass density of the universe controls the space-time curvature of the universe. If the mass density is larger than a certain critical value, then space is curved in such a way that the extent of the universe is finite, analogous to the surface area on a globe being finite. If one could quickly traverse through the universe, one would eventually return to where one started, but the limiting speed of light in an expanding universe does not really allow this possibility. If the mass density is lower than this critical value, then space is curved in such a way that the extent of the universe is infinite, analogous to what the surface of a saddle looks like. In one direction the saddle is curved downward while in another direction the saddle is curved upward. Continuing the saddle surface on upward and downward continuously renders a surface that has no end. In between these two possible curvatures of the universe is a flat surface that has neither curvature. Given the wide range of possible mass densities of the universe, it would seem a remarkable coincidence if the universe just happened to have the mass density that makes it completely flat, a mass density equal to the critical value. But according to our observations, that appears to be very nearly the case.

Amazingly, inflation actually requires a nearly flat universe. The initial inflation of the universe likely expanded the universe to such a great size beyond what the present visible extent of it shows today, that we can only observe very little of the entire universe. If so, regardless of what the initial curvature of the universe may have been prior to inflation, the curvature automatically gets "flattened out" by the immense stretching or inflating of space-time, just as the surface of a balloon seems to get flatter at any one point as the balloon expands. Thus the universe should actually be nearly flat if indeed inflation took place as we now believe it did. And a flat space-time universe requires the mass density of the universe to be nearly that of the critical density of the universe, as we've discussed.

The "Missing Mass" Problem

The "missing mass" problem then becomes easy to understand. If the universe did get stretched out such that the mass density of the universe is nearly the critical density of a flat universe, then we should be able to find this much mass in our universe. But of ordinary matter, we only see enough to account for at most approximately 10% of the critical mass. Ordinary matter consists primarily of Hydrogen and Helium, as previously discussed. We can detect sources of both simply by the radiation they emit. Some uncertainty is introduced by the difficulty of detecting very cool sources, which radiate very little. But it seems clear that there is not enough ordinary matter to add up to the critical mass predicted by inflation, and observed in the apparent flatness of space. However, not all matter need be ordinary matter. Any kind of matter that has mass will add to the overall mass density of the universe, even if it doesn't radiate like ordinary matter does.

So if there is non-ordinary matter or "dark matter" in the universe, how could we ever detect it? Since dark matter has mass, it exerts a gravitational force on other matter. So we must detect it by observing its gravitational influences on ordinary matter that can be observed. Actually, dark

matter has already been detected in this manner. It was originally proposed by Fritz Zwicky in the 1930's to explain how the Coma Cluster of galaxies could be held together when the motion of the galaxies appeared to be too great for the gravitational attraction of the observable mass to hold it together [25]. Since then other indicators show there must be additional matter inside galaxies. When observing the speeds with which stars revolve about the center of our galaxy, the Milky Way, and other spiral arm galaxies such as the Andromeda, we find that they do not exhibit the speeds expected on the basis of the gravitational influence of the matter that we can observe. Most of the stars far away from the center of the galaxies are moving at much higher speeds than expected, indicating that there is additional mass in the galaxy causing it [24]. One suggestion is that the matter could all be inside a supermassive "Black Hole", located at the center of the galaxy. A Black Hole is a concentration of mass so dense that not even light can escape its gravity. We can determine accurately how much mass is inside a Black Hole by measuring the orbital speeds of nearby objects. In this way, we know that there exist several such supermassive Black Holes at the center of many galaxies. However, these cannot account for the orbital behavior of stars far out in the outer arms of the galaxies, since the gravitational influence of even a supermassive Black Hole is much reduced at such great distances. There must be dark matter distributed throughout the galaxies, in order to produce the spiral arm rotations we observe. This may amount to enough matter to bring the total mass of the universe up to the critical mass predicted by inflationary expansion.

Even though we know there is dark matter in the universe, which would account for the missing mass expected from inflation, we still have not determined what this missing mass really is. Another suggestion is that it might be the mass of neutrinos, of which there are three known types. Recently we have discovered clear evidence that the neutrinos coming from our Sun change from one type to another en route to our underground detectors on earth [26]. This implies that the neutrinos must have non-zero masses. They also qualify as dark matter since the elusive neutrinos do not have an electric charge, neither do they interact as do quarks, the matter from which protons and neutrons are composed. They interact only gravitationally and via the nuclear weak force, resulting in their elusive nature, which allows neutrinos to go through millions of miles of lead with a very low probability of being absorbed. However, we have other means of knowing that the mass of neutrinos is extremely small, from the study of β-decays of unstable nuclei. Still the question remains how much of the dark matter can be accounted for by neutrinos. If the bulk of the missing mass is not from neutrinos, as many physicists suspect, then there exists dark matter of a nature not yet understood within the present model of fundamental particles. However, many theories predict particles beyond what is presently known and could account for the missing mass. Presently, we conclude that the missing mass problem is simply a problem of not knowing what is contributing to the bulk of the mass of the universe, since it does not emit radiation and beyond its gravitational influences, remains extremely difficult to detect.

The "Age" Problem

Critics relished in bashing the Big Bang theory when it appeared that there was a major conflict between the age of the universe obtained from the expansion rate as discussed in the last chapter, and the ages of the oldest stars in the Milky Way galaxy. The problem was that the ages of some stars appeared to be older than the universe itself, which cannot possibly be true. This problem arose shortly after the Hubble Space Telescope, launched in 1990, began to collect data on distant galaxies. By carefully measuring the distances to galaxies as remote from us that light would require 60 million years of our time to travel, and measuring how fast these galaxies are

moving away from us using the Doppler effect, we are able to determine how fast the universe is expanding. From the expansion rate we can then determine how long the universe has been expanding since the initial explosion we call the Big Bang. Data taken in the early 1990's with the Hubble Space Telescope showed that the universe appeared to be expanding faster than was originally thought prior to these distant measurements. To avoid local variations, it is desirable to measure the distance to galaxies much further away from us than those within a few million years of light travel, thus the new measurements were considered to be more reliable. The faster expansion rate implied that the universe was younger than 12 billion years old. That posed an embarrassing problem for astronomers, since careful studies of stars within globular clusters surrounding the Milky Way yielded ages from 13 to 15 billion years old. It appeared that the Big Bang theory and corresponding age determinations were incompatible with our understanding of stellar astronomy.

Cautious astronomers were not willing to toss aside the Big Bang theory quite yet, knowing that there were additional uncertainties in the above measurements that did not allow for such a definite conclusion. The ages of the oldest stars seemed to be quite well established. But the expansion rate of the universe was still somewhat uncertain. Although the Hubble Space Telescope was able to take data on stars more distant than any earth-based telescope had been able to, it was still not certain that the distance was great enough to completely rule out variations due to local gravitational tugs. In particular, it was well known by this time that there is an enormously massive supercluster of galaxies known as the "Great Attractor", which is expected to exert significant motion on galaxies within a few hundred million years of light travel, which includes all of the galaxies used so far in this study. What was needed was a measurement far beyond all of our local clusters of galaxies. That finally came when a survey of very distant supernovae, the death throes of massive stars, was made in the latter half of the 1990's. Using only a type of supernovae having an expected brightness, we are able to determine distances up to several billion years of light travel. From this study came two important observations. The first was that the universe appears to be accelerating in its expansion, which we will discuss next. The second was that the expansion rate of the universe was more precisely determined. The resulting age of the universe is 14.5 billion years, uncertain to 0.5 billion years [14]. By this time even more distant measurements of galaxies were available from the Hubble Space Telescope. They were much closer to agreement with the expansion rate determined from the distant supernovae. Thus the "age" problem of the universe appears to be resolved and the Big Bang theory vindicated.

The Accelerating Expansion of the Universe

We now discuss the most interesting development of recent astronomical observations. It came as such a surprise that many scientists, this author included, were very reluctant to accept it. We return to what Einstein termed as the biggest blunder of his professional career, the insertion of a term into his equations of general relativity that had no observational basis. This term is the now famous cosmological constant. It represents energy of the expanding space-time, quite distinct from the energy of matter and radiation. It serves as a repulsive pressure, counteracting the inward pull of gravity. But it has such a small influence that it cannot be observed to affect the motion of galaxies within the local region of the universe measured prior to the late 1990's. However, its effects do not diminish with increasing distance as does gravity. Therefore, if it is non-zero, regardless of how small it is, it will eventually dominate over gravity over large

enough distances. Thus if the universe grows large enough in size, the outward pressure represented by the cosmological constant then serves to accelerate the expansion.

Since measurements made prior to the late 1990's indicated no presence of such outward pressure, it was assumed that the cosmological constant was identically zero, even though some theoretical models of fundamental particles and fields predicted a non-zero value for it. A non-zero value stems from the idea that empty space is not so empty in reality. The presence of all-pervading fields interacting with "virtual" particles is responsible for explaining many observed phenomena of elementary particle physics. But how it might generate a non-zero cosmological constant appears somewhat speculative. The measurements of distant supernovae made in the late 1990's showed clear evidence that the expansion rate of the universe is now greater than what it had been, during the early stages of the universe [14]. This is one of the reasons why the universe turns out to be a little older than what we originally determined based upon the local expansion rate in the universe. Since the universe had earlier been expanding at a slower rate, trying to extrapolate back to the original Big Bang based on the more recent expansion rate gives too young of an age for the universe. This is one of the contributing factors to the resolution of the age problem.

The non-zero cosmological constant implies that there is energy in the expanding space-time universe. It is now popularly referred to as "dark energy" and its origin is as unclear as the "dark matter" that dominates the mass density of the universe. But these unanswered questions do not pose a legitimacy issue for the Big Bang theory. It shows us that the Big Bang theory is still incomplete as a cosmological model of our universe. It also shows us that the initial explosion that began the universal expansion acts only one way in time; that is, the universal expansion will never reverse itself and become eventually a "big crunch." The Big Bang is a one time non-reproducible phenomenon. The beginning of the universe will be very different from the end of the universe. As the universe continues to expand it will accelerate, and galaxies will become more spread out. Further consequences of the non-zero cosmological constant remain to be determined. As in many other areas of science, questions remaining imply that it is still an ongoing enterprise, welcoming further progress by talented scientists and further observations of our universe.

Meanwhile, the Big Bang theory has passed all of the scrutiny with flying colors. Careful examination of each of the supposed problems has only led to a clearer understanding of how the universe changed as it expanded, leaving behind the evidences that have allowed us to comprehend this history today. We do not understand all of the details of the universe back to the very beginning, but in examining the evidences left behind and interpreting them in light of well-established laws of our universe, we have been able to understand much of the early universe back to a very small fraction of a second removed from the moment the universal expansion began. The field of cosmology is still a very active field of scientific research and we should expect new developments and further scientific understanding of the very beginnings of our universe. Scientists are recognizing that there must be a connection between religious faith and the origin of our universe, since it is clear that small changes in any of several factors would have resulted in a universe radically different from what we see. It appears that the earth and its place in the space-time of our universe is precisely what it must be to support life. It is becoming clearer that the scientific evidence suggests that a Creator carefully designed the universe. We now examine how the biblical accounts of origins correspond to this evidence.

Chapter 4
Biblical Basis for the Big Bang

While the previous chapters explain the impressive scientific support for the Big Bang theory, the rather reserved reaction of most Christians is better understood on the basis of scriptural understanding of origins. For this reason, no amount of convincing scientific support will necessarily persuade some individuals of its validity. But people of faith should recognize that a scientific theory dealing with the origin of the universe also has theological implications. Discovering a correct scientific view of origins will have important implications concerning whether there is a God who transcends the matter and laws of the universe, and if there is, what certain things can be inferred about Him from creation itself. Those who hold scripture to be the most reliable source of truth should recall that scripture itself claims that we can learn about God from creation. The Apostle Paul, recognizing that the educated believers fully expected the Christian faith to agree with the testimony of nature, wrote to the church at Rome concerning those rejecting God, "For since the creation of the world His invisible attributes, His eternal power and divine nature, have been clearly seen, being understood through what has been made, so that they are without excuse." Even more so today with the influence of modern science, believers should fully expect support of biblical truth from the growing body of scientific evidence.

But resistance to the Big Bang theory persists because of perceived conflicts with a scriptural understanding of origins. So let us address what the Bible teaches concerning origins and examine whether there is any real conflict with the scientific account we have discussed, or whether there is a consistency. It is very important that just as we exercise skepticism of scientific theories and the interpretation of the evidence, we should also exercise caution in accepting a particular interpretation of scripture. And since the physical origin of the universe is not a theme addressed in detail by scripture, we must be especially careful to not infer too much based upon our favored outlook, influenced by many factors outside of scripture. Even so, the Bible does seem to agree with several basic points implied by the Big Bang theory and its supporting evidence, a very remarkable fact, considering the scriptures were first recorded a few thousand years prior to modern science.

Genesis and the Process of Creation

Genesis is a Greek word that means "beginning," and the very first verse of Genesis implies that the universe itself has a beginning. It reads "In the beginning God created the heavens and the Earth." All matter that can be seen, observed, or even inferred to exist in this universe was brought into existence at one moment by a Creator who exists outside the limits and laws of the universe itself. Hebrews 11:3 reiterates this point, "By faith we understand that the worlds were prepared by the word of God, so that what is seen was not made out of things which are visible." The cause of the existence of the universe lies outside of the universe itself. As discussed previously, the Big Bang theory also points to a beginning to all of space-time and matter, as well as the scientific laws governing them. Both scripture and science reveal to us that there must be a cause that lies outside of the universe itself.

But the Bible does not tell us that God instantly formed our universe and the earth exactly as we see it today. In fact, the earth was at first very disordered as we read in the next verse, "And the

earth was formless and void, and darkness was over the surface of the deep; and the Spirit of God was moving over the surface of the waters." There are differing interpretations concerning what the deep is, also the waters. One scholar prefers to correspond the deep to the space-time of the universe [2], while another places the frame of reference already at the surface of the earth [3]. What is certain of scripture is that during this period prior to God's preparation of the world, the conditions necessary to support life do not yet exist. Then God begins a process of transforming the formless void into a habitation fit for life. This process takes place over six "days" of creation. The reader is referred to the last chapter of *A Christian Physicist Examines the Age of the Earth* [11] for a discussion of the meaning of these "days". It is not clear from the Scriptures what the time frame of creation is, as acknowledged by many scholars [28,29,30,31]. We can only conclude that a process takes place in which the chaos is transformed into a well-ordered habitation fit for life.

The Big Bang theory also has something to say about this process. As discussed in the preceding chapters, a planet suitable for life such as the earth does not become possible in our universe until quite a few precise developments take place. These include the universal expansion at just the right rate, the cosmic "ripples" leading eventually to galaxy formation, the production of heavy elements in large stars, the supernovae spreading them throughout the galaxy, and the formation of a solar system with a just right planet, among many other such contributing factors. What we realize now is that a planet like the earth could not have existed at a much earlier time in the history of the universe. The universe went through quite a lengthy period of preparation prior to the formation of planet Earth. It appears that in many ways the early universe can seen as formless and void of the ordered conditions necessary to support life, in complete agreement with the claim of scripture.

This does not necessarily imply that the universe became more ordered in time, which would be a clear violation of the 2nd law of thermodynamics. Rather one non-isolated system, planet Earth, went through a miraculous sequence of events, preparing it for life. The Big Bang theory does not give specific predictions about what takes place on planet Earth, but it is important for us to realize the amazing and perhaps unique sequence of events on earth, revealed to us by modern science. The earth received just the right amount of radiation from its star, our Sun, to warm temperatures to the range of liquid water. It was joined with a Moon of sufficient size to stabilize the spin-axis of the earth against chaotic motion. It developed a thin, transparent atmosphere, which nonetheless serves as a shield against harmful ultraviolet radiation and provides sufficient greenhouse warming. The oxygen level of the atmosphere was boosted to a level capable of supporting land life following a vast period dominated by photosynthetic marine algae. These and many other specific characteristics of planet Earth appear to be fine-tuned to make our existence possible [32]. Modern science is confirming the creation account of the Bible, a careful process of preparation resulting in a created order described several times by God Himself with the words "and behold, it was good."

The "Stretching Out" of the Heavens

Concerning the origin of the universe and of the earth, both the Bible and the Big Bang theory provide us various unambiguous claims. However, the focus of the Genesis account appears very much centered upon the earth, whereas the focus of the Big Bang theory is on the entire universe as a whole. For this reason, it is difficult to use the Genesis account as a basis for evaluating whether the Big Bang theory agrees with scripture, since the Big Bang theory is

primarily a description of the entire universe. Fortunately, we do find occasional scriptural references to the origin of the universe in various books of the Old and New Testaments. Collectively, they give us a sense of a process whereby God prepared the universe and the earth, with the ultimate purpose of creating mankind.

But we must realize that the Old Testament was written over 2400 years ago, and the New Testament over 1900 years ago. In these ancient times, much of the world considered the sky above to have a covering or dome upon which the Sun, Moon, and stars moved. Indeed, the Hebrew word for "heavens" was used in reference either to the sky above or to the abode of the Sun, Moon, and stars. Constellations were already well known and remain virtually identical to what we see today, but the study of modern astronomy would not begin until 400 years ago. The Bible claims divine inspiration of its authorship, despite the human hands used to record it and the limited human understanding of its authors. As such it should give us a correct description of how the universe was created that agrees with modern scientific evidence. While Christians today consider the Bible a book for all times, written for a reader today as well as for the reader long ago, the language used was necessarily one that would be understood by the ancients, without the benefit of modern science. Therefore comparisons of scripture with modern science should only be made with this in mind.

Nevertheless, scriptural references alluding to the process God used in the creation of the heavens bear a remarkable resemblance to what the Big Bang theory describes. Ten times in the Old Testament, included in 5 separate books, we find references to creation in which God "stretched out the heavens" [27]. One example in Isaiah 42:5 states: "Thus says God the Lord, who created the heavens and stretched them out..." and again in Isaiah 40:22: "It is He who sits above the vault of the earth, and its inhabitants are like grasshoppers, who stretches out the heavens like a curtain and spreads them out like a tent to dwell in." There are 3 other such references in the book of Isaiah. Similarly, Psalm 104:2 speaks of the majesty of the Lord: "Covering Thyself with light as with a cloak, stretching out the heavens like a tent curtain." In Jeremiah 10:12 we see the intent of this repeated expression: "It is He who made the earth by His power, who established the world by His wisdom; and by His understanding He has stretched out the heavens." We are informed that the Lord God of Israel is the maker of all heaven and earth. Only through His divine wisdom could all that we see have come about. The process God used in creating the heavens is described simply as "stretching out". Similar passages are found in Job 9:8 and Zechariah 12:1 [1].

Although the language is different from that of modern science, this process seems suspiciously similar to what we understand today as the expansion of the universe. Indeed we could very well use the same language to properly understand the expanding space-time. As described in chapter 2, the expansion of the universe does not "spread out" matter in pre-existing space; rather space-time itself is growing larger, being stretched out to an increasingly larger volume. We find that the Bible describes an expanding universe in references over 2000 years old, whereas modern science has come to this conclusion independently within the last 80 years. This demonstrates once again that the Bible has a divine authorship, even though written with human hands. This is explained by II Peter 1:20,21 which states "But know this first of all, that no prophecy of Scripture is a matter of one's own interpretation, for no prophecy was ever made by an act of human will, but men moved by the Holy Spirit spoke from God."

The evidence of the physical universe is supporting the accuracy of the Bible. Both speak of a moment of creation for all matter, space and time, a process of preparation necessary for planet Earth to become a fit habitation, and the stretching out of the heavens we now refer to as the expansion of the universe. We are witnessing fulfillment of the prophecy given in Psalm 19:1-4:

> The heavens are telling of the glory of the God; and their expanse is declaring the work of His hands. Day to day pours forth speech, and night-to-night reveals knowledge. There is no speech, nor are there words; their voice is not heard. Their line has gone out through all the earth, and their utterances to the end of the world [1].

Without a sound, the heavens are declaring a message to us that cannot be silenced, revealing the error of various worldviews that do not acknowledge the Creator God. Accordingly, we have seen that modern science has not displaced Scripture from its position of authority concerning ultimate truth; rather it is demonstrating the reliability of Scripture. A respect for the testimony of science actually leads us to accept the Bible as truth. Once we accept this, we are led to consider the central messages of the Scriptures, which science cannot adequately address. The Scriptures reveal to us the person responsible for creation and a purpose behind it.

Who is the Creator?

Sufficient scriptural references concerning the process of creation are given for us to see that modern science is confirming Scripture. But the Bible has much more to say concerning the Person behind creation, and His purpose for creating us. The Bible repeatedly reveals to us a God wanting to have a close, intimate relationship with mankind. From the creation of man in the "image of God" described in Genesis, to the Law given to Moses, to the beckoning of the prophets to return to God, finally to the coming of the Messiah to bring the gift of salvation, we see a personal God reaching out to us throughout Scripture. The creation accounts in Scripture cannot be disassociated from the purpose God had in creating the universe, since this central message permeates Scripture. So it is completely appropriate that we address who the Creator is, before we conclude.

The first chapter of Genesis describes God in a plural sense, "The God said, 'Let Us make man in Our image, according to Our likeness...'" [1]. We see an indication that the One God of Israel is a three-fold personality, now commonly referred to as the Trinity. The New Testament goes to great lengths to identify Jesus Christ as God Himself, One with God the Father, present at creation, sent in the form of a human, and the One who will establish the new heavens and earth. Although it is humanly difficult to understand how this can be true, there will always be things about the nature of God that are beyond human understanding. We must accept the claims of Christ not on the basis of what we can fully understand, but on the basis of faith in the many witnesses that speak to His divine nature, including the Scriptures. The passages John 1:1-3, Colossians 1:16, Revelation 3:14 leave us no doubt of what role the person of Jesus Christ played in creation. John 1:3 clearly states, "All things came into being by Him, and apart from Him nothing came into being that has come into being." We find that this is not merely a lofty claim being made by the followers of Jesus following His death and resurrection. Jesus made the claim of Himself in John 8:58, "Truly, truly, I say to you, before Abraham was born, I am." We are called upon to acknowledge Him as the author of creation and the only way of salvation. As such, He is the rightful heir to all worship and praise.

Not only do we find in Scripture a description of Who God is, but also His purpose for creating the universe. Since God created man in His "image", it is clear that He intended man to have an intimate relationship with Himself, something beyond what any other living creature can. We were created to share in His glory (Isaiah 43:7). But since this was lost through sin, the central message of the Bible becomes the plan for restoration of this intimate relationship originally intended. The same Jesus present at the creation of the universe is also the focal point of God's plan for our restoration. Scripture informs us that sin cannot be removed by any good works on our part. We are restored to a right relationship with the living God only by accepting the free gift of salvation offered by Christ, upon whom our sins were laid when He died upon the cross. This happens only when we personally acknowledge Jesus Christ as Lord, and receive Him into our hearts. The central message of Scripture is a message given to each of us personally.

Conclusion

We conclude that both Scripture as well as the testimony of the heavens are giving us consistent messages. There is indeed a Creator God that has intentionally given us multiple, clear indications of His presence and purpose. The Big Bang theory is simply a framework for understanding the testimony of the heavens, seen in the expansion rate of the universe, the Cosmic Microwave Background Radiation permeating all of space, including the "ripples" associated with the formation of galaxies, and the abundances of the elements. Problems in understanding some of the observations have led to a clearer understanding the early universe, including a period of rapid expansion referred to as "inflation", which brings together our understanding of the large-scale universe with the growing knowledge of fundamental particles. While there remain questions to be answered, including the nature of dark matter and dark energy in the universe, it is clear that the Big Bang theory points to a moment of creation as described in Scripture, where the cause of it lies outside of the matter, space and time of our universe. Modern science is revealing the many factors that appear to be tuned just right for life to be possible here on planet Earth. In short, science is confirming the validity of the Bible. This demands a personal response on our part, to heed the messages being given, to acknowledge who the Creator is, and respond to His invitation to a personal relationship with Him through Jesus Christ.

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