THE EVOLUTION OF THE UNIVERSE:
CONFLICTING MODERN THEORIES

by

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It is the purpose of this thesis to present a study of the conflicting aspects of the two major twentieth-century cosmological theories, the Steady State Theory and the Evolutionary Theory. Further, the study was directed toward a decision as to which of the two is the more plausible solution in the light of recent astronomical discoveries.

The method employed involved a detailed study of each theory and its historical background, primary postulates, and the contributions of its major proponents. Prior to the presentation of each theory, both a discussion of the structure of the known physical universe and a survey of the pioneer cosmological theories of the twentieth century were included as a means of providing historical perspective.

Through the study of the impact of recent discoveries on cosmological theories, it was determined that the Steady State Theory fails to withstand a number of tests. Not only does it disagree with the evidence provided by radio source counts and the counts of quasi-stellar objects, but also it is proven invalid by the discovery of cosmic microwave radiation.

Thus, the primary conclusion of this study concerns the probable invalidity of the Steady State Theory and the

continuing validity of the Evolutionary Theory. However, any conclusion reached in the field of cosmological science is speculative and subject to change with the advent of additional astronomical data.

APPROVAL PAGE

This thesis has been approved by the following committee of the Faculty of the Graduate School at The University of North Carolina at Greensboro.

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CHAPTER I

INTRODUCTION

It has often been said that the Greeks found the universe a mystery and left it a polis. Certainly this is the aim of twentieth-century cosmologists. To be sure, the universe as we know it today is very different from that of the Greeks: the rise of the twentieth century brought with it such increased technological advances and scientific discoveries that our knowledge of the universe far exceeded earlier concepts and focused scientific interest beyond our own Milky Way. Indeed, George Gamow writes:

> The main problem of cosmology today is to explain the origin and evolution of the giant stellar families, known as galaxies, which are scattered through the vast expanses of the universe as far as can be seen with the strongest telescopes.[1]

Thus, if one is successful in explaining the origin and evolution of the galaxies, the evolution of the known universe is solved: and the elucidation of the structure and history of the universe as a whole is one of the principal aims of cosmology.

This increased interest in achieving an accurate theory of the evolution of the universe is evidenced through the great number of proposed theories which have originated in the twentieth century. Many of these theories were perhaps heretical and, at times, unscientific; nevertheless, they have initiated great progress in the realm of scientific cosmological theories based on astronomically sound data. Reactions to this new scientific cosmology are varied. Evry Schatzman has stated that "cosmology today seems an extraordinary and perhaps desperate attempt to comprise the whole universe in a single formula."[2] In contrast, D.W. Sciama, a current cosmologist, writes that

> In retrospect the greatest achievement of our age in astronomy will be seen to be the new insight gained into the workings of our Universe on the largest possible scale.[3]

As the twentieth century has progressed, theories concerning the origin and evolution of our universe have become centered around two major schools of thought. The first of these is that of the Evolutionary Theory which is supported primarily by Georges Lemaître and George Gamow; the second is that of the Steady State Theory whose proponents include Fred Hoyle, Hermann Bondi, and Thomas Gold.

Purpose

The primary purpose of this thesis is to present a study of the conflicting aspects of these two major theories. However, a thorough assessment of both the Evolutionary Theory and the Steady State Theory involves much more than a mere presentation and discussion of the primary postulates of each theory.

As an astronomical science, cosmology is itself of an evolutionary nature. No theory concerning the evolution of the universe arises full-blown; rather, each theory relies upon preceding theories and previous assessment of astronomical data. Therefore cosmology is a science dependent upon the validity of each individual element, and very often the invalidity of seemingly minor data topples convincing cosmological theories. For this reason, a research paper concerning the currently significant theories of the origin and evolution of the universe must delve back into earlier cosmological theories and previously-observed astronomical data in order to present an accurate and complete study.

In addition to the purpose of a complete study of these conflicting theories and their predecessors, a secondary purpose is the establishment of the concept of cosmology as a <u>bona fide</u> astronomical science. Prior to the twentieth century rise in cosmology, it was a field of dubious importance. Not always based on fact, cosmology was then pervaded by philosophical and non-scientific elements. It is the purpose of this study to emphasize the new importance of cosmology as a segment of astronomy based on scientific fact which seeks through scientific means to discover the facts concerning the evolution of the known universe. George Gamow emphasizes this new direction when he speaks of a "complete system of cosmogony that will satisfy the principal aim of science by reducing the observed complexity of natural phenomena to the smallest possible number of initial assumptions."[4]

Still one additional purpose must be cited. This study is intended for both the layman interested in twentieth century cosmology and those individuals who seek a more detailed investigation. In order to facilitate a reconciliation of these two purposes, the study seeks to maintain an intermediate level of complexity, thus serving this dual purpose.

Scope

As mentioned in the preceding section, the scope of this study lies almost exclusively within the boundaries of the twentieth century. There are various reasons for this; however, these limitations are primarily the result of the obvious increase in importance experienced by cosmology following Albert Einstein's statement of his general theory of relativity in the second decade of the twentieth century. Thus the study deals primarily with cosmological thought between the years 1915 and 1972.

In addition, the scope of the study has been extended to include a brief study of the establishment of the galaxies as the prime element of the universe. Certainly an understanding of the galaxies is a preliminary essential to any study concerning the evolution of the universe.

Primarily the major content of this study deals with the two current cosmological theories, the Evolutionary Theory and the Steady State Theory. This is achieved in three areas: a thorough historical background, an intensive research of the basic postulates, and a survey of the major proponents and their particular contributions. Still another chapter is devoted to the questions left unanswered by these major cosmological theories.

Thus one can perhaps define the scope of the following study as being set within the limitations of the twentieth century and dealing primarily with the Evolutionary and Steady State theories. The purpose of other information concerning early cosmological theories and astronomical observations is justified by the fact that cosmology, as a scientific field, is a constantly evolving process which is dependent on previous discoveries.

Terminology

Before proceeding, a clarification of certain terms is necessary. Therefore those terms which seem ambiguous or which are not completely scientific in nature have been compiled and their definitions as given in the following section will be those accepted by the writer.

Cosmology

George Gamow, one of the leading proponents of the Evolutionary Theory, defines this branch of astronomical science as "the study of the general nature of the universe in space and in time---what it is now, what it was in the past and what it is likely to be in the future."[5] Perhaps a somewhat more specific definition of the word <u>cosmology</u> would refer to it as a highly speculative branch of astronomy which attempts to describe the general properties of the universe in space and time, and the kinematics and dynamics of matter and radiation in it on the largest scale.

<u>Cosmogony</u>

Currently this particular term refers to a specialized aspect of cosmology. It is reserved for the more restricted problem of the origin and evolution of the individual elements of the known universe---the solar system, stars, and galaxies.

<u>Evolutionary Theory</u>

This constitutes the most generally accepted theory concerning the origin and evolution of the universe. It has as its foundation Hubble's discovery of the expanding universe. George Gamow discusses this theory as follows:

> If the universe is now expanding, it must have been once upon a time in a state of high compression. The matter which is now scattered through the vast empty space of the universe in tiny portions which are individual stars must at that time have been squeezed into a uniform mass of very high density. It must have been subjected to extremely high temperatures since all material bodies are heated when compressed and cooled when expanded.[6]

Steady State Theory

As one of the two major conflicting theories, the Steady State Theory has been profoundly influential on twentieth-century cosmology. Hermann Bondi, a major proponent of the theory, defines it as being in complete contrast to the evolutionary models of relativistic cosmology. According to Bondi, the basis of the Steady State Theory is the assumption that the universe is not only uniform in space, but also unchanging in time when viewed on a sufficiently large scale.[7]

CHAPTER II

THE NATURE OF THE UNIVERSE

Man's interest in the concept of an extended universe is, in relation to his study of astronomy, quite recent. Not until the middle of the eighteenth century was the existence of galaxies beyond the Milky Way suggested. In 1750, Thomas Wright set forth <u>An Original Theory or New Hypothesis of the Universe</u> in which he proposed that the Milky Way was not the only island in the sea of space. However, contemporaries of Wright were skeptical and it was only with Immanuel Kant's similar conclusion, which he produced independent of Wright in 1755, that astronomers seriously considered the possibility. As one of the first to propose this possibility, Kant wrote in his <u>General Natural History and Theory of the Heavens</u> of 1755:

> It is far more natural and conceivable to regard them [the nebulous stars] as being not such enormous single stars but systems of many stars, whose distance presents them in such a narrow space that the light which is individually imperceptible from each of them, reaches us, on account of their immense multitude, in a uniformly pale glimmer. Their analogy with the stellar system in which we find ourselves, their shape, which is just what it ought to be according to our theory, the feebleness of their light which demands a presupposed infinite distance: all this is in perfect harmony with the view that these elliptical figures are just universes and, so to speak, Milky Ways, like those whose constitution we have just unfolded. And if conjectures, with which analogy and observation

> perfectly agree in supporting each other, have the same value as formal proofs, then the certainty of these systems must be regarded as established.[8]

Thus astronomy began to stretch outward beyond the confines of the Milky Way and to establish some ideas concerning the universe as a system of countless galaxies or, as Kant implied in his reference to these nebulous stars, many, many Milky Ways of similar construction. Yet it was not until 1924 that Kant's and others' hypothesis concerning other galaxies was actually confirmed: at that time, the American astronomer Edwin P. Hubble established through the use of Cepheid variables that the nearest spiral nebulas (or galaxies) were vast systems of stars situated more than a million light-years beyond the limits of our own galaxy.[9]

Classification of Galaxies

In this manner, the primary element of our known physical universe was established. Yet mere acknowledgement of the existence of the galaxies is insufficient. In order to understand the nature of the universe, one must be aware of the nature of its primary constituent---the galaxies. Again it is Hubble to whom astronomy is indebted: his scheme for classifying galaxies according to their morphology dates from 1925, yet with minor revisions, it remains in use today. Hubble's system of classification recognizes three main classes of galaxies: ellipticals (E), ordinary spirals (S), and barred spirals (SB), as well as irregular galaxies. Three stages of spirals are distinguished according to the relative size of the nuclear or central bulge (decreasing from Sa to Sc) and the relative strength of the arms (increasing from Sa to Sc). Elliptical galaxies characteristically have a smooth structure, extending outward from a bright center, and differ in ellipticity from round (E0) to a lenticular three: one axis ratio (E7). Ordinary spirals are characterized by spiral arms emerging directly from a lens-shaped nucleus while the arms of barred spirals emerge from the ends of a diametrical bar. Irregular galaxies are unclassifiable according to the Hubble system since they exhibit no consistent symmetry or form. The chart below represents Edwin Hubble's basic scheme for the morphological classification of the galaxies (figure 1).

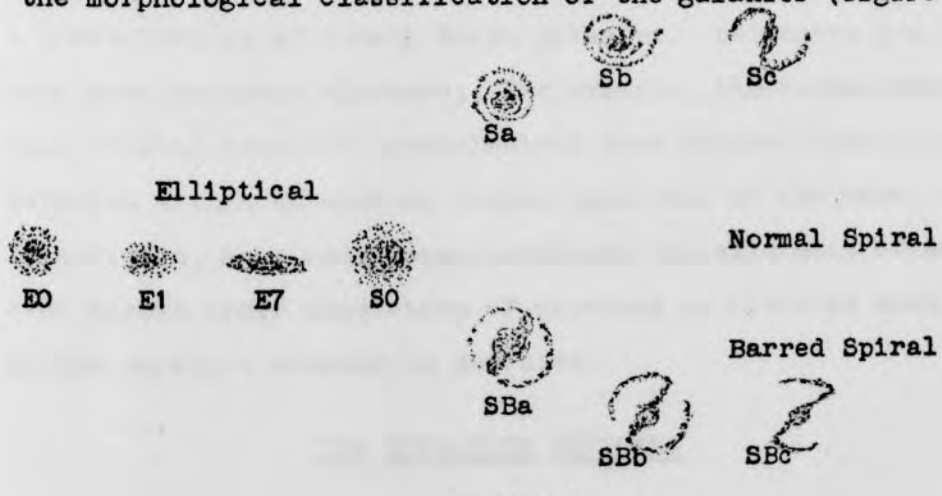


Figure 1

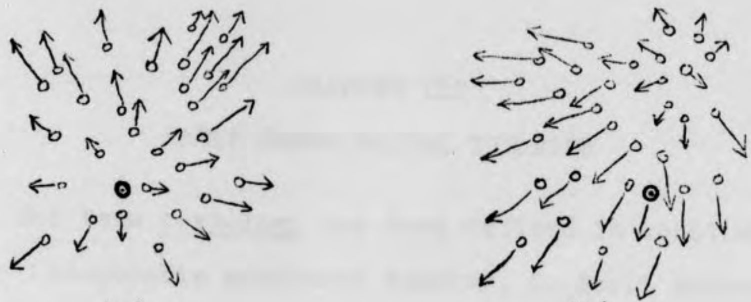
Distribution of Galaxies

Assuming that the galaxies represent the primary constituent of the universe, some knowledge of their distribution provides further indications of the structure of the known universe. When viewed as an entity, the distribution of galaxies is recognized as being statistically isotropic, the same in every direction. There is no clear evidence of a major piling up of galaxies nor any evidence of a dense center of the observable universe. However, this isotropy should be understood to exist only on an overall level; the detailed distribution of galaxies is far from uniform in character. Not only are there close pairs of galaxies and triplets, and small groups, such as Stephen's Quintet in Pegasus, but also larger groups of perhaps a few dozen members: indeed, the Milky Way itself is a member of a concentration of twenty known galaxies. Yet there are even more populous clusters; for example, the Corona Borealis cluster contains approximately four hundred individual galaxies within an area no larger than that of the moon. In addition, many astronomers advocate the existence of an even higher order consisting of clusters of clusters such as the multiple cluster in Hercules.

The Expanding Universe

As established previously, much of the ground work in the realm of galaxies has been either initiated or achieved through the efforts of Edwin Hubble. Yet ascertaining the distance of galaxies and establishing a system of morphological classification was only part of Hubble's achievement. One of the foremost discoveries for the development of the science of cosmology was his discovery that the galaxies are generally in recession and that the velocities of recession are by no means random. Indeed, George Gamow emphasizes the essential nature of the discovery, referring to Hubble's discovery as the "key factor for the understanding of this large-scale cosmic evolution."[10] Briefly, Hubble's discovery revealed that the radial distance of a galaxy is directly proportional to its velocity. Hubble firmly established a definite linear relation between the recession velocity and distance in 1929, revealing that the velocity of recession of a galaxy is directly proportional to its distance from us.

At first glance, Hubble's discovery might appear to have restored to the Milky Way its previous privileged status; however, it is quickly apparent that Hubble's result does not imply that the Milky Way is a unique center of repulsion. D.W. Sciama provides two charts which reveal the expansion of the universe as seen from different galaxies according to Hubble's law (figure 2).[11]



(a) (b)

(a) The recession velocity of a galaxy is proportional to its distance from the Milky Way.

(b) The expansion of the Universe as seen from another galaxy. The recession velocity is still proportional to the distance.

Figure 2

Certainly this particular aspect of the nature of the universe has proven to be the most influential factor with regard to cosmological theories, instigating a number of theories concerning the probable origin, present condition, and future of our universe, as well as providing material for extended disagreements concerning the outstanding current cosmological theories.

CHAPTER III

EARLY COSMOLOGICAL THEORIES

The term cosmology has been defined in countless ways by innumerable scholars; however, D. Scott Birney succinctly reveals the scope and purpose of this frequently employed term in his definition of cosmology as "...the study of the universe: its past history, present structure and probable future evolution."[12]

The science of cosmology is nothing more than a department within the complex of the astronomical sciences. It is a discipline of speculation based on observed facts, which in turn, are provided by practical astronomers.

As the study of the universe, cosmology revealed a marked increase in importance in the twentieth century and, as is generally the case, this increase of interest was born of necessity. According to Fred Hoyle, a leading twentieth-century cosmologist, the primary feature of applied astronomy is observation; yet, observation in the field of astronomy suffers from the inherent handicap that it can never tell us positively how things change with time since over the period of a human life or even over the whole of human history, very few astronomical objects change in any detectable way.[13] Thus arises the need for cosmology.

Beyond this factor, there remain several other reasons for the increased interest in cosmology in the twentieth century. Milton Munitz emphasizes the concept that the twentieth century represents a revolution with respect to the establishment of a universe whose primary constituents are galaxies and is, in a sense, related to the Copernican revolution. He writes:

> We must recognize, at the same time, a certain parallel in the problems confronting cosmology today and those which engaged the attention of cosmologists at the beginnings of modern astronomy following upon the Copernican revolution. In that earlier period, as we have seen, the assimilation of the earth as a member of the planetary family of the sun, and the sun as a member of the system of stars, raised the fundamental question as to the extent and possible structure of the universe, where the latter is taken as made up of the stars as its basic astronomical units. Today the scale has shifted from stars to galaxies.[14]

The establishment of the fact that the basic unit of the universe was that of galaxies was certainly a necessary condition for the development of modern cosmology as an astronomical science; however, this alone was far from sufficient. According to J.D. North, two other developments were even more necessary. The first of these was the discovery that Newton's theory of gravitation led to inconsistencies when employed on a cosmic scale; the second, and perhaps most important, was Einstein's General Theory of Relativity.[15]

Gravitation and Cosmological Theories

One of the primary factors necessary to modern cosmology is a workable explanation of gravitation.

Indeed, as stated by North, this is one of the three necessary conditions for the rise of cosmology in the twentieth century. George Gamow emphatically states this essential role of gravitation as follows:

> Since the only forces at work between the galaxies that make up the material universe are the forces of gravity, the cosmological problem is closely connected with the theory of gravitation, in particular with its modern version as comprised in Albert Einstein's general theory of relativity.[16]

Einstein's general theory of relativity which, unlike his special theory of relativity, takes accelerated motion into account, is concerned primarily with measurements from an accelerated system, such as from a planet moving in a gravitational field. This assumption enabled Einstein to postulate that Newton's gravitational effects were actually caused by a curvature in the geometry rather than a true field of force. Thus in essence, what Newton called gravitational force is, according to Einstein's general theory of relativity, nothing more than a curvature of space associated with the presence of matter.

In developing this theory, Einstein made three specific predictions concerning the motions of planets or of light rays which differed from those calculated according to the theory of Newton. First, Einstein stated that the elliptical orbit of the planet Mercury around the sun should rotate slowly at the very small regular rate of 43" per century. His second prediction was that a ray of light from a distant star which barely grazed the sun would have a deflection of 1".74, concave towards the sun, as opposed to Newton's prediction of a shift of 0".87. Third, Einstein's general theory of relativity included the prediction that light originating in a gravitational field (i.e., a strongly curved space) will be shifted to the red since light vibrations will be slower in such a field. Observation, the deciding factor in science, has consistently verified these postulates.

Relativistic Cosmology

Albert Einstein

With the establishment of Einstein's general theory of relativity, the rise of cosmology in the twentieth century was firmly established. Rightly so, it was Einstein himself in 1916 who made the first attempt to apply his general theory of relativity to the structure of the physical universe as a whole. In developing his theory of the universe, Einstein used two basic assumptions: (a) he assumed that the geometric structure of space (the "spatial metric") is independent of time, or in other words, that on a large scale the universe is stable, static, and permanent; (b) further, he assumed that both space and the large scale distribution of matter in it are homogeneous and isotropic.

Einstein's model of the universe was static in nature since it did not envisage the possibility of the recession of the galaxies or the expansion of the universe as a whole; this is due primarily to the fact that not until 1924 did Edwin P. Hubble establish the recession of the galaxies which led to the concept of the expanding universe.

As discussed in the preceding section, Einstein ascribed to gravitation the ability to create the curvature of a space-time continuum. And, in developing his theory of the universe, Einstein came to the conclusion that the curvature of space must be independent of time, in other words, that the universe must be unchanging as a whole even though it does change internally. Yet, having accepted these conditions, Einstein found there was no solution to his equations which would permit a static universe; therefore, he was forced to introduce a hypothetical force which was independent of mass and gained in strength with the increase of distance between two interacting forces. This introduction of a cosmological constant has produced a great deal of discussion. J.D. North, in his history of cosmology writes:

> Einstein's extension of the field equation is analogous to the extension of Poisson's equation with which he opened his paper: which came first to him is not clear. For the most part, his followers were content to give a loose interpretation of the Einsteinian theory in

> Newtonian terms and it was not difficult to see...a small repulsion from the origin directly proportional to the distance and acting over and above the ordinary gravitational attraction between masses. There would, loosely speaking, be a distance at which such a repulsion would be in equilibrium with the gravitational attraction. As Einstein admitted, the extension of the field equations was "not justified by our actual knowledge of gravitation" but was merely "logically consistent."[17]

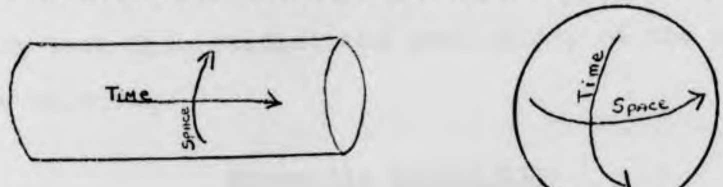
Further evidence concerning the unusual nature of Einstein's cosmological constant is given by Willem de Sitter who also constructed a static model of the universe. He writes:

> The field equations, in their most general form, contain a term multiplied by a constant, which is denoted by the Greek letter λ (lambda), and which is sometimes called the "cosmical constant." This is a name without any meaning, which was only conferred upon it because it was thought appropriate that it should have a name, and because it appeared to have something to do with the constitution of the universe; but it must not be inferred that, since we have given it a name, we know what it means. We have, in fact, not the slightest inkling of what its real significance is. It is put in the equations in order to give them the greatest possible degree of mathematical generality, but, so far as its mathematical function is concerned, it is entirely undetermined....[18]

Yet, with the introduction of the "cosmological constant," Einstein produced a static model of the universe---one of the earliest relativistic cosmological theories.

Willem de Sitter

One other static model of the universe is of value. Like Einstein, Willem de Sitter introduced his static theory in 1917 prior to Hubble's important discovery. Thus, as Einstein, de Sitter was later proven false by observational data. However, his cosmological theory remains important in a survey of early relativistic cosmology with regard to its relation to Einstein's model of the universe. That is, the spherical universe of Einstein consisted of space co-ordinates which were positively curved while its time co-ordinate was straight. Thus Einstein's model could be represented by a cylinder which, like a sphere, was closed and thus had a finite volume. De Sitter's spherical universe included not only curved space co-ordinates, but also a curved time co-ordinate.[19] These two static models of the universe are depicted below (figure 3):



Einstein De Sitter

Figure 3

De Sitter's alternative to Einstein's world model satisfied the same laws of world gravitation, yet rather than being actually static, it was empty, being devoid of matter and radiation. In his book Kosmos, De Sitter contrasts these two solutions of the field equations for a homogeneous, isotropic universe, calling them solutions A and B:

> The universe A [Einstein's model] is really and essentially static, there can be no systematic motions in it. It has an average density, but no expansion. It is therefore called the static universe. B [De Sitter's model], on the other hand, is not really static, it expands, and it can only parade in the garb of a static universe because there is nothing in it to show the expansion. B is therefore called the empty universe. Thus we had two approximations: the static universe with matter and without expansion, and the empty one without matter and with expansion.[20]

The world models of both Einstein and De Sitter were very early attempts to explain the structure and evolution of the universe; therefore, their value is rooted primarily in their historical position. For, with Hubble's 1929 discovery of the Doppler effect or "red shift," these early static relativistic theories were invalidated since neither took into account the possibility of the expansion of the universe.

Kinematic Relativity

E.A. Milne

While it is now a generally accepted fact that the spectral red shifts of distant galaxies and clusters of galaxies represent velocities as a manifestation of the Doppler effect, there have been several cosmological theories put forth which account for the red shifts by other means. Perhaps one of the most original is that of the British astronomer E.A. Milne, whose cosmological theory interpreted the red shifts as being due to a change in the rate of flow of time rather than as a velocity effect. In 1932, Milne challenged the almost exclusive reliance upon general relativity as a base from which to construct cosmological theories of the universe: employing a system which he identified by the term kinematic relativity, Milne constructed a world model in which the idea of time assumes a central importance.

Milne, whose name is most often associated with the concept of the cosmological principle, proposed the principle that

> not only the laws of nature, but also the events occurring in nature, the world itself, must appear the same to all observers, wherever they be, provided that their space-frames and time scales are similarly oriented with respect to the events which are the subject of observation.[21]

Thus, assuming the universe to be expanding, homogenic and isotropic, Milne considered the universe to be contained in an expanding sphere of Euclidean space whose radius is equal to the velocity of light times the total time of the expansion. Also, since the galaxies continue increasing their velocity, yet cannot go beyond that of light because the special theory of relativity predicts this to be the greatest measurable velocity for a material object, they will be bunched together at the spherical surface of the universe.

In short, the cosmological model which Milne constructed with the aid of the special theory of relativity was one in which the galaxies were all in uniform recession from one another. Thus, the probable conclusion of this world model concerning the origin and evolution of the universe would be that "...all the galaxies must have been compressed together in a comparatively small volume a finite number of years ago...."[22] However, his is a theory which has failed to be accepted; rather, those theories accepting Einstein's general theory of relativity have proven more satisfactory to current cosmologists.

CHAPTER IV

THE EVOLUTIONARY THEORY AND ITS PROPONENTS

From the preceding chapters, the rise of cosmology in the twentieth century reveals itself as a movement of considerable magnitude. Prior to the twentieth century, cosmology was hardly an astronomical science; yet it became decidedly so in this new era of discovery. Suddenly astronomical observation was insufficient: viable theories concerning the origin and evolution of the universe were sought. And, as is recorded in Chapter III, numerous hypotheses were offered. According to Hermann Bondi, a leading proponent of the Static State Theory, the number of different theories should not come as a surprise although cosmology is a subject in which so little information is available. He too emphasizes the conflict in cosmological hypotheses, saying that they all account more or less well for the existing observations, but they differ sharply in their forecasts of future ones.[23] At present, the Evolutionary Theory seems to be the more logical of the two with regard to the most recently observed astronomical data.

In order to gain an accurate perspective concerning the Evolutionary Theory, one must approach this hypothesis from three standpoints: (a) a historical framework concerning the development of the evolutionary hypothesis; (b) a scientific description of the theory; and (c) a survey of its major proponents and their thoughts concerning the Evolutionary Theory.

Historical Background

The Evolutionary Theory belongs to the class of relativistic cosmology since this hypothesis in all its ramifications is based upon Einstein's general theory of relativity. This is not to say, however, that the Evolutionary Theory is like Einstein's published theory of 1917 in which the universe is presented as a static construction. One very essential event took place between Einstein's initial general theory and the later cosmological theory of the universe as an evolutionary model: Edwin Hubble found the first evidence of actual physical expansion of the universe. The red shift has been mentioned earlier; however, it is primarily this element which laid the foundation for the theory of the expanding universe. In turn, this theory serves as the basis of the Evolutionary Theory and of subsequent cosmological theories.

Employing the concept of an expanding universe, the Evolutionary Theory was devised as an attempt to explain the origin, the evolution, and the probable future of our known physical universe. Perhaps the earliest work on an evolutionary theory is attributable to the Belgian theoretical astronomer, Georges Lemaître, who proposed the "primeval atom" concept of the origin of an evolutionary universe. Still another primary proponent of the Evolutionary Theory is George Gamow, whose reference to the origin of the evolutionary universe is known as the "hot big bang" theory.

How did these theories arise? Certainly neither Lemaître nor Gamow are solely responsible for the Evolutionary Theory, for in the science of cosmology, almost every theory or discovery stems from previous theories or observations and, in turn, each is then employed as a basis for further theories. What then is the foundation for this Evolutionary Theory?

In the realm of astronomy, Hubble's discovery of the recession of the galaxies and the physical interpretation of this recession as an indication of universal expansion can be emphasized as the prime foundation of the set of evolutionary theories. Certainly without the discovery, this explanation for the origin and evolution of the universe would never have been formulated. For, with the establishment of the concept of universal expansion, there also came the possibility for a finite beginning of the universe.

In addition to Hubble's discovery, one other cosmological discovery pointed toward an expanding universe, thus setting the stage for the introduction of an evolutionary theory. In 1922, a Russian mathematician, Alexander

A. Friedman discovered an algebraic error (essentially a division by zero) made in the process of derivation of Einstein's proof for a static universe. Thus, the possibility of a non-static universe could not be excluded. Friedman then showed that two non-static models were possible: one pictured the universe as expanding with time; the other, contracting.[24]

To be sure, there were other influential factors. Outside the realm of astronomy, the nineteenth century theory of Charles Darwin was a significant contributing factor. If in the area of biology, the concept of evolution toward a higher order was possible, certainly it was an equal possibility on a cosmic scale.

One other element must be considered as a prerequisite for the development of the group of evolutionary theories: this is Einstein's general theory of relativity, the value of which has been established in Chapter III.

The Evolutionary Theory

Of the two major conflicting cosmological theories, that of the Evolutionary Theory appears to be more consistent in its agreement with astronomical data. Also, it is an appealing theory which gives the universe a finite origin. Yet one may well ask what are the outstanding features of this theory.

The prevailing Evolutionary Theory which vies with the Steady State Theory is essentially that of George Gamow.

According to Gamow, the universe started from a very dense state of matter. This immediately instigates questions: why was our universe in such a highly compressed state, and why did it start expanding? Perhaps the simplest and mathematically most consistent answer is that of Gamow:

> The Big Squeeze which took place in the early history of our universe was the result of a collapse which took place at a still earlier era, and that the present expansion is simply an "elastic" rebound which started as soon as the maximum permissible squeezing density was reached.[25]

Thus at the beginning of the expansion process, the universe was in a state of extraordinarily high density, pressure and temperature. In fact, Gamow proposed that the temperature was great enough to enable thermonuclear reactions to occur. During the first few minutes of the universe's existence, matter is thought to have consisted only of protons, neutrons, and electrons since any group of particles that might combine into a composite nucleus would have immediately disassociated into its components due to the effects of the extremely high temperature. Gamow refers to the mixture of particles as <u>ylem</u>---the name that Aristotle gave to primordial matter.[26]

After five minutes, the universe cooled enough to permit the aggregation of protons and neutrons into deuterons, tritons, helium, and heavier elements. As the element building progressed, the prevailing physical conditions changed rapidly because of the still very rapid universal expansion. As a result, a combination of events combined to terminate the atom-building process: the collisions between nuclei and free neutrons decreased as their concentration decreased; the temperature dropped, thus lowering the probability of neutron capture; and the neutrons which were not captured merely decayed and added to the hydrogen buildup. Thus the element-building process was terminated by universal expansion and the decrease in the concentration of free neutrons by decay.

An important feature of the Evolutionary Theory is that in the early stages of the universe's expansion, radiant energy was dominant over the mass of matter; however, in an expanding system, the density of radiant energy decreases faster than does the density of matter. Thus after approximately two hundred fifty million years, the density of matter became greater than that of radiant energy. While subjugated to radiant energy, the matter is thought to have been spread uniformly throughout space in the form of thin primordial gas; yet, afterwards the gas broke up into giant gas clouds, or protogalaxies, which drifted apart as the universe continued to expand and ultimately condensed into stars and formed the galaxies as we now see them.

rapidly because of the still very rapid universal expansion. As a result, a combination of events combined to terminate the atom-building process: the collisions between nuclei and free neutrons decreased as their concentration decreased; the temperature dropped, thus lowering the probability of neutron capture; and the neutrons which were not captured merely decayed and added to the hydrogen buildup. Thus the element-building process was terminated by universal expansion and the decrease in the concentration of free neutrons by decay.

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Major Proponents

Georges Lemaître

The Evolutionary Theory actually began with Georges Lemaître. As early as 1931, Lemaître put forth his theory of the origin of the universe: it was his belief that the universe began at a time when all the matter in the universe was contained in a very dense state which he named the "primeval atom." This condition was short-lived and the atom exploded in a super-radioactive disintegration, a process which continued until the universe was broken down into atoms.

According to Lemaitre's hypothesis, as the explosion of this "primeval atom" progressed, space expanded quite rapidly and the radius of the universe increased in proportion to the velocity of the particles derived from the explosion. In addition, the average density of matter in space decreased as the radius continued to increase. All that occurred during this period is included in the first stage of his tripartite hypothesis.

The second stage is referred to as the Einstein stage. Since at all times the matter in Lemaître's universe was exerting gravitational force upon its constituent parts, this gravitational force eventually slowed down the expansion of the universe by balancing the force of cosmic repulsion until it was in a state of equilibrium. In truth, the second stage of Lemaître's universe was the static Einstein world model---a situation which Lemaître believed to have existed for about two billion years.

Since the Einstein stage was inherently unstable, a third stage in the evolution of the universe was inevitable. Thus began a stage of what Lemaître considered to be renewed expansion. Also, it was in the latter part of the first expansion and the beginning of this final stage that local condensations of matter resulted in the formation of galaxies and stars. Of interest is the fact that the expansion of the final stage of the Lemaître universe is thought to continue until the De Sitter model of the universe is attained---an empty universe in which there is nothing left to expand.

Lemaître's theory concerning the origin and evolution of the universe marked the beginning of a new phase in cosmological thought. Seeing both the advantages and disadvantages of the Einstein and the De Sitter models, he sought a model between the two---possessing both material content and definite spectral displacement. Thus deriving the following formula, $t = \int \sqrt{\frac{dR}{\{(\lambda R^2/3) - 1 + (\alpha/3R) + (\beta/R^2)\}}}$, Lemaître was able to recover De Sitter's solution if α and β were set equal to zero and Einstein's solution if R were made constant and β zero.

To be sure, his "primeval atom" theory of an evolutionary universe failed to withstand the rigors of later astronomical findings; nevertheless, it remains of outstanding historical value as one of the earliest cosmological theories incorporating the concept of universal expansion. In addition it is seemingly the earliest example of the Evolutionary Theory---later refined and altered by George Gamow---which has become so influential in current cosmology.

George Gamow

The concept of a universe which evolved from a primordial state received its greatest impetus through the work of George Gamow. First proposed in 1946, this cosmological theory has withstood opposition and proven to be the most influential Evolutionary Theory. Indeed, it is essentially the Gamow theory which vies with the theory of continuous creation in the controversial search for an explanation of the origin and structure of the universe. Gamow himself summarizes his theory as follows:

> Thus we conclude that our universe has existed for an eternity of time, that until about five billion years ago it was collapsing uniformly from a state of infinite rarefaction; that five billion years ago it arrived at a state of maximum compression in which the density of all its matter may have been as great as that of the particles packed in the nucleus of an atom..., and that the universe is now on the rebound, dispersing irreversibly toward a state of infinite rarefaction.[27]

To be sure, Gamow's position is supreme with regard to the Evolutionary Theory: it is his theory which is currently accepted as the foundation of this influential cosmological theory, and his writings are those to which cosmologists most frequently refer. This is not to overlook the contributions of Lemaître: certainly his initial hypothesis was invaluable in the development of the Evolutionary Theory. However, there are a number of distinctions which must be made concerning the theories of these two proponents of the Evolutionary Theory.

Contrasting Elements

Although the Gamow and Lemaître theories of the origin and structure of the universe are similar in several respects, one basic difference actually sets the two theories considerably far apart. According to Lemaître's theory, the universe is finite in both extent and content; in opposition, Gamow considers the universe to be unequivocally infinite.

Lemaître's Evolutionary Theory was based on Riemannian geometry since it employed the equations of the general theory of relativity: thus in keeping with the characteristics of Riemannian geometry, his universe was finite and unbounded. According to Lemaître's theory, at the beginning, the entire universe was contained within the "primeval atom."

In contrast to the finite and unbounded universe of Lemaître, the universe of Gamow is considered to be limitless and infinite. To be sure, Gamow advocates this type of universe in his book The Creation of the Universe.[28] The basic difference between the theories of Lemaître and Gamow produces unusual consequences. For example, Lemaître's concept of the origin of the universe involves the explosion of a single super atom while that of Gamow consists of the simultaneous explosion of an infinite number of mass points which were spaced very close together.

Conclusions

Generally, the Evolutionary Theory has maintained its influential position due to the appeal of its several attractive features. Perhaps its foremost attraction is the fact that it agrees with other pieces of evidence which point toward a formation of the elements about ten to thirteen million years ago. Beyond this, there is the aesthetically agreeable feature of giving a definite origin to our universe.

CHAPTER V

THE STEADY STATE THEORY

AND ITS PROPONENTS

Generally speaking, all scientific theories concerning the evolution of the universe share a group of explicit or implicit assumptions or principles upon which they are based: homogeneity, isotropy, conservation of energy, and so on. Fundamental to cosmology is the so-called cosmological principle: "the universe looks very much the same from any location and in all directions."[29] In other words, there is no privileged position with regard to space. Yet this cosmological principle omits one very vital factor---the element of time. And it is the addition of this element of time which brought forth the cosmological theory that has proven most successful in its opposition to the Evolutionary Theory. Indeed J.D. North, in his history of modern cosmology introduces his chapter on "Continual Creation and the Steady State Theories of Bondi, Gold, and Hoyle" with the following statement concerning the impact of this cosmological theory on twentieth-century astronomy:

> Whether or not the steady state theories of Bondi, Gold, and Hoyle constitute relativistic cosmology's most important rival, a considerable number of people believe this to be so. In the first place these theories appeared to be well-supported by observation, and they overcame the "time-scale difficulty" in a particularly simple way.[30]

The Steady State Theory proposed, in opposition to the accepted cosmological principle mentioned above, a perfect cosmological principle which included time: "The universe looks very much the same from any location, in all directions, and at all times."[31] Time---it appears such an innocent addition, yet the perfect cosmological principle led to some drastically different conclusions. This is a theory of considerable import and influence on the development of twentieth-century cosmology. Thus, in order to fully comprehend this theory based on the four-dimensional isotropy of the universe, a detailed study in the following areas is necessary: (a) the historical framework of the Steady State Theory; (b) a detailed discussion of the theory and its conflicts with the Evolutionary Theory; and finally, (c) an investigation of the major proponents of the Steady State Theory and their individual contributions.

Historical Background

The Steady State Theory has, without doubt, proven to be of major import to the science of astronomical cosmology. Indeed, Dennis Sciama in his discussion of twentieth-century cosmological theories, writes:

> I deliberately mention separately the Steady State Theory of Hermann Bondi, Thomas Gold and Fred Hoyle, because I think it is fair to say that of all the heretical theories this is the one that has irritated and excited the most people, has provoked the most good astrophysics

and has more or less survived to the present day.[32]

Similar to the Evolutionary Theory, the Steady State Theory was not conceived overnight; rather, it is a structure founded on the work of many individuals and many different ideas. Indeed the idea of continuous creation, one of the primary elements of the Steady State Theory, was suggested at least as early as 1928 by Sir James Jeans; however, his conjecture was unsupported by subsequent astrophysics. Jeans felt that no satisfactory account of the special character of the arms of the nebulae had been given. Therefore he postulated that

> The centers of the nebulae are of the nature of "singular points" at which matter is poured into our universe from some other, and entirely extraneous, spatial dimension, so that, to a denizen of our universe, they appear as points at which matter is being continually created.[33]

However, beyond a few isolated cases, little notice was taken of the concept of continuous creation until its incorporation into the Steady State Theory.

Just as there were two primary proponents of the Evolutionary Theory of Lemaître and Gamow, so the Steady State Theory involves three primary instigators. The Steady State Theory of the universe was first introduced by Hermann Bondi and Thomas Gold in 1948, and only later did the British astronomer Fred Hoyle become a major contributor to the theory of a steady state universe.

The reasons for the success of the Steady State Theory are complex; nevertheless, it has remained as the major opponent of the Evolutionary Theory of Gamow. Perhaps the impact of this cosmological theory can be partially explained by the philosophical appeal of a steady state universe. Hoyle emphasizes this philosophical appeal in contrasting the steady state universe to other theories:

> Without continuous creation the universe must evolve toward a dead state in which all the matter is condensed into a vast number of dead stars....With continuous creation, on the other hand, the universe has an infinite future in which all its present very large-scale features will be preserved.[34]

Beyond the realm of philosophical appeal, the Steady State Theory has remained as a possible solution to the problem of the origin and evolution of the universe. What are the scientific aspects of this cosmological theory and what explanation does it offer concerning the development of our known physical universe?

The Steady State Theory

The Steady State Theory can be said to have generated a renewal of interest in the science of cosmology. Indeed, the introduction in 1948 of this new and somewhat startling approach to the question of the origin and evolution of the universe evoked a multitude of reactions, ranging from total disbelief to complete acceptance.

As mentioned previously, Bondi, Gold, and Hoyle's concept of continuous creation was not new; however, the emphasis placed upon it was indeed greater than ever before. In the Steady State Theory, continuous creation is postulated as the driving force which not only governs the universe but indirectly determines its large-scale features.

In essence, the Steady State Theory purports that matter is being continuously created in space as a means of compensating for the loss of matter through the expansion of the universe. From estimates of the mean density and the rate of expansion, the rate of creation is now thought to be at most one particle of proton mass per litre per 5×10^{11} years.[35]

According to Fred Hoyle, there is no doubt that every galaxy we observe to be receding from us will in about 10,000,000,000 years have passed entirely beyond the limit of vision of an observer in our galaxy; yet, the same number of galaxies will still be visible since new galaxies will be condensed out of the background material at just about the rate necessary to compensate for those exceeding the limits of the observable universe. Thus the Steady State Theory appears to be a very simple explanation; yet, there is the question of the origin of the created material, for which Hoyle gives the following explanation:

> Where does the created material come from? It does not come from anywhere. Material simply appears---it is created. At one time

> the various atoms composing the material do not exist, and at a later time they do.[36]

Perhaps the greatest stumbling block to an acceptance of the Steady State Theory lies in whether or not the process of continuous creation violates the law of the conservation of energy which states that energy can neither be created nor destroyed but can only be transformed from one form to another. However, it is the contention of Bondi, Gold and Hoyle that since the energy introduced in the form of created matter merely counterbalances that lost through the expansion of the universe, there is no violation of the law. Therefore the total energy of the universe remains constant.

One of the most intriguing elements of the Steady State Theory is its explanation concerning the transformation of matter. According to the theory, continuous creation provides the matter which ultimately makes up the different galaxies, stars and other elements in the universe. Supposedly, stars are formed by the gradual accumulation of created hydrogen atoms which mass together due to their mutual gravitational attraction. As the mass becomes greater, the density increases to the point where the internal pressure and temperature enable nuclear reactions to begin. At this time, conditions in the star are ideal for forming elements. After a sufficient length of time, these stars, called supernovae, erupt, distributing their contents into space where they then recombine.

Hermann Bondi summarizes the process as follows:

> Individual galaxies age and move apart from each other owing to the expansion. In the increasing spaces between them, newly created matter condenses to form new galaxies, so that the average distance remains the same. Condensation is the process of birth of a galaxy; expansion to regions hard to see is the process of death, and growing up comes in between. Although each galaxy ages in this manner, a bird's-eye view of the system will always reveal the same picture....[37]

Major Proponents

Hermann Bondi and Thomas Gold

The Steady State Theory was first proposed by the team of Bondi-Gold. Working under the supposition that the cosmological principle advocated by Milne was insufficient, Hermann Bondi and Thomas Gold based their theory on the postulate of the perfect cosmological principle. Whereas Milne's cosmological principle required the large-scale aspect of the universe to be independent of the position of the observer, Bondi and Gold made it also independent of the time of observation. Thus the Bondi-Gold principle requires that not only must the average density of both matter and radiation remain constant, but also the age-distribution of the nebulae must be unchanging in time: as the older nebulae separate with the general expansion, new nebulae are formed in the intervening spaces out of newly-created matter.

In a sense the extension of the principle to include symmetry in time can be considered as an extension of the basic philosophy whereby symmetry in space was postulated in the original formulation of the cosmological principle. Therefore by a simple extension of the accepted homogeneity of the universe to include the element of time, a new cosmological theory is achieved.

Fred Hoyle

The second important contribution to a theory of a steady state universe was made shortly after that of Bondi and Gold by Fred Hoyle. Although Bondi, Gold and Hoyle achieve the same Steady State Theory, there is a fundamental difference between the approach and development of the theory of Bondi and Gold and that of Hoyle: while Bondi and Gold based their theory on the more philosophical perfect cosmological principle, Hoyle arrived at the Steady State Theory through the mathematical framework supplied by a modification of Einstein's general theory of relativity.

As Bondi and Gold, Hoyle was led by his acceptance of a steady state universe to the inevitable topic of continual creation. It is his suggestion that the creation of matter is by means of a creation field. In agreement with Bondi and Gold, Hoyle proposes matter to be created in the form of hydrogen and offers the following explanation:

> In what form is this new matter created? This question is closely concerned with the problem

> of evolution. Every closed system is known to go through irreversible changes. Cosmically, the most important of these is probably the conversion of hydrogen into helium, which takes place in every star, the excess energy being radiated away into space. Each system, each galaxy is therefore ageing. How can the over-all aspect of the universe remain unchanging, if every galaxy is evolving irreversibly? Only if new galaxies are being born, and old ones drift out of the range of telescopes through the expansion of the universe. The newly created matter must therefore stand at the beginning of the evolutionary chain, and, according to current astrophysics, this is cold diffuse hydrogen. The creation process must therefore imply the creation of hydrogen atoms of low velocity at a uniform rate.[38]

The expansion of the universe, too, is considered to be a result of the creation of matter. According to Hoyle, the introduction of each new hydrogen atom into the observable universe produces small local space-pressure points which exert a force on existing excess material and causes the expansion of the universe. In essence, Hoyle attempts to explain the accepted universal expansion as a dependent of the continuous creation of matter which is the primary postulate of the Steady State Theory.

Conclusions

Of the two major cosmological theories, the proposal of a steady state universe is, in many ways, the simpler. However, simplicity does not imply validity. Recent evidence from radio source counts, the red shifts of quasi-stellar objects, and the cosmic microwave radiation tend to discredit the theory with regard to the postulations of Bondi, Gold, and Hoyle concerning the continual creation of matter.[39]

Certainly an influential cosmological theory, the steady state universe may yet prove to be correct: it is the nature of cosmology that new astronomical data tends to revive discarded or discredited theories. Therefore, the ultimate fate of the Steady State Theory is unknown. To be sure, it remains a philosophically attractive theory.

CHAPTER VI

THE IMPACT OF RECENT DISCOVERIES ON COSMOLOGICAL THEORIES

Astronomy in the twentieth century has proven to be a science of discovery and expansion. New observational data is constantly superceding previous work and influencing the direction of future research. In view of this constant flux, the longevity of the conflict between the Evolutionary and Steady State Theories is remarkable. Continuing over a span of approximately twenty years, the dispute has been reconciled by a rash of recent astronomical discoveries which seem clearly to refute the Steady State Theory.

Of course, one should not infer from the refutation of the Steady State Theory that the Evolutionary Theory proposed by George Gamow is the <u>theorum</u> <u>verum</u> of cosmology. Yet of the current theories concerning the origin, evolution, and structure of the universe, the Evolutionary Theory offers the most scientifically satisfactory explanation.

What is responsible for the current rejection of the Steady State Theory? Although the reasons are complex and the rejection is far from comprehensive, one may correctly relate the failure of the Steady State Theory to its variance with the following discoveries: (a) radio source counts; (b) quasi-stellar objects; and (c) cosmic microwave radiation.

Although a detailed investigation of these factors lies beyond the scope of this study, their influence on current cosmological theories requires that they be discussed in relation to the Steady State and Evolutionary Theories.

Radio Source Counts

The discovery of radio sources was perhaps the first in a series of observed facts which reflected the possibility that the Steady State Theory was erroneous. Ironically, the beginning of the study of radio galaxies and the first exposition of the Steady State Theory occurred within a few years of one another. Yet, the first attempt to draw cosmological conclusions from the counts of the relative numbers of radio sources of different apparent radio luminosity was not made until 1955. At that time, Ryle and Scheuer came to the conclusion that the counts were incompatible with the Steady State Theory of Bondi, Gold and Hoyle and its property of continual creation of matter.

The explanation of this incompatibility is found in the nature of radio source counts. The counts themselves consist of the number N(S) of radio sources per unit solid whose measured radio luminosity (flux density) at the operating frequency of the radio telescope exceeds the quantity S. Therefore the relation between N and S which would be expected for a uniform distribution of stationary sources has the form $N \propto S^{-\frac{3}{2}}$. A plot of log N against log S would then be expected to be a straight line of slope $-\frac{3}{2}$ or -1.5.

The precise slope of this line is of great interest because it is considered a possible test between the two major theories. The value -1.5 is derived from the following: the number N of sources brighter than the quantity S is proportional to the volume of space d^3 where d is such that a source at distance d has a flux equal to S. The flux S, in turn, varies according to the inverse square law; thus S is proportional to $^1/_{d^2}$. The ratio of log N to log S is the ratio of the exponents of d or 3 to -2, giving the value -1.5. However, the slope actually observed for all extra-galactic radio sources is approximately -1.8. Yet, the -1.8 observed slope implies that the radio sources per unit volume were greater in the past than they are now: therefore, the Steady State concept is clearly at variance with the radio source counts.

Quasi-Stellar Objects

In the previous section, the cosmological significance of radio source counts was suggested. These radio sources are of two types, the radio galaxies and the quasi-stellar objects, while the preceding log N---log S curve mixed both together. The obvious question arises: what is the log N---log S curve for the two types of radio sources taken separately and what cosmological significance does this have?

In 1966, the Frence astronomer Philippe Veron conducted a critical study of this kind and found that the radio galaxies essentially fit a slope of -1.5. The radio galaxies are not extremely far away, having a maximum red shift of forty-six per cent: therefore, this is the slope to be expected in any cosmological theory. This requires that the steep -1.8 slope of all radio source counts is due in large measure to the quasi-stellar objects which have the slope of -2.2. D.W. Sciama considers this steep slope to indicate evolution in the properties of quasi-stellar objects and, as such, provides clear-cut evidence that the universe in the past was different from what it is today.[40] Naturally such evidence would completely rule out the possibility of a steady state universe.

Cosmic Microwave Radiation

The problem of cosmology is to substitute observational science for myth and speculation; yet, it frequently is engulfed by the sea of detailed observational data available. Certainly the need in cosmology is for observations of large-scale phenomena which can serve as essential bases of theory. To be sure, most current cosmological theories are based on one such observation: Edwin P. Hubble's discovery that other galaxies are moving away from ours and that their velocity is proportional to their distance from us. This concept of recession is the basis for such widely different cosmologies as the Evolutionary Theory and the Steady State Theory.

Presently, it appears that radio astronomers have discovered another basic cosmological phenomena which, like Hubble's discovery, may serve as a basis for cosmological theory. This factor, first set forth by Arno A. Penzias and Robert W. Wilson in 1964, is the low-energy cosmic microwave radiation that apparently fills the entire universe. R.H. Dicke, together with his colleagues P.J.E. Peebles, P.G. Roll, and D.T. Wilkinson of Princeton University immediately proposed that this was the cosmic black body radiation derived from the initial expansion of the universe as proposed by George Gamow.

Briefly, cosmic black body radiation within the Evolutionary Theory provides a very close view of an element of the original expansion of the universe, whereas both quasi-stellar objects and radio source counts concern distant justifications of the Evolutionary Theory. Peebles and Wilkinson summarize the position of cosmic microwave radiation within the Evolutionary Theory as follows:

> At some time in the distant past---about seven billion years ago---all the matter in the universe must have been packed together in an inferno of particles and radiation. As the universe expanded out of this holocaust, the matter cooled and condensed to form galaxies and stars. The radiation, which had started

> out as enormously energetic gamma rays, was also "cooled" by the expansion; its wavelength increased and it now appears mostly in the radio and microwave bands.[41]

In order to consider the cosmic microwave radiation as an indication of an evolutionary universe as opposed to that of a steady state, it was crucial to ascertain the viability of the prediction that because the radiation was emitted by a source in thermal equilibrium (the condensed universe), its intensity should vary with wavelength in the manner of an ideal thermal radiator, or "black body." To accomplish this, it was necessary to trace the observed intensity of the radiation as a function of wavelength and therefore see if the measurements fell on the black body curve.

Observation showed that measures of cosmic radiation fall within a typical black body curve which is appropriate for a source with a temperature of three degrees Kelvin (degrees centigrade above absolute zero), thus bearing witness to the possibility that the cosmic microwave radiation is indeed blackbody radiation of the evolutionary universe.[42] However, one must remember that cosmic microwave radiation is a relatively new discovery and as such, cannot yet be considered as conclusive evidence.

Summary

Current research within the field of cosmological astronomy tends to establish the inaccuracy of the Steady

State Theory. Fred Hoyle, although one of the major proponents of this theory, has himself acknowledged that "the steady-state concept, as a strict precept, is at variance with the counts of radio sources....The data shows that radio sources were either systematically more frequent, more powerful, or both, in the past than they are at present."[43] However, not only has the Steady State Theory lost favor with many cosmologists, but also the Evolutionary Theory is beginning to be questioned. E.R. Harrison, in a recent report "On the Origin of Structure in Certain Models of the Universe," suggests that gravitational instability fails to meet the requirements of a steady state universe and that it also suggests that the Evolutionary Theory should be updated and reformulated into a more acceptable proposition.[44]

CHAPTER VII

CONCLUSIONS

Seemingly, the raison d'etre of the twentieth-century science of cosmology is the determination of scientifically plausible theories of the origin and evolution of the universe. Certainly this has been accepted as a serious task; while only the most outstanding and influential twentieth-century cosmological theories have been included in this study due to the necessary limitations of time and scope, the number of possible entries is extensive.

A summarization of the preliminary elements which were essential to the development of current theories concerning the origin, structure, and evolution of the known physical universe includes those factors discussed in Chapter II: recognition of the galaxies as the primary element of the universe; the discovery of the inconsistencies of Newton's theory of gravitation, when employed on a cosmic scale; and finally, the development of Einstein's theory of relativity.

From the numerous cosmological theories propounded in the twentieth century, two have been of outstanding consequence: the Steady State and the Evolutionary Theory. The purpose of this study has been primarily that of an introduction and discussion of these two theories and an attempt to justify the Evolutionary Theory as the more plausible of the two. The principal concern of the majority of cosmological research appears to be centered around this very problem. E.R. Harrison emphasizes this interest in these two major theories of the origin of structure in the universe and succinctly contrasts the two:

> Cosmology is confronted with the problem of explaining how large-scale structures originated in the universe. Within the framework of conventional theory two hypotheses are possible. In the <u>primordial structure hypothesis</u> [Evolutionary Theory of the universe] structural differentiation of a rudimentary form is inlaid within the universe from its earliest moments, whereas in the <u>instability hypothesis</u> [Steady State Theory of the universe] structure evolves naturally from small initial disturbances.[45]

As evidenced in the previous chapter, scientific thought with regard to these two theories is diverse. There exists not only those who cling steadfastly to their choice of the two theories, but also those who would seek new paths to an understanding of the origin and evolution of the universe. For example, Nikola St. Kalitzin of the Bulgarian Academy of Sciences suggested a new basis for cosmological theories through the development of a multi-temporal special theory of relativity in his presentation at the fourth international astrophysical meeting held at Liège in 1967.[46] A development of even greater relevance is the fact that several advocates of the Steady State Theory have recently recanted or, as in the case of Fred Hoyle, have produced an altered theory of the steady state hypothesis. Hoyle discusses his latest ideas and the results of his work with Narlikar concerning a modification of the Steady State Theory in his book <u>Galaxies</u>, <u>Nuclei</u>, <u>and Quasars</u>.[47]

To be sure, it is quite possible that neither the Steady State Theory advocated by Hermann Bondi, Thomas Gold, and Fred Hoyle nor the Evolutionary Theory proposed by Georges Lemaître and further developed by George Gamow is, in truth, the solution to the cosmological dilemma. Certainly, Chapter VI evidences the short-coming of each theory. Yet each theory is valuable for the cosmological questions it raises and the astronomical discoveries it induces. As a science, cosmology is ultimately dependent upon observation; thus, whenever observation produces what are seemingly contradictions to a theory or facts which are unexplained by current cosmological theory, revision or discarding of the theory is requisite. Yet, there is scientific value in a cosmological theory although it may prove to be incorrect. Frequently some specific element of the rejected theory proves to be influential in later cosmological theories.

As it now appears, the Steady State Theory is a weaker solution to the problem of origin and evolution of our universe than the Evolutionary Theory. Yet it has proven itself to be a theory of considerable import and one which instigated much research and speculation. Therefore, its value is evident and it has been the purpose of this paper to emphasize the contributions of both these major theories.

The answer to the problem of one correct cosmological theory is elusive. Perhaps there is no one theory or perhaps our scientific knowledge prohibits our understanding of the universe. Nevertheless, scientists must continue their search. Fred Hoyle succinctly summarizes this necessity as follows:

> Many theories have to be considered, and there are so many alternatives to be investigated within each one that some astronomers and physicists are inclined to dismiss cosmology as a hopeless subject of study. By this, I suppose, it is meant that we are so unlikely to find a satisfactory theory that there is little point in making the effort....I believe that we must still make the effort. Otherwise the philosophy of ignoring cosmology could persist indefinitely, and could impede progress should progress become possible in the future.[48]

In summary, cosmology as a valid astronomical science was founded in the early twentieth century and although no one correct theory of the universe has yet appeared, the contributions of proposed cosmological theories have been great. Cosmology and its theories concerning the origin, evolution, and future of our physical universe are bounded only by our powers of scientific astronomical science. As man continues to reach out in exploration of our universe, cosmology maintains its quest to understand and categorize the development of the universe.

FOOTNOTES

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[34]Munitz, Theories of the Universe, 429.

[35]North, The Measure of the Universe, 208.

[36]Fred Hoyle, The Nature of the Universe (New York: Harper, 1951), 95.

[37]Bondi, El Cosmos, 41-42.

[38]Munitz, Theories of the Universe, 411.

[39]Sciama, Modern Cosmology, 117.

[40]ibid., 94.

[41]P.J.E. Peebles and David T. Wilkinson, "The Primeval Fireball," Frontiers in Astronomy (San Francisco: W.H. Freeman and Company, 1970), 329.

[42]ibid., 332.

[43]Fred Hoyle, Galaxies, Nuclei and Quasars (New York: Harper and Row, 1965), 98.

[44]E.R. Harrison, "On the Origin of Structure in Certain Models of the Universe," Instabilité gravitationelle et formation des étoiles des galaxies et de leurs structures caractéristiques (Cointe-Sclessin, Belgium: Institut d'astrophysique, 1967), 17.

[45]ibid., 15.

[46]Nikola St. Kalitzin, "A Multitemporal Theory of Relativity and Its Applications to Quasars and to Elementary Particles," Instabilité gravitationelle et formation des étoiles des galaxies et de leurs structures caractéristiques (Cointe-Sclessin, Belgium: Institut d'astrophysique, 1967), 81.

[47]Hoyle, Galaxies, Nuclei and Quasars, 101.

[48]ibid., 86.

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