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**Elites and Paradigms:
A Sociological Analysis of the Big Bang and Plasma Debate
in Theoretical Cosmology**

by

Alex Ipe, B.A.

**A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of**

Master of Arts

Department of Sociology and Anthropology

Carleton University

Ottawa, Ontario

April 17, 1996

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**Elites and Paradigms: A Sociological Analysis of the
Big Bang and Plasma Debate in Theoretical Cosmology**

submitted by Alex I. Ipe, B.A.
in partial fulfilment of the requirements for
the degree of Master of Arts

Dennis Forcese, Thesis Supervisor

Chair, Department of Sociology and Anthropology

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May 2, 1996

Abstract

The Big Bang theory of cosmology argues that the universe was born in a violent, cataclysmic explosion approximately twenty billion years ago. It is a model that has come to play a central role not only in cosmology, but in the related fields of nuclear and particle physics as well. Yet, in recent years, a small group of plasma cosmologists have begun to vigorously challenge the Big Bang paradigm with a theoretical model of their own. But, thus far, their views have gained little sympathy within the mainstream cosmological community. This thesis attempts to understand why the plasma model has been ignored and attacked by orthodox physicists, its sociological analysis guided by an integrated Elite-Kuhnian theory.

ACKNOWLEDGEMENTS.

According to conventional wisdom, photons born during the cataclysmic event known as the Big Bang, have taken roughly 20 billion years to reach the inhabitants of a tiny, blue sphere known as Earth. Upon careful reflection, it seems this contribution to academia has taken roughly the same amount of time to complete. Of course, this is a wild exaggeration on my part; but the voyage has been a long one, relatively speaking. And since no complex endeavor is formulated in a vacuum, I would like to take this time to offer my greatest thanks to all who have accompanied me on this fascinating odyssey:

Professor Dennis P. Forcece, who has guided the evolution of this thesis with great interest and skill. I owe him a heartfelt thank-you for undertaking the supervision of a thesis that dared to traverse an academic landscape that very few sociological theses have ever crossed.

Professor Terry A. Nosanchuk, whose detailed knowledge of the esoteric discipline that is physics, made this project all the more enjoyable.

Professor Peter J. Watson, Chair of the Physics Department at Carleton University, who graciously agreed to participate in two interviews conducted by a sociology student of all people! His understanding, patience, and words of wisdom, clarified the abstract entity known to the world as Einstein's General Theory of Relativity, and its mathematical offspring, the Big Bang Theory.

Of course, the views expressed, and the interpretations woven within this text are my own, as are all empirical errata present in the thesis.

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"Since Galileo, scientists had adopted the view that they were objective observers of the natural world. That was implicit in every aspect of their behavior, even the way they wrote scientific papers, saying things like 'It was observed...' As if nobody had observed it. For three hundred years, that impersonal quality was the hallmark of science. Science was objective, and the observer had no influence on the results he or she described.

"This objectivity made science different from the humanities, or from religion - fields where the observer's point of view was integral, where the observer was inextricably mixed up in the results observed.

"But in the twentieth century, that difference had vanished. Scientific objectivity was gone, even at the most fundamental level. Physicists now knew you couldn't even measure a single subatomic particle without affecting it totally. If you stuck your instruments in to measure a particle's position, you changed its velocity. If you measured its velocity, you changed its position. That basic truth became the Heisenberg uncertainty principle: that whatever you studied you also changed. In the end, it became clear that all scientists were participants in a participatory universe which did not allow anyone to be a mere observer."

- Michael Crichton, The Lost World, 1995

Section I Introduction: The Debate and the Theoretical Models

The discovery that all the galaxies in the visible universe are receding from us, and from one another, convinced many cosmologists that the universe had come into existence at a specific time in a distant Age, an Age long past. This belief rose within the cosmological community in the late 1940s, a belief which later assimilated the dramatic title known to the world as the Big Bang theory. The Big Bang was the beginning, a miraculous phenomenon that gave life to our universe, and all the matter and energy within its seemingly infinite domain. Why it happened is a mystery whose answer is forever lost in the halls of time. That it happened is beyond doubt, at least where the empirical evidence is concerned (Sagan, 1980:246).

Yet, in recent years, a small group of scientists, known as plasma physicists, have begun to challenge the Big Bang paradigm, arguing that the universe has existed for an infinite period of time, and will continue to exist for ages to come. For these researchers, time is an entity without a beginning or an end, like a celestial wheel; the Wheel of Time turns, and in its wake the Cosmos unfolds, the drama is acted, and the end is a concept without meaning.

The imaginative theories put forth by this small group of unorthodox researchers, has attracted very little interest from mainstream physicists, a fact that hardly surprises the members comprising this tiny band of marginal scientists. So dominant is the Big Bang theory within cosmology, they argue, that alternative theories are brushed aside, their observations swiftly condemned as faulty and speculative, ideas born of the imagination and not careful empirical observation.

Yet, upon closer examination, the social and political environment in which this academic battle is being waged, becomes readily

apparent. Like any human endeavor, scientific practice cannot be completely separated from the larger social community in which it exists. Scientists are, obviously, human beings engaged in mortal chores, and thus, are far from being the cold, detached observers Western myth has proclaimed them to be. Astrophysicists are no exception, and their human vulnerabilities are transparent when we examine the Big Bang debate.

Indeed, for many physicists who firmly believe in the validity of the Big Bang, and have spent their professional careers testing its theoretical assumptions, abandoning a well known model for an enigmatic one is a difficult feat; it would be very painful for any physicist to abandon his or hers life's work. Thus, the intellectual attacks directed at plasma cosmologists is not surprising, but wholly understandable and expected.

This thesis presents the argument that the resistance faced by plasma physicists to their alternative cosmological model is a resistance born of orthodox ideology; it is a resistance born of conservatism, rather than that of objective, empirical observation. It is argued that this conservative outlook is a product of the highly stratified structure of the scientific community, a social realm where a select few hold the reins of influence and power. It is argued that researchers who dare to put forth ideas that challenge the beliefs of the elite scholar, face harsh criticism because their "...ideas transgress professional boundaries or threaten social hierarchies"(Duncan,1974:112).

It is argued that revolutionary concepts arise from scientists courageous enough to venture outside the academic parameters of their field of specialization, researchers who dare to challenge the status

quo, the rebel who dares to confront authority. It is a romantic image, but it has occurred time and time again in the history of science, and is occurring now in the exploration of cosmology.

What follows is an investigation into the esoteric realm of theoretical cosmology, an investigation whose objective is to explore the hegemonic status of the Big Bang theory within this unique scientific community. In order to facilitate the conceptual mapping of the terrain which we are about to traverse, the theoretical frameworks known as the elite model (Bottomore, 1993; Higley et. al, 1979; and Michels, 1962), and Thomas Kuhn's theory of scientific change (1970), will be brought to bear in our analysis.

While the two, above mentioned models differ in their theoretical composition, their unique, individual structures truly compliment one another, enabling the reader to view the complex activity that is scientific research in its entirety. In essence, each social model is "...linked to a different model of scientific organization - to Crane's 'core and scatter' science, and Kuhn's 'crisis and normal science', respectively" (Duncan, 1974:112). Therefore, by integrating both theoretical frameworks into a comprehensive entity, it is hoped that the forthcoming investigation will provide a holistic and balanced account of the scientific community, and scientific research in general.

The elite model is especially useful, in that it helps to explain the social and political structure of not only the cosmological community, but also the scientific community as a whole. For example, it can account for the fact that greater social prestige is bestowed upon theoreticians than their experimental counterparts (Mulkay, 1976:449); the concentration of research productivity in the hands of a select

few(Price,1963:118); the highly skewed distribution of honorific awards, awards monopolized by a small, intellectual elite group of researchers(Mulkay & Milic,1980:23); the differential citation rates between elite and non-elite scientists(Cole & Cole,1973:55); the concentration of eminent scientists at the most prestigious universities in the United States(Zuckerman,1970:243); and the unequal distribution of research funds to a select group of academic institutions(Mulkay,1976:451). In sum, the elite framework has the capacity to explain the complex geometry inherent in the social realm known as the scientific community, and how the "...stratified and clustered nature of scientific communities, the nature of personal influence and information links becomes crucial to scientific change"(Duncan,1974:110).

Similarly, Kuhn's theory of scientific change provides the conceptual tools with which to analyze the incredible resistance and adaptability of theoretical models even in the face of troubling, empirical evidence that suggests long standing fundamental assumptions in a specific, dominant model need to be re-examined. Kuhn's description of the scientific community is a highly focused treatment of the political and cultural forces which resonate within the physical sciences. As such, it provides a clear model with which to comprehend this esoteric field of investigation. But in many ways, Kuhn's thesis is a specific manifestation of the elite model, and both frameworks overlap considerably on a number of conceptual points, facilitating the argument that the two theories are really two sides of the same proverbial coin, and can be integrated quite easily into a comprehensive paradigm.

Kuhn describes science as a dichotomous entity, separated into two

beings, one referred to as "...normal science - problem solving, the fleshing out of existing frameworks... - and revolutions, the vertiginous intellectual upheavals through which knowledge lurches genuinely forward"(Gleick,1992:320). It is this specific theme which lies at the heart of Kuhn's thesis, a theme which informs the analysis of the philosophical and empirical battles now being waged within cosmology over the Big Bang paradigm. This vision of normal and crisis science helps to explain the social processes through which scientific change occurs. It can account for the hostility faced by those who put forth unorthodox ideas and theories. It reveals the behavior of journals and funding agencies to research topics that go against the grain of conventional wisdom within a specific discipline. It gives one important interpretation to how scientific discovery and evolution occurs, a vision of "a few freethinkers working alone, unable to explain where they are heading, afraid even to tell their colleagues what they are doing..."(Gleick,1987:37).

I argue in this thesis that scientific growth is not a linear, purely rational process, but is a social practice that is constantly walking a narrow path between the forces of ideology and hegemony. Indeed, I argue that the Big Bang theory is a standard paradigm, a model whose dominant position within the cosmological community, and the support it receives from the scientific elite, allows it to effectively negate the conceptual attacks hurled at it from plasma cosmologists like Nobel laureate Hannes Alfvén and Eric J. Lerner.

1.1 Reviewing the Debate on the Big Bang

To date, an analysis that situates the Big Bang debate within the social and political context of the cosmological community, is an avenue of research that remains to be explored. Paradoxically, those scholars who have attempted to shed light upon the intangible cultural forces interwoven with the Big Bang model, have been exclusively physicists, or members of the physical science community (eg. Crichton, 1987; Davies, 1994; Hilgevoord, 1994; Lerner, 1991; and van Fraassen, 1994). But these analyses are overwhelmingly philosophical and descriptive in nature, and lack the insight that could have been gained by the presence and guidance of a pragmatic social theory.

While the ideological turbulence associated with the Big Bang has not, thus far, attracted the attention of social researchers, the social forces manifesting themselves within the context of this debate have received considerable scrutiny from sociologists of science; that is concepts such as stratification, inequality, discrimination, and ideology as they relate to the physical sciences and other paradigmatic debates, have been thoroughly explored within the literature (Amick, 1974; Barber, 1962; Blume & Sinclair, 1973; Duncan, 1974; and Stewart, 1986).

Indeed, the forces responsible for crafting the current theoretical debate within cosmology, were forces born of human agency, of ideological battles that had very little to do with the practice of objective science, and everything to do with personal convictions and beliefs.

It is very easy to forget that scientific investigation is a human endeavor; it is a task performed by human beings, not machines. As such, the popular image of scientists as objective observers of the physical world is an image that can be challenged, and has been challenged over

the years by social scientists, and even by members of the physical science community (eg. Cole & Cole, 1967, 1973; Cole, 1992; Crichton, 1987; Hilgevoord, 1994; Davies, 1994; and Leiss, 1975). By the dawn of the twentieth century, in the wake of Einstein's revolutionary theories, and the development of quantum mechanics, the notion of scientific objectivity had vanished. Scientists now realized that the very act of studying and measuring a physical phenomenon, altered that phenomenon in a very subtle, yet significant fashion, a fact of empirical analysis that social scientists had acknowledged and accepted long ago. In time, physical scientists, too, came to accept this fundamental, basic principal, a principal that was as valid in the natural sciences as it was in the humanities. As Crichton states, "...it became clear that all scientists were participants in a participatory universe which did not allow anyone to be a mere observer"(Crichton,1995:393).

In essence, the debates flaring within the realm of cosmology over the Big Bang is a modern manifestation of an ancient image, an image of a marginal group of researchers attempting to study a well worn problem from an unorthodox point of view, only to face ridicule, and at times, hostility from their traditional colleagues, an image that eventually attracted the academic eye of the sociologist of science.

In the early days of the sociology of science, some of the great theorists of old wrote pioneering analyses on the relationship between science and the social world (eg. Durkheim, 1915; Engels, 1947; Hessen, 1931; Marx, 1962; and Weber, 1946). For the most part, these works were highly theoretical, at times resonating with the well worn arguments of philosophers and philosophical logic. While the accounts of Hessen,

Engels and Marx were not burdened by philosophical presuppositions, they were constrained by a parochial sensitivity toward economic and political issues. Thus, Marx, and other like minded researchers, viewed science as a creature wrought by economic forces, an entity born of the shadow of industrial evolution. As Marx states:

"The mode of production of material life conditions the social, political and intellectual life process in general. It is not the consciousness of men that determines their being, but, on the contrary, their social being that determines their consciousness"(Marx,1962:363).

As the winds of time flowed across the academic landscape, Marxist scholars began to focus their attention on the social threads of influence interwoven with the practice of science. Yet, in their academic analyses, they could not disengage themselves from the theoretical web constructed by their famous leader, for all Marxist monographs on the scientific enterprise continued to revolve around the dynamic interplay of economics and science. As Hessen argues in one article, "In his [Newton's] mechanics he was able to solve that complex physiotechanical problems which the rising bourgeoisie had set for decision"(Hessen,1931:204).

Branching off from the traditional Marxist approach, Robert K. Merton, considered by many to be the founding father of the sociology of science, tackled the relationship between science and society from a non-economic angle. Indeed, Merton seemed to chastise the purely economic analyses of science characteristic of Marx and others. Specifically, Merton writes:

"All too often, the sociologist who repudiates the mythopoeic or heroic interpretation of the history of science lapses into a vulgar materialism which seeks to find simple parallels between social and scientific development. Such misguided efforts invariably result in a seriously biased and untenable discussion (Merton,[1938] 1957:67).

In his own analysis of science, Merton adopted a holistic approach in mapping the complex threads binding the practice of science with the wider social sphere. That is, Merton branched off from the economic analyses of Marx and Engels, and attempted to look at the scientific enterprise in the context of social, economic, and political reality. Merton's unique style of social investigation, first manifested itself in his now classic work, Science, Technology and Society in Seventeenth Century England, originally published in 1938. In this monograph, Merton argued that the theoretical and conceptual problems studied by British scientists of the seventeenth-century, were not tackled out of sheer academic curiosity, but were studied because of the considerable pressure placed on the physical scientists to conform their research interests to the interests of the economic and political powers of the time. Indeed, Merton adopts a functional analysis in this article, arguing that the interdependence between science, economic, politics, was functional for English society, particularly at this time in English history when England's imperialistic shadow was racing across the globe. In essence, Merton argues that science performed the function of facilitating England's evolution into a global, political and economic super-power. As Merton states:

"The burgeoning of capitalistic enterprise in seventeenth century England intensified interest in more adequate means of transport and communication. St. Helena, Jamaica, North America were but the beginnings of England's great colonial expansion. This and the relatively low cost of water-transport led to the marked growth of the merchant marine"(Merton,[1938] 1962:71).

For many years, Merton studied science exclusively within the theoretical model of functional analysis, a paradigm that had prospered in the literature under Merton's guidance, and which was the most prevalent theoretical tool in the sociology of science in its early days(Mulkay & Milic,1980:9). Yet, like so many things in life, dominant ideas and philosophies evolve and transform over time, sometimes emerging under a new guise, or crumbling into conceptual dust. For Merton, while the functional model was useful in sketching the social structure of science, its utility had a limit.

In time, Merton began to focus his attention on the internal social structure of science, pondering whether the socio-political composition of the scientific community had the potential to influence scientific research and ideas.

In his exploration, Merton uncovered a fascinating picture of science, one that shattered the somewhat media induced mythical image of science as a noble, democratic activity above the petty concerns of politics and economics. What Merton discovered was a highly stratified culture, a culture in which the eminent scientist grew into legendary statehood; in contrast, their lesser known colleagues existed in a state of obscurity, their research, for the most part, ignored, their ideas lost in the pages of academia(Merton,1968). This empirical observation led Merton to coin the now famous term known as the 'Matthew Effect' in honour of the passage written in the Biblical Gospel known as Matthew:

"For whomsoever hath, to him shall be given, and he shall have more abundance; but whomsoever hath not, from him shall be taken away even that he hath"(Matthew,13:12).

In many ways the 'Matthew Effect' was the first realization that the scientific community could be analyzed like any other socio-political, socio-economic reality. While the 'Matthew Effect' is not a self-contained framework, it is a very specific manifestation of an elite theoretical paradigm. Unfortunately, Merton makes no attempt to analyze the scientific culture with the guidance of an elite framework, content with the practice of quantifying and analyzing the stratified nature of science. But, thanks to Merton's pioneering research and influence, the sociological literature is dominated by complex statistical analyses of the inegalitarian, discriminatory, and elitist structure of scientific research (eg. Amick, 1974; Cole & Cole, 1967, 1970, 1973; Cole, 1992; Barber, 1961; Crane, 1965; Gaston, 1970; Holland, 1957; Mulkay, 1976; and Zuckerman, 1962, 1967a, 1967b, 1970).

Indeed, if one were to stand back and observe the various scholarly works from a distance, a distinct pattern would emerge from the literature, a pattern that could be represented as a three-dimensional triangle, its four distinct faces reflecting an intellectual division of labour within the sociology of science. On one side, there would be the quantitative scholars (eg. Merton, Barber, Cole & Cole, Crane, and Zuckerman) whose research interests revolve around the stratified fabric of the scientific community. On the adjacent side of the abstract prism, are those writers who tend to focus on the elite members of scientific society, mapping the threads of influence that emanate from these individuals, intangible threads that are inexorably woven into the very social fabric of the particular community they serve (eg. Mulkay, 1976; Soderqvist & Silverstein, 1994; Hart & Victor, 1993; and Mullins, 1972). On the third side of the triangle are the researchers who emphasize the human players in the drama called science (eg. Dolby, 1975; Leiss, 1975;

Lewenstein, 1995; and Rossiter, 1993). On the fourth and final side of our cognitive triangle, are the rarest of scholars in this field of specialization: the anthropologists.

Anthropological analyses of the physical sciences are few and far between. Yet, they do exist, one of the most well known accounts being Sharon Traweek's ethnographic analysis of the high energy physics community in both the United States and Japan. As is the case with such research, the social detective is interested in understanding the way human beings make sense of the world around them; to wade in the conceptual pools of the Other's psyche; to tell the tale of the human being standing before us. Where Traweek (1988) is helpful is in painting the physics community and its members with great skill and detail, forcing us to realize that science is a human activity, performed by beings of flesh and blood, and not robotic entities devoid of emotion or the shadow of irrationality.

Yet, despite the marvelous tapestry of human experience she weaves in her text, Traweek ignores the role that human pride and prejudice plays in paradigmatic debates and controversy. As well, she side steps the issue of how social variables are interwoven with the cognitive structure of science, the theories employed, the research paths explored or brushed aside for lack of interest.

As well, paradoxically, Traweek tends to exaggerate the behavior of the physicists in her study, as well as the community in which they practice their craft. For example, Traweek describes the high energy physics community as a "...culture of no culture, which longs passionately for a world without loose ends..."(Traweek,1988:162). This comment helps to reinforce the traditional image of physicists, an image that portrays them and their scientific colleagues as living computers,

standing outside the web of social and political influence. This comment does little to shatter that image, and is surprising coming from the one specialist whose job was to have unmasked that image, revealing the reality hidden within its shadows.

Traweek is not alone in ignoring the conceptual structure of scientific practice; indeed, every theorist mentioned, thus far, in this document has conveniently overlooked the cognitive models used by physical scientists in their everyday research, and the social processes by which these models are born and later discarded. Indeed, sociologists of science have overwhelmingly, focused their academic lenses on the internal social organization of the natural sciences (Cole,1992:4). In truth, this lack of attention paid to the content of science is not wholly surprising. In the early days of the sociology of science, social theorists like Karl Mannheim ([1929] 1954), believed that the essence of scientific practice - the testing of theories by empirical experimentation and observation - was beyond the influence of social variables; science was indeed perceived by these early scholars as "...an extreme culture of objectivity..."(Traweek,1988:162). Stephen Cole summarized the beliefs of his past academic colleagues concerning the content of science, in his book Making Science(1992):

"In natural science, at least, a 'truth' existed, and any scientific theory which did not express that truth would eventually be found inconsistent with empirical data and ultimately discarded. In this sense, natural scientists were trying to discover the next page of a book that had already been written, whose conclusion, though currently unknown, was predetermined or inevitable. Nature, rather than sociological processes, determined the way in which scientific knowledge developed"(Cole,1992:3).

In 1957, Thomas S. Kuhn undertook his first, major assault against the traditional image of scientific evolution and progress, with the publication of The Copernican Revolution. Within its pages, Kuhn mapped the social, political and religious forces interacting with one another in the mid sixteenth-century, forces that eventually merged into a cohesive entity that tenaciously attacked Nicholas Copernicus' heliocentric model of the solar system. Indeed, so controversial was Copernicus' theory that in "...1616 the Catholic Church placed Copernicus' work on its list of forbidden books 'until corrected' by local ecclesiastical censors, where it remained until 1835"(Sagan,1980:53). It was Kuhn who first detailed the human sources of this resistance to Copernicus' radical paradigm, and how that resistance slowly melted away with the passage of time. Indeed, Kuhn's Copernican Revolution set the stage for his greatest, and most controversial text, a book that generated as much praise as anger when it was first introduced to the public in 1962(Gleick,1987:36).

This now classic and famous work so synonymous with Kuhn, and entitled, The Structure of Scientific Revolutions ([1962] 1970), was the first attempt by a scholar to analyze the conceptual framework of science, and how the social fabric upon which science is performed, influences the creation of paradigms; he looked at the social processes that facilitated or impaired the creation of a new model of the natural

world. In his writings, Kuhn challenged the crystal image of science, the image that for so long had depicted science as a rational, objective process, an impartial practice by which the pools of knowledge swelled through the orderly accumulation of facts. After the passage of Kuhn, this was a representation that quickly lost its cohesion and its credibility.

Kuhn's historical approach provided a much wider screen through which to witness the evolution of the scientific process. As a former physicist, Kuhn was able to bring to the social studies of science, a very personal, intuitive feel for how science is conducted; his was an interpretation of the history and social conduct of science born of human experience.

Yet, in his panoramic sketch of the natural sciences, Kuhn avoids explicitly testing the sociological implications of his model, content to concentrate on the much broader, revolutionary aspects of scientific evolution. As Kuhn states:

"Already it should be clear that the explanation must, in the final analysis, be psychological or sociological. It must, that is, be a description of a value system, an ideology, together with an analysis of the institutions through which the system is transmitted and enforced"(Kuhn,1970:21)

To date, such a holistic, comprehensive analysis has not been undertaken by specialists in the sociology of science. Stephen Cole's most recent work Making Science (1992), makes a commendable attempt to trace the relationship between scientific practice and the social reality upon which this practice is undertaken. However, Cole's analysis is separated into various conceptual themes, themes he does not weave together into a comprehensive tapestry of scientific and human experience.

In the wake of Kuhn's eye opening account of scientific change,

there emerged, from the academic shadows, those who wished to pursue the Kuhnian analysis in another direction. These researchers, known as social constructivists and philosophers of science (eg. Collins, Mulkay, Feyerabend, Hesse, McMullin, Woolgar and Knorr-Cetina), believe that "truth" is an elusive entity that can never be captured. They argue that the physical laws of nature elucidated by physicists, do not exist in the natural world per se, but are human cognitive constructions (Cole, 1992:5; McMullin, 1994:287). Specifically, the views of these theorists can be summarized as follows:

"Nature does not determine science; instead, they say, the social behavior of the scientists in the laboratory determines how the laws of nature are defined. Given these assumptions, the social behavior of the scientists becomes the most important determinant of the content of their ideas" (Cole, 1992:5).

While the scholarly contributions of these theorists are insightful, they suffer from the age old philosophical specter of endless debate; that is, one philosopher makes a specific argument on the nature of scientific empiricism, for example, while yet another philosopher, one nurtured in an alternative school of thought, counters the reasoning of his or her distinguished colleague, with a brilliantly argued thesis of his/her own. These epistemological battles - while entertaining - are tedious, and without end, since much of what philosophers discuss cannot be subjected to empirical analysis; and if they were, indeed, testable, there would arise new debates concerning the nature of that empirical avenue of inquiry. Furthermore, physical scientists find these philosophical arguments a great bother, and provide clear evidence that many of those who engage in such reasoning, have never practiced the craft of scientific investigation. Steven Weinberg, the 1979 winner of the Nobel Prize for physics, summarized this view in a recent monograph:

"If the content of science is ultimately impersonal, its conduct is part of human culture, and not the least interesting part. Some philosophers and sociologists have gone so far as to claim that scientific principles are, in whole or in part, social constructions, like the rules of contract law or contract bridge. Most working scientists find this 'social constructivist' point of view inconsistent with their own experience"(Weinberg,1994:49).

Philosophical orthodoxy aside, Kuhn's thesis, while as debatable as some of the arguments put forward by the social constructivists, nevertheless, gives an honest, thoughtful, and personal picture of the human side to scientific research. Indeed, in a wonderful stroke of good fortune, approximately six years after Kuhn published his landmark text on scientific change, there emerged from the shadows of the literary world, a text that, effectively, elevated Kuhn's thesis from the abstract realm of academic thought, into the pragmatic, everyday world of scientific investigation. It was a book that drew as much admiration for its content as it did for the honesty of its famous, young author, a legend, now, in the field of science: James D. Watson, co-discoverer of the structure of the DNA molecule, and the 1962 winner of the Nobel Prize for Medicine and Physiology. In his now classic text The Double Helix (1968), Watson paints a very blunt, honest picture of how science is really done, at the same time, describing the cultural and political forces that he and his fellow researcher, Francis Crick, had to contend with in their attempt to break the secret of the DNA molecule. Watson eloquently states his intentions for writing this very personal text:

"As I hope this book will show, science seldom proceeds in the straightforward logical manner imagined by outsiders. Instead, its steps forward (and sometimes backward) are often very human events in which personalities and cultural traditions play major roles"(Watson,1968:xi).

With these words, Watson wove a tale of science that very few 'outsiders' had ever seen before. He illustrated in dramatic fashion that Kuhn's conceptualization of the scientific process was, indeed, founded upon human experience, and was far more than mere academic rhetoric.

Indeed, nearly twenty years after Watson published his classic text, Kuhn's model of scientific change was, once again, substantiated in the scientific literature, when James Gleick invoked Kuhn's thesis in his now famous book Chaos: Making a New Science (1987). This work was about the genesis of a new field of scientific specialization, namely, the field known today as Chaos mathematics. It was an attempt to illustrate, much as Watson's autobiography of over two decades ago, the messy practice of scientific evolution and discovery. It drew a historical and conceptual image of science that coincided remarkably well with Kuhn's own controversial model. In many ways, this account seemed to confirm the beliefs of both social and natural scientists that Kuhn was here to stay, regardless of the winds of praise or hostility.

While the works of Watson and Gleick were marvelous, eye opening accounts of the scientific process, the sociologist of science would frown upon their analyses for the simple fact that they were works that did not ground themselves in explicit sociological models or methodology. While Gleick did invoke Kuhn's thesis, he did not systematically subject the Kuhnian model to empirical examination, as one would in a purely academic treatment.

Yet, many sociologists, inspired by Kuhn and Watson, have carried out empirical analyses of the Kuhnian framework(eg. Allen, Qin & Lancaster, 1994; Duncan, 1974; Farrall, 1975; Gibbons & King, 1972; Griffith & Mullins, 1972; Hull, Tessner & Diamond, 1978; Lewenstein,

1995; Levin, Stephan & Walker, 1995; and Stewart, 1986).

Yet, each of the above works tested only a specific, conceptual brick composing the Kuhnian model. For example, Kuhn often remarked that older scientists were less receptive to new ideas than their younger colleagues (Kuhn, [1962] 1970:144). Those who tested this principle, found very little correlation between age and resistance to unorthodox ideas (eg. Hull, Tessner & Diamond, 1978; Levin, Stephan & Walker, 1995). This finding is not surprising considering the fact that the researchers ignored the larger social and political context in which senior and junior scientists practiced their craft. Furthermore, these analyses simply used absolute age as an independent variable without qualifying age with other crucial criteria, such as the level of prestige enjoyed by a senior researcher within the field in question, and the senior scientists own research interests and field of specialization.

Perhaps, it is Duncan (1974) who comes closest to mapping the social processes intertwined with scientific change. In his analysis, Duncan looks at the reception of spatial diffusion theory in geography from the theoretical vantage point of Merton's 'Matthew Effect', and Kuhn's thesis of revolutions (Duncan, 1974:109). However, his account is splintered, in the sense that he views the evolution of this theory from two separate angles without attempting a holistic, integrative approach. Indeed, as he states, "The interesting possibility of integrating these two models remains" (Duncan, 1974:112).

My intervention into this field is an attempt to understand the conflicts and controversies present in science, in the light of sociological theory. By invoking the elite model in its entirety - not simply relying on the special instance of the 'Matthew Effect', and integrating it with Kuhn's thesis of scientific change, it is hoped that a more holistic picture of scientific evolution will emerge.

In addition, this analysis extends the somewhat isolated, conceptual boundaries of social investigation prevalent in the sociology of science. It is a multifaceted approach which takes into account the intricate social forces that exist in the realm of scientific investigation. This account hopes to "stand on the shoulders of giants" to comprehend the dynamics of human ideology and belief that are involved in the current Big Bang debate unfolding within cosmology. This is a field of specialization, and a paradigmatic battle that has, thus far, been neglected by the sociologists of science.

"Kelly shook her head. She turned away from Malcolm and moved up the boat, to sit alongside Thorne.

"'Are you listening to all that?' Thorne said. 'I wouldn't take any of it too seriously. It's just theories. Human beings can't help making them, but the fact is that theories are just fantasies. And they change. When America was a new country, people believed in something called phlogiston. You know what that is? No? Well, it doesn't matter, because it wasn't real anyway. They also believed that four humors controlled behavior. And they believed that the earth was only a few thousand years old. Now we believe the earth is four billion years old, and we believe in photons and electrons, and we think human behavior is controlled by things like ego and self-esteem. We think those beliefs are more scientific and better.'

"'Aren't they?'

"Thorne shrugged. 'They're still fantasies. They're not real. Have you ever seen a self-esteem? Can you bring me one on a plate? How about a photon? Can you bring me one of those?'

"Kelly shook her head. 'No, but...'

"'And you never will, because those things don't exist. No matter how seriously people take them,' Thorne said. 'A hundred years from now, people will look back at us and laugh. They'll say, 'You know what people used to believe? They believed in photons and electrons. Can you imagine anything so silly?' They'll have a good laugh, because by then there will be newer and better fantasies.' Thorne shook his head. 'And meanwhile, you feel the way the boat moves? That's the sea. That's real. You smell the salt in the air? You feel the sunlight on your skin? That's all real. You see all of us together? That's real. Life is wonderful. It's a gift to be alive, to see the sun and breathe the air. And there isn't really anything else.'"

- Michael Crichton, The Lost World, 1995

Chapter 2 Theoretical Models: Elite Theory, Hegemony, and the Kuhnian Thesis

2.1 Classical Elite Theory

The theoretical paradigm known as elite theory, does not offer a comprehensive analysis of the physical sciences per se. However, elite theory was initially formulated to study the complex interactions of social and political forces which comprise the entity known as the western, industrialized nation-state, as well as smaller units like municipalities and organizations.

Thus, elite theory can be invoked to analyze our particular question; its utility lies with its analytic power. According to the celebrated English physicist, Stephen Hawking, a theory is:

"...just a model...and a set of rules that relate quantities in the model to observations that we make. It exists only in our minds and does not have any other reality (whatever that might mean). A theory is a good theory if it satisfies two requirements: It must accurately describe a large class of observations on the basis of a model that contains only a few arbitrary elements, and it must make definite predictions about the results of future observations"(Hawking,1988:9).

It can be argued that the elite model, indeed, satisfies Hawking's criteria for a pragmatic and useful theoretical framework, and thus, can be employed in this document with a high degree of scholarly confidence.

In order to situate elite theory within its historical context, the analysis must commence at the roots of contemporary elite theory known as the classical elite model.

Social theorists have at their disposal numerous conceptual maps with which to explore the social and political structures of human societies. Perhaps the most commonly employed conceptual map to chart the social terrain, is that which represents communities as being socially stratified; where academic distinctions are made between various social classes or strata(Higley et al.,1979:1; Mills,1956:3). While such a theoretical strategy is simplistic, artificially smoothing the reality of the social topography under scrutiny, it does allow scholars to study the intricate fabric of socio-political systems with some degree of conceptual ease. As Higley et al. state, "Consequently, the license for using them lies not in their empirical accuracy, but in the cogency of the analyses and explanations that they facilitate"(Higley et al.,1979:1).

The distinctions made by theorists in their analysis of social systems, are given various discursive, or symbolic labels. Perhaps the most common dichotomy within this realm of inquiry, is that between elites and non-elites(Higley et al.1979:1; Marger,1981:65). This theoretical division is not a unique one, and is by no means confined to the halls of academic thought; it is, indeed, a distinction cloaked in a common sense understanding of the social realm. It is common sense, because even the non-academic realizes that the social landscape is a reality where wealth, power and influence are not entities distributed randomly within a given community, but are highly skewed in favour of one specific social class, or stratum known as the elite(Higley et al.,1979:1; Mills,1956:3-4).

In essence, the elite model argues that in any community, power and its related concepts are concentrated in the hands of a few, elite

individuals; those which are excluded from this social stratum are, by definition, the non-elite masses(Higley et al.,1979:1; Bottomore,1993:2; Marger,1981:65). However, the structure of the community, or society in question influences the relationship between the two theoretical strata. For example, in a static society, elites and non-elites can be viewed as two distinct, homogeneous entities, with very little interaction between the two strata. The term static society refers to a social reality in which:

"...there is very little vertical mobility between social classes in the sense that between generations there is little social ascent or descent in terms of the relative places subsequent generations hold in the social structure; for example, in a static society a son tends to repeat his father's occupation"(Clement,1975:2).

In contrast to the static society, there exists another theoretical entity known as the dynamic society(Clement,1975:2). In this social realm, vertical mobility occurs with a high degree of frequency, and talent, in all its manifestations, is used efficiently and generously(Clement,1975:2). However, the fact of the matter is that:

"Such a society has yet to exist, but theoretically it is known as a 'meritocracy'. In such a society it is assumed that there could be both a highly structured society controlled by elites and open recruitment to these elites"(Clement,1975:2).

In the empirical, western, democratic realm, no society fits the above mentioned models very neatly, though reality seems to approach the dynamic model more than its counterpart. In any event, the fact that communities can be divided and contained within abstract categories such as the elite/non-elite dichotomy, has ignited numerous academic debates. Some theorists argue that the presence of elites can be explained by reference to "natural" or genetic variations in human capacities, and is a "natural" by product of human evolution(Higley et al.,1979:2;

(Marger,1981:65). Still other theorists claim that the existence of elites can be traced to the social inequalities present in society, inequalities whose eradication is a question of academic debate(Higley et al.,1979:2). However, neither of the above mentioned arguments can fully account for the presence of an elite stratum in nearly all human communities. With this realization, scholars began to mould and shape the cognitive web that would become the elite model.

The essence of the elite framework is that, when the degree of social organization reaches a high level of complexity and intricacy, then the will, or the interests of the individual must be neutralized "...by authoritative decisions in order to sustain collective endeavors. Thus complex organization, not society itself, is the basis of elites"(Higley et al.,1979:2). Thus, when a social entity evolves into a multifarious organization, a leadership group is needed to make judgments that transcends the beliefs and concerns of the individual; in this fashion, the leaders can give the community a sense of cohesion, unity and direction(Marger,1981:65). The classical elite model, in effect, justifies the existence of an elite stratum, arguing that it is functionally necessary for the good of the organization. Indeed, this rationale can be applied to any complex organization with a specialized division of labour(Marger,1981:65). In essence, elite power rests:

"...in...positions of authority in key political and economic organizations and the material and human resources they thereby control. Modern elite theory has rested its case primarily on this explanation of elite rule(Marger,1981:65).

The concept of elites has a long history within Western, philosophical thought, dating as far back as the writings of Plato(Marger,1981:65). However, the theoretical roots behind the elite model can be traced back to the scholarly writings of Gaetano Mosca (1939), and Vilfredo Pareto (1935), two Italian theorists who founded the framework of modern elite theory(Higley et al.,1979:1; Marger,1981:65). A very brief discussion of the theoretical works of these writers will be discussed below.

Pareto's elite thesis can be described as primarily socio-psychological in nature, a characteristic which hinders its conceptual effectiveness. In order to effectively study a social phenomenon, a consistent theoretical representation is needed; Pareto's tendency of jumping from a micro, psychological framework to a macro, sociological model, and then returning to the micro analytic stance, makes social analysis a difficult enterprise(Marger,1981:66).

In essence, Pareto's elite theory represents society as composed of a powerful stratum at the top of the social pyramid, and a subordinate stratum at the bottom, with some degree of circulation between the two spheres of reality(Marger,1981:66).

In contrast, Mosca's elite model is rooted in traditional sociological, and not psychological factors. Mosca argues that the power of the elite derives from it being an organized, homogeneous entity facing a heterogeneous, unorganized majority(Marger,1981:66).

In addition, Mosca makes a slight gesture toward the psychological arguments of Pareto, by stating that the elite have in possession certain attributes which helps to solidify their dominant status within society(Marger,1981:66,53).

As well, Mosca introduces a crucial concept in his analysis of elites; it is a concept he terms "social forces"(Mosca,1939:53). This abstraction refers to technical or intellectual talents, material resources, social influence, and moral suasion(Mosca,1939:53; Marger,1981:67; Bottomore,1993:4).

In essence, the theoretical concepts that can be gleaned from the social analyses of Pareto and Mosca are the following: all human societies are stratified into various social strata, with economic, political power, and social influence concentrated in a social group known as the elite; this minority rules over the non-elite majority(Bottomore,1993:5; Marger,1981:68). Over time, the elite stratum undergoes changes in its composition, recruiting new members from the subordinate strata of society. In other instances, the dominant group is displaced, and a new counter-elite emerges from the background of political turmoil. In addition, elites are characterized by their organization, personal attributes and social forces(Bottomore,1993:6; Marger,1981:68).

Recent modifications to classical elite theory, postulates the existence of three distinct communities within the elite stratum; these are referred to as the disunified, ideological unified, and consensual elites(Higley et al.,1979:13).

The argument is that individuals holding key positions within an organization, look upon their fellow elites with a fair degree of suspicion and distrust(Higley et al.,1979:9). In order to position themselves favorably within the power structure, these persons usually form

alliances with like minded members in order to secure for themselves a greater portion of political pie(Higley et al.,1979:9). Thus, in a disunified elite structure, elite individuals are on their own, constantly formulating strategies that would see the downfall of their fellow elite factions(Higley et al.,1979:10). Indeed, a disunified elite structure can be characterized as follows:

"Mutual distrust and fear is thus the basic aspect of a disunified elite structure. Its members necessarily doubt the reliability of their access to authoritative decision-makers. Those who oppose current policies and practices necessarily see change as involving the removal or alteration of the faction that controls the coercive forces"(Higley et al.,1979:9).

In such a social reality, political stability is impossible. Indeed, political stability can only manifest itself within the landscape of a unified elite structure(Higley et al.,1979:10). In this social environment, there exists a common belief among the elites and non-elites that the political system is functioning reasonably well. When differences of opinion arise within a community governed by a unified elite concerning social or economic matters, "...the tendency is towards civil strife on such issues once they rise to public consciousness"(Higley et al.,1979:10). Civil unrest is usually quelled through the use of coercive force. Hence, the social and political stability which results from the presence of a unified elite, is not motivated by democratic ideals and values, or solving social ailments through elite-mass co-operation. Instead, political stability:

"...is always the artificial product of shrewd decisions made by elites. This shrewdness involves suppressing, distorting and otherwise manipulating issues which, if expressed and acted on openly and widely, would result in disastrous conflict"(Higley et al.,1979:10).

Unified elite structures can be further broken down into two entities: ideological unified and consensual unified elites(Higley et al.,1979:10). The ideological unified structure is characterized by a

community in which all elite members adhere to a specific philosophical or ideological belief(Higley et al.,1979:10). Those who dare to deviate from this ideological consensus, are harshly penalized, at times even punished by the community. However, conformity to the currents of ideological thought within this social structure is rewarded and praised(Higley et al.,1979:10). Indeed, the ideological unified structure has been quite successful in the pages of human history. As Higley et al. state:

"Once established, this elite structure produces highly stable political regimes in which irregular seizures of power by force become unknown. Since its creation in the victory of a small band of communist radicals in 1921, the ideological unified Russian elite structure has supported a stable regime. The political victories of fascist radicals in Italy between 1922 and 1926 and in Germany in 1933 resulted in similar elite structures and similarly stable regimes which were terminated only by defeats in international warfare"(Higley et al.,1979:11).

Lastly, the consensual unified structure produces political stability not through the use of force, but through the active participation of elites and non-elites in the social and political arena. In this social community, elite unity exists due to the "...failure of elite persons to organize and accentuate elite and non-elite conflicts and divisions"(Higley et al.,1979:11). In addition, rival elite factions within this structure tend to minimize their ideological differences, adhering to an unwritten code of social and political conduct(Higley et al.,1979:11).

The nature of the consensual unified elite is, in part, rooted in a long history and tradition of co-operation, a legacy which facilitates elite unity. However, this alone cannot account for the strong unity characteristic of the consensual elite, for elites are bound to the web of social and political forces which constitutes their reality. Hence,

other factors are at work which effectively perpetuates the consensual elite community through the corridors of time. According to Higley et al., a consensual elite emerges when elites judge that it is in their interest to ride the existing currents of social and political reality.

They state:

"It occurs, in other words, only when elites see in such institutions and procedures satisfactory opportunities for obtaining power's psychic and social awards and sufficient scope for pursuing their managerial and non-egalitarian interests. It is the assurance of access to power within the framework of existing institutions that deters them from translating their oppositions into attempts to seize powers by force"(Higley et al.,1979:12).

Of the three models presented above, only the consensual unified elite approaches - for the most part - the empirical reality of contemporary, Western, industrialized communities and organizations. Yet, aspects of all three models can be found in the social and political structures of numerous social systems; there is, as one can imagine, a fair degree of overlap between the above mentioned theories. It is a fact that no one framework can accurately describe the social realm humans exist in. But at least theoretical paradigms can give us valuable insights into the complex structure of human social communities.

2.2 Michels' Iron Law of Oligarchy

Robert Michels theoretical model, unlike that of Pareto's, and even to an extent, Mosca's, is based on strong sociological foundations; sociological variables such as social organization and division of labour form key aspects of his paradigm(Marger, '981:70). Michels' thesis revolves around the central issue of elite rule. He contends that the reality of oligarchy - rule by a few - is inevitable in the social reality of large, complex organizations. Due to the intricate web of social relations characterized by complex systems, it is not realistic to assume that every member of the organization can make important decisions in an efficient manner(Michels,1962:205; Marger,1981:70-71). Thus, in order for a social entity to survive and perpetuate itself, logic dictates that executive powers must be delegated to a select few individuals(Michels,1962:205; Marger,1981:71). In time, these select persons tend to be categorized as an elite. Indeed, the inevitability of elites in complex, social environments is summed up in Michels' succinct statement: "Who says organization, says oligarchy"(Michels,1962:365).

When organizations reach a certain degree of sophistication, it becomes stratified into specialized groups, allowing "leading specialists" to grab the reins of power and influence within the organization(Michels,1962:114; Marger,1981:71). This elite status allows members of the dominant stratum to "...control the training and recruitment process of future leaders, thereby creating a self-reproducing class"(Marger,1981:71), or stratum.

Michels' thesis also argues that non-elites tend to accept a social structure governed by a few, select persons. He states that the non-elites, or masses, are not qualified to rule themselves, as well as being indifferent to the stratified nature of their

community(Michels,1962:88; Marger,1981:71). As Michels states: "Though it grumbles occasionally, the majority is really delighted to find persons who will take the trouble to look after its affairs"(Michels,1962:88).

In essence, the indifference felt by the masses towards the elite, reinforces the social and political position of the elite. Indeed, given that the elites have access to information denied the masses, control of that information, a high degree of prestige and credibility within the community, ideological cohesion, and control of the recruitment and socialization of new elites, counter movements among the masses are easily subdued and contained(Marger,1981:72).

In addition, those who dare to challenge the hegemonic position of the dominant group are neutralized through a process of cooptation (Michels,1962:170; Marger,1981:72). That is, potential challengers are "brought into the fold", in a sense, their ideas tolerated to a certain degree by the elite; in specific cases, these non-elites are allowed to enter the privileged social realm of the elite and partake of its resources(Michels,1962:170; Marger,1981:72). This cooptation process is quite evident in the political community, when:

"...political 'outs' calling for change, often accuse the political 'ins' of enjoying sumptuous life-styles at tax-payers' expense but seem to take on similar life-styles when they become the 'ins'. The same kind of transformation, of course, occurs among neophyte officials of any organization, public or private"(Marger,1981:72).

Another theoretical principle embedded in Michels' elite model, is the notion that the elite, by definition, is a conservative entity. As Michels states:

"As soon as the new leaders have attained their ends, as soon as they have succeeded (in the name of the injured rights of the anonymous masses) in overthrowing the odious tyranny of their predecessors and in attaining to power in their turn, we see them undergo a transformation which renders them in every respect similar to the dethroned tyrants....The revolutionaries of today become the reactionaries of tomorrow"(Michels,1962:187).

The social explanation for the conservative ideology prevalent within the elite community rests upon the logic that over a period of time, elites become a vital, functional entity within the organization. Their specialized status acts as a social barrier between themselves and the non-elite masses, allowing them "...to pursue policies which stabilize or enhance their own power, not the collective interests of the organization(Marger,1981:73). Thus, elites have much to gain from the current arrangements of the social sphere, and forces which threaten to "rock the boat" are dealt with in a harsh manner(Michels,1962:187; Marger,1981:72-73; Higley et al.,1979:6). In effect, social movements which threaten the hegemony of elites, tend to increase the self-preservation instincts of the elite stratum. As Higley et al, state:

"...elites who are secure and who are able to exercise their power effectively are more likely to look after the interests of less powerful persons and groups than insecure and frustrated elites. This proposition embodies the axiom that ample psychic and social rewards, derived in this case from opportunities to wield power effectively, tend to reduce the predaciousness of personal behavior and increase its altruistic and benevolent character. One implication is that, by atomizing power concentrations, sweeping democratic and populist reforms tend to make elites more spiteful and violent towards each other and less benevolent towards non-elites. In this way, such reforms actually diminish the possibilities for democracy"(Higley et al.,1979:6).

In essence, explicit attempts to undermine elite hegemony will induce a radical, defensive and offensive strategy within the elite community. However, if the "boat" is not rocked by the winds of ideological reforms, then elites will be more "open-minded" to slight changes in their power base.

2.3 Contemporary Elite Theory

Modern conceptualizations of the elite model, while very similar to the classical framework, are founded on a different philosophical plane. Whereas classical theories tended to justify the division of society into elite/non-elite strata, contemporary elite theories view the masses as innocent victims of elite manipulation and control(Marger,1981:78). This theoretical model is known as radical elitism(Marger,1981:78).

Radical elitists, unlike their classical counterparts, argue that the emergence of an elite community is not an inevitable consequence of social evolution, but is grounded in the economic and political structures of the industrialized state(Marger,1981:79). In addition, according to the radical elite model, elites are primarily concerned with their own future and well being, indifferent to the masses they govern, and thus "...their actions therefore have a negative effect on the society; elite rule is not, as Pareto and Mosca contend, necessary and desirable"(Marger,1981:79).

Indeed, since elites are located in strategic positions within the corporate, government, academic, and mass communication realms, they are able to control and manipulate the flow of information, and thus, are fully capable of influencing public opinion(Marger,1981:79).

Radical elitists also conceptualize the elite stratum as being composed of a homogeneous group of persons with very similar social and economic backgrounds. While new members may be selected from the non-elite strata, they are, however, socialized in elite ideology and values. Through this social process, the elite entity is able to thrive and perpetuate for very long periods of time(Marger,1981:79).

While there exists numerous elite theories, all, really, variations on the same theme, this section will focus on the theoretical writings of

C. Wright Mills, whose definitive work The Power Elite (1956), became the catalyst to awakening social theorists to the structure of the elite community in the late twentieth century (Bottomore, 1993:22; Marger, 1981:79, 211).

In his now famous text The Power Elite (1956), Mills attempts to collate the social and political structures of three distinct elite communities: the business, political and military elites (Mills, 1956:18; Bottomore, 1993:26; Marger, 1981:211). He argues that it is in the realm of the above mentioned environments that key decisions and policies are formulated concerning the destiny of the nation (Mills, 1956:19; Bottomore, 1993:26; Marger, 1981:211). Indeed, through careful documentation, Mills identifies those individuals who are in a position to make key, strategic decisions concerning the future of the institutions they govern. For example, the executives in the corporate world, the President of the United States in the political realm, and the Joint Chiefs of Staff in the military sphere of activity (Mills, 1956:18; Bottomore, 1993:24; Marger, 1981:211-212). These individuals, Mills refers to as the power elite.

Now, given the variable nature of human perception, different elite scholars tend to operationalize the term elite in different ways; however, the variance in this conceptualization is small. Mills' own definition of the word elite, while unique, to an extent, bears similarities with those of other theorists:

"Accordingly, the problem of defining the power elite concerns the level at which we wish to draw the line. By lowering the line, we could define the elite out of existence; by raising it, we could make the elite a very small circle indeed. In a preliminary and minimum way, we draw the line crudely, in charcoal as it were: By the power elite, we refer to those political, economic, and military circles which as an intricate set of overlapping cliques share decisions having at least national consequences. In so far as national events are decided, the power elite are those who decide them"(Mills,1956:18).

Mills contends that the power elite is a socially homogeneous, cohesive entity(Mills,1956:283). Yet, despite their social and economic similarities, elite cohesion is facilitated by the fact that the various elite communities tend to "interlock", or merge with one another in specific social and political settings(Mills,1956:11,283). Indeed, as Mills states, "...no matter what else they may be, the people of these higher circles are involved in a set of overlapping 'crowds' and intricately connected 'cliques'(Mills,1956:11). The primary force which induces these interlocking alliances, is that the interests and well being of one elite community, complements the interests and well being of the other(Mills,1956:11; Marger,1981:212).

Mills' thesis also outlines the power structure of a stratified community. According to this model, power is located at the top of the social pyramid, a sub-elite located in the middle - much like Mosca's model - and the non-elite masses at the bottom(Mills,1956:245; Marger,1981:213).

In this conceptual reality, the balance of power exists with the middle stratum, or sub-elite. As such, the three strata are in a constant state of tension, and neither group can fully impose its will on the other at all times(Mills,1956:246-247).

While Mills emphasized the cohesive nature of elites as a social entity, even he acknowledged that no community is without ideological

variance(Mills,1956:280; Marger,1981:229). However, the differences of opinion and philosophical outlooks "...do not represent basic cleavages on matters which concern the essential nature of the political economy"(Marger,1981:231). Thus, while disagreements do take place within the elite stratum, these tensions do not represent tears in fundamental elite ideology or world view(Marger,1981:223).

In essence, Mills' analysis does not rest on psychological profiles like Pareto's, or the needs of the organization like Mosca's framework; though it does overlap significantly with Michels' cognitive outline. In essence, Mills argues that elite power in modern, industrialized states, is attached to key positions within organizations(Mills,1956:361; Marger,1981:213).

In sum, Mills' thesis conceptualizes the structure of power in American society - though his model can easily be generalized to any complex social entity - as follows:

'The top of modern American society is increasingly unified, and often seems willfully co-ordinated; at the top there has emerged an elite of power. The middle levels are a drifting set or stalemated, balancing forces: the middle does not link the bottom with the top. The bottom of this society is politically fragmented, and even as a passive fact, increasingly powerless: at the bottom there is emerging a mass society"(Mills,1956:324).

2.4 Elites and Class

So far in this document, a number of definitions have arisen concerning the term elite. Yet, the variance displayed in all these operationalizations is quite small, and it would be a matter of no great conceptual feat to draw the discursive threads from the various definitions of elite into a comprehensive accounting. Thus, let us say that by the elite we refer to individuals with the power, or capacity to affect the social, political and economic decisions of a community or organization(Higley et al.,1979:3). As well, the elite represents a set of uppermost positions within the reality of an organizational entity that is characterized by a stratified social structure(Clement,1975:5). In the words of Rupert Wilkinson, an elite is "a distinctive group holding high status in its community and knit together by a strong group feeling, ethos, and style(Wilkinson,1969:xiii). In essence, the presence of an elite implies that the financial and honorific awards of a community are distributed in a non-random, unequal fashion(Mulkay,1976:446). In addition, it is theorized that the social threads binding the members of an elite, are stronger and more tenacious than those which bind the elite with the non-elite masses(Mulkay,1976:446). The thesis also assumes that the power to control and direct the activities of others is intricately bound with membership within an elite culture(Mulkay,1976:447). The final assumption interwoven with the operationalization of an elite, argues that the elite have the ability to selectively recruit future members into its exclusive fold(Mulkay,1976:447).

The implication of this conceptualization is that, if a community or organization were structured on an egalitarian model, then the entity known as the elite would cease to exist(Clement,1975:5); yet, if the

composition of a community "...were sufficiently differentiated and hierarchically ordered, then a set of elite positions could be identified"(Clement,1975:5).

While these conditions specify the elite as a power group, it does not allow the elite to be viewed as a social group. In order for the elite to meet this criteria, its structure must be specified, and its members must interact with sufficient frequency that they can be described as displaying solidarity, cohesion, coordination, and consciousness of kind(Clement,1975:5).

In all the analyses presented on the elite model, the term class is, at times, integrated with the concept of elites. Yet, there is a subtle, but distinct difference between the two categories. In the first instance, class, in the Marxian sense, refers to those who control the means of production, whereas elites are those who hold key positions of power within organizational entities such as corporations, politics, and academia(Bottomore,1993:22; Higley et al.,1979:7). In addition, class interests lie in property ownership and connections with various definitive social classes. Elite interests revolve around preserving or extending power positions within organizational entities(Higley et al.,1979:7). Lastly, the final distinction between the terms elite and class:

"...is that elites are less committed to particular economic systems than are social classes. Elite power requires only the existence of large and complex organizations. Considered abstractly, it is of little consequence to elites whether these are capitalist, socialist, or a mixture of both. Elites are usually more interested in holding and extending their strategic organizational positions than they are in the social aims, such as greater liberty or equality, that particular economic varieties of organizations ostensibly serve"(Higley et al ,1979:8).

While it is true that elite and class positions tend to overlap

considerably in specific cases(Clement,1975:9; Higley et al.,1979:8), the class component becomes irrelevant when analyzing the social and political composition of organizations such as the Canadian Medical Association, or the College of Physicians and Surgeons. Doctors belonging to these institutions can be defined as representing a particular social class, but only physicians in administrative capacities within these institutions, can be referred to as elites, due to the executive powers that are attached to their strategic position within the organization.

2.5 Ideology and Hegemony

As we have seen, there are numerous variations on the elite model, its underlying structures moulded and shaped over the years by the winds of time and the academic hands of scholars. Yet, the differences displayed by the various elite paradigms are subtle, the multifarious images they adopt influenced mostly by philosophical and ideological beliefs. But if we were to step back from all the models so far displayed within this text, and gaze down upon the larger theoretical landscape, we would notice that all elite models postulate the same fundamental themes, weave the same discursive threads.

In essence, elite theories argue that in most social systems, a small group of individuals hold the reins of economic and political power, using their strategic positions within the community to their advantage.

Given this reality, it is a fair assumption to make that the elite constitute a hegemonic collectivity within a given social realm. The term hegemony simply refers to predominance, or domination; hence, the elite can be classified as a dominating entity within society, since the web of power and influence effectively emanates from their hands, permeating every strata within a community(Marger,1981:308). In a egalitarian society, all groups would have - theoretically - equal access to wealth and power, neutralizing the ability of any one group to dominate the other. However, since most human societies are characterized by a stratified social landscape, hegemony is elevated from the sphere of theoretical abstraction, into a pervasive force.

The concept of hegemony has been treated by numerous theorists over the years, but perhaps one particular scholar has done more work than any other at illuminating this intricate subject. That scholar is Antonio

Gramsci.

Gramsci argues that hegemony is intricately tied to the exercise of leadership, and that it is only through the effective emulation of leadership that power is eventually obtained (Gramsci, 1971:57; Perry, 1992:24-25). As Gramsci writes:

"A social group can, and indeed must, already exercise 'leadership' before winning governmental power (this indeed is one of the principal conditions for the winning of such power); it subsequently becomes dominant when it exercises power, but even if it holds it firmly in its grasp, it must continue to 'lead' as well" (Gramsci, 1971:57-58).

Indeed, political leadership becomes another manifestation of the shadow of domination, "...in as much the absorption of the enemies' élites means their...annihilation often for a very long time" (Gramsci, 1971:59). In this sense, hegemony is also intertwined with constructing a union of political and economic objectives, in time merging with a unified intellectual and moral entity (Gramsci, 1971:181-182; Perry, 1992:25). Throughout his analysis, Gramsci traces the threads of hegemonic discourse to illustrate how the non-elite masses are socialized into accepting a social system which, in essence, ignores their presence, bestowing all of society's rewards upon the elite stratum (Gramsci, 1971:181-182).

Indeed, hegemony is effective because it cloaks the interests of the elite as that of the non-elite community, articulating the will of the people as its own (Gramsci, 1971:181-182; Perry, 1992:25). Yet, hegemony's adaptive nature lies, in part, in accepting the demands of the subordinate groups within society. In this way, consent for the prevailing power structures is generated since the non-elite masses feel that they are effectively negotiating the system, participating in the social arena as empowered citizens (Gramsci, 1971:160-161; Perry, 1992:25-26). Indeed, Gramsci argues that:

"...hegemony presupposes that account be taken of the interests and the tendencies of the groups over which hegemony is to be exercised, and that a certain compromise equilibrium should be formed - in other words, that the leading group should make sacrifices of an economic-corporate kind. But there is no doubt that such sacrifices and such a compromise cannot touch the essential; for though hegemony is ethical-political, it must be economic, must necessarily be based on decisive function exercised by the leading group in the decisive nucleus of economic activity"(Gramsci,1971:161).

In this sense, hegemony is not a force imposed from on high, but is an entity negotiated within the intricate terrain of the social pyramid(Gramsci,1971:161,181-182; Perry,1992:26).

Yet, despite its adaptive qualities, hegemony is not an absolute force, but a shadow often swayed by the winds of philosophical beliefs emanating from the subordinate masses, ever susceptible to the threat of counter-ideologies(Gramsci,1971:80,183). Thus, hegemony is always in a constant state of tension, negotiating its passage between the twin towers of force and consent(Gramsci,1971:80,183; Perry,1992:27). That is:

"The 'normal' exercise of hegemony on the now classical terrain of the parliamentary régime is characterised by the combination of force and consent, which balance each other reciprocally, without force predominating excessively over consent"(Gramsci,1971:80).

In actual practice, hegemony is articulated through the social instrument of ideology. While Gramsci does not deal with ideology in any systematic fashion, his analysis of ideology is intricately woven with his theoretical work on hegemony(Perry,1992:29).

The term ideology can take on various "masks" depending on the context in which it is used. According to Marger:

"An ideology is an explanation of how and why a socio-political system works as it does, as well as a justification for that system. Most simply, it is a set of beliefs and values which rationalizes a society's structure of power and privilege.

"That ideology which explains and justifies the status quo - that is, the prevailing power and reward structures - is called the dominant ideology"(Marger,1981:307).

Yet, an ideology can also be conceptualized as a

"...framework of assumptions, ideas and values incorporated into the perspective an individual or collective uses to guide analyses, interests and commitments into a system of meaning"(Clement,1975:270).

In essence, an ideology is a conceptual map an individual or a group employs to understand and collate the nature of the social - or physical - world. Given its very human structures, ideologies are easily influenced by bias, and social and political forces. As such, an ideology is far from being an objective measure of reality.

From the vantage point of history, ideologies were employed by elites to justify their preeminent status in society relative to the non-elite masses(Higley et al.,1979:165; Marger,1981:307; Clement,1975:271). Ideologies, thus, justifies and rationalizes the stratified social nature of a given community(Marger,1981:307). Ideologies are, in essence, a system of beliefs "...promoted by and reflect the interests of particular groups within society"(Clement,1975:271), particularly the interests of the elite collective. Yet, the question arises, how does elite ideology perpetuate itself, generation after generation? One possible answer lies in its theoretical nature.

In contrast to Marxists notions of ideology, elite theorists do not conceptualize ideology as 'false consciousness'; nor do they view ideology as a cloak of illusion crafted by the elite community to distort non-elite perceptions of the social world. Indeed, Gramsci argues that the Marxist notion of ideology is not an accurate explanation of the workings of the social realm. He states that:

"The claim, presented as an essential postulate of historical materialism, that every fluctuation of politics and ideology can be presented and expounded as an immediate expression of the structure, must be contested in theory as primitive infantilism, and combated in practice..."(Gramsci,1971:407).

Thus, we must view ideology as an entity that is constantly being wrought and moulded through elite/non-elite negotiation(Gramsci,1971:377; Perry,1992:29). Thus, ideology is a presence that emerges and is given life by the social landscape, in time permeating human interactions "...which in turn provide a system of explanation and orientation which directs the activities of people"(Clement,1975:271).

If ideology can be viewed as a terrain upon which social contests are waged, then it is clear that ideology is not a cohesive, monolithic entity to which all members of a community pledge allegiance. In essence, ideology can be conceptualized as social "threads", constantly engaged in weaving a particular image or tapestry, the designs it constructs, changing in rhythm to the elements striking its tenuous form(Perry,1992:30).

Indeed, the non-static nature of ideologies explains its ability to change and transform over time. This metamorphosis is linked to the shifting social backgrounds of those communities which are the carriers of specific philosophical discourse(Clement,1975:271). In this way, one can theorize that:

"...ideologies arise and are formed in groups both on the basis of the situations into which they are born, and the experiences they accumulate within a given social order"(Clement,1975:271).

In essence, the argument is that ideology cannot be traced to a single, solitary social pool, for its actions do not manifest themselves in a linear, rational manner, but in a non-linear, chaotic fashion(Perry,1992:30). Indeed, Therborn argues that ideology is "...better illustrated by the cacophony of the sounds and signs of a big

city street than by the text serenely communicating with a solitary reader"(Therborn,1980:vii-viii).

As such, a particular ideology is correlated with a specific collectivity only through actual social practice. In time, specific ideologies coalesce within specialized communities or institutions, such as the political sphere, the mass media, and the military(Clement,1975:271-272; Perry,1992:30).

In his now famous text, The Canadian Corporate Elite, Clement nicely summarizes the nature of ideology:

"Ideologies represent an interdependent set of ideas which become embodied in various social groups arising out of their 'locations' and serve to defend, orient and direct the interests and actions of these groups"(Clement,1975:272).

2.6 The Matthew Effect

In 1968, Robert K. Merton of Columbia University argued that in the physical sciences, financial and honorific awards are not distributed evenly among scientists. Instead, researchers of high visibility and eminence tend to receive a disproportionate share of their respective community's attention (Merton, 1968:56; Cole, 1970; Duncan, 1974:110). Merton dubbed this social phenomenon the 'Matthew effect', in honour of the Gospel According to Matthew which states, "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath" (Merton, 1968:58).

In pragmatic terms, the 'Matthew effect' postulates a dubious phenomenon in science, a phenomenon in which credit for a scientific breakthrough, or discovery "...tends to go to the most famous researcher associated with it rather than to the most deserving one" (Gibbs, 1995:98). Indeed, the most deserving researcher might be an unknown graduate student working under a famous professor; the graduate student performs all the messy experimentations and calculations, discovers a unique phenomenon in the midst of the computations, and then gives the results to his or her mentor, who subsequently publishes the results and receives most of the academic spotlight (Gibbs, 1995:98-99). As one physicist stated, "The world is peculiar in this matter of how it gives credit. It tends to give the credit to [already] famous people" (Merton, 1968:57).

This form of honorific stratification is troubling, considering the fact that many scientists who have been denied eminent awards such as the Nobel prize, have contributed as much to their chosen field as some of their famous colleagues (Merton, 1968:56). Indeed, a paper published by Diane Crane in 1965 argued that, highly productive scientists at an

eminent institution tended to gain more scholarly recognition for their work than equally productive researchers at a non-prestigious institution(Crane,1965:699-714; Merton,1968:56).

The implications of the 'Matthew effect' are wide ranging. In the first instance, it affects the communication process of science, allowing the research of esteemed scientists to grow in recognition and academic visibility at the expense of lesser known colleagues of equal intellectual caliber. In pragmatic terms, this means that the research of famous scientists will be cited more often than their humble counterparts; this practice is in itself of no small significance, for citations represent the most basic form of scientific acknowledgement and respect(Merton,1968:62; Gibbs,1995:98).

In essence, the 'Matthew effect' facilitates the channelling of information and financial resources to elite scientists, allowing these scholars the luxury of pursuing promising avenues of research that might be beyond the monetary resources of their less esteemed colleagues, research that might, in all probability, bear fruit at some time in the future and further enhance the reputation of an already famous scientist(Duncan,1974:110). As Merton states, "The scientist's peers and other associates regard each of his [sic] scientific achievements as only the prelude to new and greater achievements"(Merton,1968:57).

A further consequence of the 'Matthew effect' is that it delegates to elite researchers the power to establish the norms and values within a specific field, norms and values that ultimately govern scientific research. These norms define what is considered acceptable avenues of research; what problems are worth pursuing. In effect, these norms and values represent the rules of the scholarly community, rules a young

researcher must follow if he or she wishes to climb the stratified social pyramid(Merton,1968:60).

As such, these normative prescriptions facilitate the establishment of an orthodox environment, and act as an obstacle to new ideas and ways of knowing. The social resistance to radical views is especially strong if it emanates from researchers who possess little prestige or visibility in the scholarly community(Duncan,1974:130).

In essence, the 'Matthew effect' is a specific manifestation of the elite model, as indicated earlier in this document. Like the elite model, the 'Matthew effect' acknowledges the empirical reality that societies - whether they be nation-states, organizations, or highly specialized communities - are stratified into elite and non-elite factions, separated by a social, economic and political barrier that is both intangible and invisible, yet, is very real.

While Merton composed the 'Matthew effect' independent of the elite model - he meant it to be a paradigm with which to study the socio-political structure of the natural sciences - it resonates nicely with elite theory, and overlaps considerably on a number of conceptual points. This is not surprising since both frameworks were initially constructed to study structural inequality, albeit in different contexts; elite theory represents a general theory of human communities, whereas the 'Matthew effect' is a socio-political model of the physical sciences.

In the context of this thesis, the 'Matthew effect' will be viewed as a specific hypothesis derived from the more general framework of elite theory. It will represent a focused, testable question with which to explore the social and political environment of theoretical cosmology.

2.7 The Kuhnian Thesis

While Robert Merton's 'Matthew effect' addressed the intellectual and financial stratification inherent within science, it did not discuss, in any explicit sense, the complex cultural and political terrain upon which science is conducted.

An analysis of the manifestation of political and ideological will within the seemingly objective realm of the physical sciences, can be found within the Kuhnian thesis of scientific evolution and change. While Kuhn did not explicitly analyze the twin concepts of politics and ideology, these theoretical constructs are very clearly articulated in his scholarly writings on scientific revolutions(Duncan,1974; Stewart,1986).

Kuhn's concept of scientific change, and the social and cultural forces that act as a catalyst for that change, drew the wrath of scientists when he first published his thoughts in 1962, and the debates that emerged about the Kuhnian model over thirty years ago, continues to this day, as volatile and explosive as ever(Gleick,1987:36).

Kuhn challenged the traditional image of science as a linear phenomenon, an objective practice by which knowledge was accrued through the steady accumulation of facts and figures, and theoretical models(Gleick,1987:36). For Kuhn, science was not a logical, impartial process, but an entity often swayed by human bias and personal beliefs(Kuhn,1970:2; Gleick,1987:36). He represented science as a dichotomous being; for the most part, science consisted of researchers pursuing legitimate, traditional problems within their field of specialization: tidying up a cumbersome theory through mathematical juggling, or refining a potentially important experiment; then there are the rebels, researchers who willingly take academic risks, scientists

bold enough to plunge into the chaotic pools of unorthodox research where new discoveries are inevitably made(Kuhn,1970:6-7; Gleick,1987:36). As James Gleick writes, "Not by accident, he made scientists seem less than perfect rationalists"(Gleick,1987:36).

For Kuhn, normal science consists largely of fleshing out details, pursuing problems whose outcomes are predicted by a relatively complete body of theory; surprises are not expected in this mode of investigation. In essence, normal science entails the monotonous, day-to-day ritual of conducting modified versions of experiments that have a long, and distinguished pedigree; it implies the mopping up of operations, an activity that engages the attention of most scientists throughout their academic careers(Kuhn,1970:24; Gleick,1987:36). As Kuhn states:

"The success of a paradigm - whether Aristotle's analysis of motion, Ptolemy's computations of planetary position, Lavoisier's application of the balance, or Maxwell's mathematization of the electromagnetic field - is at the start largely a promise of success discoverable in selected and still incomplete examples. Normal science consists in the actualization of that promise, an actualization achieved by extending the knowledge of those facts that the paradigm displays as particularly revealing, by increasing the extent of the match between those facts and the paradigm's predictions, and by further articulation of the paradigm itself"(Kuhn,1970:24).

The fact that science is so worked into a ritualistic pattern of activity, is not too surprising. If every scientist were to question the fundamental assumptions of cherished theories, trying to explain observational evidence from first principles, they would never be able to pursue pragmatic avenues of research(Gleick,1987:36). As such, all scientists in their respective fields, are socialized into their disciplines' theories, mathematical techniques, and terminology. By adopting the norms of their academic community, scientists, in effect, give up the reins of freedom to question the foundations and beliefs of their community(Gleick,1987:36).

In the Kuhnian tale, normal science is essentially concerned with problem solving, solving the kinds of problems first year physics students encounter in lectures, or on an examination(Kuhn,1970:36; Gleick,1987:36-37). The ability to solve mathematical problems of the physical world is a skill that is considered vital in the realm of science - especially, in a field such as physics; a skill that is continually refined throughout a scientist's educational and academic tenure. As Kuhn states:

"Under normal conditions the research scientist is not an innovator but a solver of puzzles, and the puzzles upon which he concentrates are just those which he believes can be both stated and solved within the existing scientific tradition"(Kuhn,1977:234).

The winds of normal science flow across the academic terrain for generations, until there arises a conceptual revolution, a dramatic metamorphosis in the theoretical lens through which the physical world is observed(Kuhn,1970:67,111; Gleick,1987:37). This cognitive transformation arises out of the shadow of incongruity and confusion, when nature behaves in a way contrary to traditional beliefs (Kuhn,1970:63-64; Gleick,1987:35-36). Revolutions are born in the minds of researchers venturing beyond the conceptual parameters of their specialties, scientists so new to the field in question that they have very little investment in the traditional, dominant world view articulated by the old paradigm(Kuhn,1970:144; Gleick,1987:37). This marginal group of intrepid scholars are frowned upon by the majority of their peers, their unorthodox questions brushed aside, their daring views labelled as nonsense. Thesis proposals are refused the academic stamp of legitimacy, journal articles banished to the dark recesses of drawers and cabinets because of editorial hostility or indifference(Kuhn,1970:144; Gleick,1987:37).

Kuhn's vision of the social forces underlying scientific evolution, at times, resonates with all the adventure and excitement of a mythical tale. Yet, what Kuhn describes is not a fictional account, but an honest representation of how science is really done. As Gleick states, describing the scientific rebels that compose the infantry of Kuhn's revolutions:

"A few freethinkers working alone, unable to explain where they are heading, afraid even to tell their colleagues what they are doing - that romantic image lies at the heart of Kuhn's scheme, and it has occurred in real life, time and time again..."(Gleick,1987:37).

In times of paradigmatic crisis, when nature behaves in a fashion that stains the credibility of a dominant theory, a marginal group of intrepid souls usually venture into the academic light from the shadows of obscurity, holding in their minds a model they claim can do a better task at explaining the observational evidence(Kuhn,1970:144). In their hearts, they believe that a radical approach is the only avenue to melting the shadow of chaos, and reasserting the comforting presence of order once again. But, like most rebels, these researchers are looked down upon by their peers, surrounded by a sea of hostility that is forever shielded from sight, but can be felt like a fierce breeze. These lonely scientists realize that empirical evidence alone cannot, and will not, convert their enemies to their world view. As Kuhn states, "The competition between paradigms is not the sort of battle that can be resolved by proofs"(Kuhn,1970:148).

At the heart of Kuhn's thesis is the controversial argument that facts - empirical observations - alone cannot sway an opponent, for the very reason that 'facts' are, to an extent, subjective. That is, what is considered a fact "...depends to a large degree on one's accepted paradigm"(Stewart,1986:263). Thus, scientific progress is dependent on

the currents of ideology and time - perhaps time most of all, time for a new candidate for paradigm to gain supporters, to evolve in mathematical and theoretical rigor; time for nature to judge its newest admirer(Kuhn,1970:158-159). In essence, while experimental evidence is a powerful force in swaying scientific opinion, empirical results alone cannot wash away the convictions and beliefs of a scientist, beliefs that have been moulded and chiseled by decades of scientific practice and allegiance to a specific model. That is:

"Practicing in different worlds, the two groups of scientists see different things when they look from the same point in the same direction. Again, that is not to say that they can see anything they please. Both are looking at the world, and what they look at has not changed. But in some areas they see different things, and they see them in different relations one to another. That is why a law that cannot even be demonstrated to one group of scientists may occasionally seem intuitively obvious to another"(Kuhn,1970:150).

The melting away of a researcher's commitment to one paradigm, and the acceptance of another, is an arduous and very personal process, in many cases requiring the passage of decades. It is true that, like in any social group, new ideas are embraced more readily by some rather than others. Indeed, throughout his thesis, Kuhn emphasizes the notion that the young, and those new to a specialty, are more willing to accept an unorthodox theory because they have so little investment in the traditional one(Kuhn,1970:151-152; Stewart,1986:263). In fact, not only are the young and new scientists more willing to adopt a radical model, they are as equally likely to develop new theories and models(Stewart,1986:263).

In essence, Kuhn implies that scientists adhere to models that serve their ideological interests, as opposed to those that do a better task at explaining the fundamental mechanics of the physical world(Kuhn,1970:151; Stewart,1986:263). As Stewart writes, personal interests "...are

represented by desires to protect one's previous intellectual contributions or even to use theories compatible with one's social beliefs..."(Stewart,1986:263).

Indeed, the incredible resistance to paradigmatic change and evolution have been remarked upon by practicing scientists themselves, scientists who, for one brief instant, were able to step outside the narrow parameters of their respective discipline, and view the scientific enterprise as a very human endeavor(Kuhn,1970:151). For example, the words of Charles Darwin, reached across the expanse of time, to echo Kuhn's own arguments about scientific change:

"Although I am fully convinced of the truth of the views given in this volume..., I by no means expect to convince experienced naturalists whose minds are stocked with a multitude of facts all viewed, during a long course of years, from a point of view directly opposite to mine....[B]ut I look with confidence to the future, - to young and rising naturalists, who will be able to view both sides of the question with impartiality"(Darwin,1889:295-296).

Perhaps one of the most eloquent commentators on the social and ideological nature of science, and scientific theories, was Max Planck, a physicist endowed with unparalleled genius and imagination, who won the Nobel Prize for physics, and who was one of the founding fathers of quantum mechanics, wrote:

"a new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it"(Planck,1949:33-34).

In sum, Kuhn's model is more than just an abstract, theoretical argument; it is a story of science that resonates with the lived experiences of many of history's great scientists, and represents the human factor in scientific evolution and change.

Chapter 3 Analytical Framework: The Model and the Methodology

3.1 The Model

The elite model represents a powerful, cognitive tool through which one can observe and collate the complex tapestry of human social systems. Specifically, it is an abstract attempt to understand the highly stratified nature of the western, industrialized nation-state. It imagines that the skewed distribution of power and wealth characteristic of so many socio-political systems, is a phenomenon that replicates itself at all scales of the social pyramid; that is, the stratified structure of a political entity such as a nation, is itself composed of smaller, yet distinct communities of inequality. This assumption, the assumption that human beings weave and thrive in a social sphere that is highly fractured along socio-economic and socio-political boundaries, turns out to be one cloaked in empirical garb, rather than unsubstantiated conjecture. As any elite theorist would proclaim, a journey through the finer and finer scales of the intangible threads composing the substance of the social terrain, reveals that the complex web of stratification does not melt into the theoretical background at increased levels of magnification, but continues to thrive, an orderly shadow in the chaotic waters of human behavior.

In contrast to the elite paradigm, Kuhn's thesis is a conceptual painting of scientific evolution, of the social and political forces that emerge from the dark recesses of ideology, and manifest themselves with astonishing force in times of paradigmatic crisis. Kuhn's is a highly focused analysis of a social group, and while he does not talk in explicit terms of the socio-political winds resonating within the chambers of science during periods of vigorous debate and controversy, it is, nevertheless, implied in his analysis of the scientific community.

Indeed, as Kuhn states:

"To one last reaction to this book, my answer must be of a different sort. A number of those who have taken pleasure from it have done so less because it illuminates science than because they read its main theses as applicable to many other fields as well. I see what they mean and would not like to discourage their attempts to extend the position, but their reaction has nevertheless puzzled me. To the extent that the book portrays scientific development as a succession of tradition-bound periods punctuated by non-cumulative breaks, its theses are undoubtedly of wide applicability. But they should be, for they are borrowed from other fields. Historians of literature, of music, of the arts, **of political development**, and many other human activities have long described their subjects in the same way"(Kuhn,1970:208; emphasis added).

To the extent that Kuhn acknowledges the works of theorists in other fields - particularly, the analytical models wrought in the realm of political studies - it is no wonder that the Kuhnian thesis of scientific resistance and change mirrors those found within the context of the elite framework. Indeed, it would be no great conceptual feat to argue that the Elite and Kuhnian paradigms, in essence, represent two sides of the same proverbial coin. As such, the pools of light they cast upon the intricate mechanics of social systems, merge and melt into one another at numerous conceptual points. Thus, it seems reasonable to articulate the logic that the two models effectively map specialized manifestations of the same social phenomenon. Given this assumption, the discursive threads composing both representations of the social terrain, can be easily woven into a comprehensive pattern - an abstract illustration - that can act as a reasonable guide for the analysis that is to follow. For the sake of identification, let us christen this amalgamated paradigm the Elite-Kuhnian model.

I identify 10 critical propositions of the Elite-Kuhnian model which constitutes the conceptual framework for my analysis of the current paradigmatic debate encircling the Big Bang model of the origin of the

universe. In specific terms, the Elite-Kuhnian model predicts the following characteristics of any complex, social system, and of a scientific community entangled in the web of ideological debate, and faced with a paradigmatic threat which challenges the community's traditional theoretical model, and conceptualizations of the physical world(Perry,1992:37):

1. any social system characterized by organizational complexity will contain an elite and non-elite strata;
2. an elite refers to individuals holding the top positions of power and influence within a social community characterized by a definitive hierarchial structure. Power in this context refers to the ability to affect and influence communal decisions and ideology;
3. as a social unit, elites exhibit coordination, cohesiveness, consciousness of kind, and command social prestige;
4. elites are characterized by a high degree of intellectual specialization which encourages the formation of an orthodox ideology;
5. elite communities do not exist in a social vacuum, but tend to overlap, linked by common needs and interests;
6. in times of paradigmatic and philosophical crises, a non-elite group of researchers will emerge to challenge the dominant, communal world view;
7. the ideas put forth by this marginal group of scientists, are frowned upon by the elite traditionalists, their unorthodox views encountering a wall of ferocious resistance, the paths available to them to communicate their idea, few or non-existent;
8. this academic hostility is the product of viewing the physical world from two different cognitive communities, each influenced by a specific ideology;

9. related to this, the hostility bestowed upon a marginal model is born of scholarly investment; that is, younger scientists or those who have recently entered a specialized field from another academic discipline, are more likely to adopt an unorthodox paradigm because they have little or no intellectual investment in the traditional one, as compared with their more eminent colleagues; they are also more likely to develop new paradigms that contradict the orthodox model;

10. in paradigmatic debates, it is extremely difficult for the unrecognized group of researchers to convert their elite counterparts solely on the basis of empirical evidence. The conversion of the traditionalists to a new paradigm, to a new way of seeing the physical realm, is an incredibly arduous process whose resolution may take generations.

In essence, I will argue in this thesis that the resistance facing alternative cosmological models concerning the origin of the universe - specifically, the plasma paradigm - is a resistance that can best be comprehended within the context of the Elite-Kuhnian model. The current ideological and philosophical battle between the pro and anti-Big Bang forces, resonates with past paradigmatic debates within the physical sciences, debates that have been carefully documented by the pages of history and the passage of time[¶]. In effect, the Elite-Kuhnian framework illuminates the reality that "...science as a field does not progress in a uniquely rational manner different from other fields of human endeavor..."(Crichton,1987:358).

[¶] (Reference: Perry,1992:38).

3.2 Methodological Outline

Science is a phenomenon guided by theoretical constructs, abstract representations that are - consciously or unconsciously - at times, looked upon by the physical scientist not as crude approximations of reality, but as an entity that represents the "truth" about a particular phenomenon. Indeed, throughout the history of science, theories have enjoyed a privileged position within the realm of scientific investigation. Yet, many people seem to forget that theories are constructions of the human mind, and as such, can never represent a truly objective statement on the physical or social world. As Crichton states, "Science offers a picture of the world, but its picture is not to be confused with the underlying reality itself"(Crichton,1987:363).

While theories in the natural sciences have the luxury of being represented in highly technical mathematical forms, and tested within the carefully controlled environment of a laboratory, social theories are denied such luxuries. As such, social scientific theories are far more susceptible to ideological influences than their physical science counterparts. Nevertheless, despite this vulnerability, social theories allow us to shed some light - however small - upon the very complex pattern that is human behavior and social interaction.

In the wake of the above comments, I now wish to address the body of empirical evidence I will draw upon to test the predictions of the Elite-Kuhnian model. Since the objective of this study is to analyze the social and political structure of the cosmological community, and the current philosophical and ideological battles being waged over the Big Bang paradigm, I have had to investigate a literature encompassing both the social and natural sciences. This multi-dimensional approach, I hope,

will enable me to draw a fair representation of the social realm in which cosmological research is conducted.[¶]

Since I have proposed to analyze the cultural landscape in which cosmological research is practiced, I have had to draw upon a wide spectrum of empirical indicators. Specifically, I require indicators documenting the stratified structure of the scientific community as a whole, not solely the cosmological community which is just one specialized social entity among the many that exist under the vast canopy known as science. In light of this quantitative requirement, I have drawn upon, and reviewed as thoroughly as possible, financial and statistical data published by the United States Government, and the scientific community's main funding agency the National Science Foundation. Specifically, I have focused upon the following public publications and documents:[¶]

I

Impact of Federal Research and Development Programs, Study No. 6, report of the Select Committee on Government Research, House of Representatives, 1964.

II

National Science Foundation: A General Review of its First 15 Years: Report, 89th Congress, 2nd Session, 1966. United States. Congress. House. Committee on Science and Astronautics. Washington, USGPO. 1966.

III

Schaffter, Dorothy
1969 National Science Foundation.

[¶](Reference: Perry, 1992:16).

IV

National Science Foundation authorization, 1971:
hearings, 91st Congress, 2nd Session, on H.R. 15696,
superseded by H.R. 16595, 1970. United States. Congress.
House. Committee on Science and Astronautics. 1970.

V

National Science Foundation authorization, 1976:
United States. Congress. House. Committee on Science and Technology.
Washington, D.C., 1975.

VI

National Science and Technology Policy Issues 1979: pt. 1:
a compendium of papers: United States. Congress. House. Committee on
Science and Technology. Washington, D.C., 1979.

VII

National Science and Tecinology Policy Issues 1979: pt. 2:
implementation of the national science policy Act: United States.
Congress. House. Committee on Science and Technology.
Washington D.C., 1979.

In addition, to support my argument that the scientific community is stratified along social and political lines, I employ secondary sources which have analyzed these issues in great detail. Specifically, I rely on the highly quantitative and statistical analyses offered by Amick (1974), Cole & Cole (1967; 1970; 1973), Cole (1992), Barber (1961), Crane (1965), Gaston (1970), Gray (1961), Holland (1957), Mulkay(1976; 1980), and Zuckerman (1962; 1967a; 1967b; 1970).¶

To support my argument that the Big Bang paradigm enjoys a dominant position within the astrophysics community, I analyze its representation within certain scientific journals. The selection of these periodicals were constrained by the following methodological approach: According to

¶ (Reference: Perry, 1992:19-20).

Carleton University's on-line database, the University has approximately one million bibliographic records, and over one million inventory records. Based on this information, it was assumed that Carleton's selection of scientific journals would be fairly representative of the kinds of journals published by the global scientific community. Therefore, using the CUBE bibliographic database, titles for all the multi-disciplinary science, physics, and astrophysics journals were obtained. This primary list contained 199 journals. In order to produce a manageable number of journals, only those periodicals published in North America and Europe were transferred to the secondary list. Then, using the Current Contents database, the remaining journals were reviewed as to their contents, to ascertain whether they published topics in cosmological issues. Every journal was reviewed as thoroughly as possible. In the end, 24 journals that explicitly dealt with cosmological topics, were selected for the master list.

Since the main goal of this analysis is to observe how the Big Bang theory is treated in prestigious and non-prestigious journals, the 24 journals were ranked according to their relative standing within the scientific community. In order to rank the final group of periodicals, I have drawn on information contained within the pages of the 1993 JOURNAL CITATION REPORTS. The JCR, in effect, computes how many times a particular journal was cited in a given year. Given the fact that the JCR "...reports current information on nearly 6,000 of the world's leading journals"(JCR,1993:5), it is the most comprehensive guide to scientific information available. Using the 1993 JCR, each of the 24 journals were recorded with their respective citation rates for 1993. Then, the journals were grouped into three distinct categories based on their individual citation figures; these categories were then labelled,

prestigious, semi-prestigious, and non-prestigious journals, respectively.¶

In most similar analyses, researchers usually compare the highest and lowest cited journals, but that approach was not possible here. In our sample, certain journals had citation rates that were too high for them to be placed in the non-prestigious category; similarly, these same periodicals had citation rates that were low enough that they were effectively excluded from the ranks of the prestigious journals. Hence, it was decided to construct a third category for those journals whose citation rates fell between the two extreme groups.

After all the journals were assigned to one of the three categories, three of the highest cited journals in the prestigious and semi-prestigious categories, and three of the most poorly cited journals in the non-prestigious category, were surveyed.¶

Now, the question becomes, what was surveyed? All research articles, essays and news concerning scientific research were included in the survey. Editorials, book reviews, and letters written by readers of a particular journal, expressing an opinion, or defending the contents of a research paper, were excluded from the survey, as were sections dealing with factual errors.

Since the purpose of this survey is to describe the distribution of pro and anti-Big Bang articles within the periodicals, the terms pro and anti-big Bang, must be clarified*. A pro-Big Bang article is one that explicitly supports the Big Bang paradigm, or employs it in the scope of cosmological research without questioning its theoretical assumptions. An anti-Big Bang article is an article that explicitly rejects, or

* Examples can be seen on page 226.

¶ Please refer to Appendix B for the operational definitions of these terms.

questions, the validity of the Big Bang model. Finally, there are those articles which do not take an explicit academic stand on the Big Bang theory; these articles tend to compare the Big Bang with other cosmological frameworks, citing the strengths and flaws of the various theories dealing with the origin of the universe. In the case of such balanced accounts, the respective articles will be labelled as inconclusive.

The survey of the selected journals was non-random, commencing in 1989 and proceeding in chronological fashion to 1994. The reason for this strategy is not wholly arbitrary.

In late 1989, NASA launched the \$150 million dollar COBE (Cosmic Background Explorer) satellite, a satellite whose primary task was to measure the cosmic background radiation to an incredibly high degree of accuracy, searching for infinitesimally small fluctuation in this radiation, fluctuations that would solidify the Big Bang's theoretical reputation within the astrophysics community - and in the physics community as a whole. Thus, 1989 was a time when the Big Bang was on everyone's mind - on the minds of those who had invested a great deal of their intellectual resources into the theory, and for those who were harsh critics of the model. Thus, it was decided that a survey beginning in January 1989 to December 1994, would illuminate, however small, the ideological debates being waged within astrophysics over the Big Bang paradigm.

It should be noted that the final list of 24 journals, and their subsequent division into the various stratified categories, can be seen in Appendix B.

At this point in the discussion, I would like to make a few comments on the use of citation records. While the use of citations to assign rankings to academic journals is controversial, there is some validity to the argument that states that highly respected journals - those publications

perceived by scientists as important arenas of scholarly communication - will be cited and referenced more often than non-prestigious publications.

Furthermore, as it pertains to this document, it would have been convenient to have done a random survey of the 24 periodicals' citation rates over a broad period of time, so as to construct a mathematical average citation rate with its associated error bar, for each journal. Unfortunately, only the most recent JCR document is kept at Carleton University, and inquiries into other universities proved to be a fruitless effort.

Yet, despite this setback, the use of the 1993 JCR database permits us to construct an approximate ranking - however crude - for the various journals. Indeed, it can be argued that the prestigious journals have established a faithful following over their many decades of existence, attracting the cream of the scientific crop. In addition, it can be argued that because of this loyal cohort of researchers, the citation rates of the prestigious publications have not displayed extreme levels of statistical variance over their scholarly careers.

To test the contention that scientists' receptivity to new theories is influenced by the amount of intellectual investment they have placed in the traditional model, a sample of eminent cosmologists was surveyed*. This sample was constructed by first compiling an extensive bibliography of research publications in the field of cosmology. This bibliography was amassed with the help of the following sources: (a) Astronomy and Astrophysics, a bibliographic guide by D.A. Kemp (1970); (b) Bibliography of Astronomy, 1970-1979 by Robert A. Seal and Sarah S. Martin (1982); and (c) A Guide to the Literature of Astronomy by Robert A. Seal (1977). In all the above references, the sample was constructed based on scientists

* Please see page 226, Appendix C.

recorded under the headings of Theoretical Astrophysics and Cosmology.

The scientists chosen were those whose names predominated the literature in the fields of cosmology and theoretical astrophysics. Furthermore, my selection of these cosmologists was also influenced by a certain degree of subjectivity. As a former student of physics and astronomy, I was well aware of the physicists who had acquired a high level of distinction within the field, and whose work was frequently cited within the literature. As such, my sample of scientists is not representative of all eminent astrophysicists, or pro-Big Bang supporters. However, it is heavily weighted towards the more famous and celebrated physicists who are alive today, and conducting research in astrophysical issues - specifically, those whose specialty is the Big Bang theory.

In addition, the sample was quite small - 4 of the most celebrated researchers were chosen - namely because I was cognizant of time and did not want to turn this one empirical indicator into another thesis, which it was in danger of becoming; another reason for the limitation rests on the fact that each of these cosmologists made explicit comments supporting the Big Bang paradigm, and were quite disparaging of its competitors.

In order to obtain an approximate picture of the publication history of the pro-Big Bang researchers, a random survey was conducted of Physics Abstracts, specifically the Author Index of Physics Abstracts; the Author Index lists all the works that a scientist has published in a given year, with a brief description of each publication, and cross-indexed to the Subject Index, and the main collection of abstracts.

Since this abstracts publication is the most comprehensive repository of scholarly research conducted in all areas of physics, and

since the information contained in this database is "...derived from a wide range of sources including journals, reports, books, dissertations and conference papers published in all countries and languages of the world"(Physics Abstracts,1995), it seems a reasonable tool with which to measure a scientists research productivity.

Carleton University's collection of Physics Abstracts extends from 1907 to September 1995. For pragmatic reasons, this population had to be narrowed considerably. Since some of the most distinguished cosmologists working today, were not born until late in the twentieth century, and in some cases, were humble graduate students in the late 1960s, it was decided that our population parameters would commence from the year 1970 when these students had long since earned their PH.D's and were actively engaged in academic research. Thus, I surveyed Physics Abstracts from 1970 to 1994, the most recent year when all the abstract publications were available.

In the survey, each year from 1970 to 1994 was given an index number from 01 to 25. Then, using a table of random numbers located in Appendix C of the text UNDERSTANDING DATA (1992) by B.H. Erickson and T.A. Nosanchuk, a random sample of 10 years was selected. The random years were chosen by starting at the upper top left hand "cell" of random numbers, and reading the "cell" from left to right. At the end of the first line, the second row in the "cell" was read, once again, from left to right. This procedure was repeated, down the left hand column of "cells", until 10 random numbers were generated that corresponded to the population year 1970-1994. Since this was sampling without replacement, a year that had already been selected was ignored.

The population of years selected for this analysis, and the random years surveyed, can be seen in Appendix C.

In order to compliment the scholarly works of scientists listed in Physics Abstracts, other bibliographic sources were chosen to highlight a scientist's technical, as well as non-technical publications, works geared towards both a specialized and non-specialized audience. Thus, in order to obtain this empirical data, the following bibliographic sources were consulted: Books in Print (1995), and Whitaker's Books in Print (1995).

In order to construct a quantitative measure of prestige for the scientists chosen in this study, the Science Citation Index (SCI) was surveyed from 1989 to 1993, the last year of the Index available at Carleton University. The reason for this temporal constraint is simple: because the ideological debates revolving around the Big Bang theory began to intensify in the late 1980s and early 1990s, it was decided that a survey of the SCI during this time frame of academic uproar was reasonable. The citation frequencies of the eminent pro-Big Bang theorists will be compared with those of the anti-Big Bang camp, to ascertain whether unorthodox views on the origin of the cosmos are as equally cited as the traditional ones.

To measure the various social characteristics of the cosmologists in this thesis, information from a variety of bibliographic sources was collected. The two main references consulted were: American Men & Women of Science (1993), and the Cambridge Biographical Dictionary (1990).

In sum, my analysis of the Big Bang debate is based on a number of primary and secondary sources.[¶] It is hoped that this holistic approach will shed some light upon the fascinating academic and social battles being waged over the Big Bang paradigm in theoretical cosmology.

[¶] (Reference: Perry, 1992:20).

3.3 Conversations With Dr. Peter J. Watson

This thesis will attempt to analyze the Big Bang debate from a neutral perspective, detailing the views from scientists on both sides of this paradigmatic controversy. While this strategy in itself would suffice for the purposes of the forthcoming analysis, it would lack a human dimension, one that can only be provided by a physicist who is practicing his or her craft within the midst of this debate.

In order to add a personal interpretation to the current cosmological debate, two formal interviews, and one informal discussion were conducted with Dr. Peter J. Watson, Chair of the Physics Department at Carleton University.

The three interviews were conducted over a span of six months; the first interview was conducted in May of 1995; the second in October; and the third in November. The interviews were held in Dr. Watson's office in the Herzberg Physics Building on campus, and lasted anywhere from 30 minutes to an hour. All three interviews were recorded on a hand-sized micro-cassette with the permission of Dr. Watson.

Two out of the three interviews were transcribed as faithfully as possible, though there were very brief moments when the voices on the tape were too faint to hear. In essence, nothing was edited from the interviews. I did "tidy-up" the transcripts, correcting grammar, and excising all the ahs and ums that tend to occur in everyday conversations, thus making the transcripts easier to read.

The third interview was not transcribed for the following reason: While planning the third and final interview, I told Dr. Watson that I was not interested in conducting another formal interview; the meeting was simply to get his comments to Eric J. Lerner's controversial book The Big Bang Never Happened (1991). I asked him if it would be acceptable if

I brought my tape recorder to the session so I could quote him in the thesis as accurately as possible. He approved my request. Given the nature of our third meeting, and my words to Dr. Watson, I felt it would be improper to transcribe the conversation that transpired during our final interview.

In sum, the interviews clarified a number of difficult conceptual points as related to the Big Bang theory itself, and provided an invaluable, personal interpretation of this interesting paradigmatic debate.

Transcription Conventions

The following conventions were used to transcribe the interviews. Pauses are indicated by three dots (...). When a train of thought fades into silence, this is indicated by four dots (....). When the speaker suddenly jumps from one concept or word to another, or where we interrupt each other in mid-sentence, this is marked by a dash (--). Areas on the tape where the voices are too faint to be heard, are indicated by a bar (_). Words spoken with specific emphasis are indicated by **bold** characters.

In addition, commas, full stops and other grammatical symbols have been used in a fashion designed to convey the original nature of these conversations.

Chapter 4: Stratification in Science

This chapter documents the social and political structure of the scientific community. In order to comprehend the reasons why certain paradigms thrive within the scientific community, while others do not, it is crucial to understand the socio-economic, socio-political structure of that community, its cultural composition, the norms and values that form the fabric of any social system.

4.1 The Social Structure of Science

Within the theoretical confines of the elite model, there is to be found one central, unwavering argument: all social groupings are stratified along social, economic, and political boundaries(Mulkay & Millic,1980:23). It is, no doubt, a daring prediction; but the value of any theory is its ability to predict the unknown, to foresee the existence of an entity or phenomenon that has yet to be experienced.

If the elite framework is to be taken seriously as an insightful representation of the "real" world, then its statements about social structure should faithfully describe the socio-economic, and political composition of a broad class of human communities. But can the esoteric realm of the physical sciences be subjected to social analysis? Is it possible for a social theory to elucidate the cultural composition of a field of inquiry devoted to the exploration of the objective, natural world?

According to the popular image of science, scientific research represents the highest and purest form of democracy. The scientific enterprise is one of systematic investigation, of free and open inquiry into the cabalistic nature of the physical world(Crichton,1990:x; Greenberg,1967:4). In this particular representation, scientists are portrayed as logical, objective entities exploring a similarly logical and objective reality, their individual biases and prejudices somehow neutralized during the course of their research. Indeed, within the cognitive parameters of this image, the natural scientist is the noblest of all scholars, forever immuned to the winds of nationalism and politics, their scholarly research motivated not by the shadow of wealth, but a selfless desire to help humanity(Crichton,1990:x).

For generations, this was the popular image of science, told to the

non-academic public through the mediums of television and popular literature. But if one were to sit upon the abstract chair known as elite theory, and view the world from its perspective, then it would become clear that this romantic vision of science is an impossibility, an illusion based on the weavings of ideals rather than of reality. Science is, if nothing else, a very human endeavor practiced by human beings working in large, complex social communities, microcosms of the much vaster social landscape. As such, the twin concepts of pure impartiality and objectivity do not exist in practice, for no human researcher can claim to stand completely outside the fabric of ideology. Thus, in essence, the realm of natural scientific research is susceptible to social analysis like any other cultural system.

In order to test the conceptual power and validity of the elite model, it will now be brought to bear in mapping the social structure of the scientific community.

4.2 The Social Distribution of Science

A model of social reality coalesced over the decades in the minds of elite theorists. At the turn of the century, it was a vague concept, one that refused to be trapped in any one distinct theoretical box. But with the passage of time, this vision, this cognitive perception of human social communities began to take a very tangible form. It was, if you will, a conceptual picture of the structure of societies, of social groupings; and for a social theory, it mirrored the "real" world with uncanny accuracy.

From the elite theorists point of view, nearly all societies are stratified, divided along various social borders, borders that are intangible but, nevertheless, very real. Given this social axiom, elite theorists formulated one simple, yet provocative assertion: that all human communities contained an elite and non-elite strata. The inhabitants of these two social spheres lived in two distinctly different "worlds", viewing the human landscape through unique sets of cognitive lenses.

The notion of an elite resonates ancient social webs in many cultures. Political and historical treatments of ancient Egypt and Greece abound with scholarly expositions on the elitist and undemocratic social structures prevalent in these two legendary civilizations of times past(Lerner,1991:59-62). Indeed, elites seem to be the only truly predictable entity in the realm of the social sciences.

But, obviously, the definition of an elite has taken on numerous transformations over the countless generations. In many ways, these operational metamorphoses were a product of social evolution; societies based on slave labour, or administered by all powerful priesthoods, are objects of antiquity(Lerner,1991:58-62). And so, from the academic

shadows, a new definition of an elite rose into the light.

The notion of an elite contains four distinct elements(Mulkay,1976:446). In the first case, it refers to a reality in which the resources and rewards of a community are distributed in a highly skewed fashion(Mulkay,1976:446). In addition, it postulates a human landscape where the social and cultural ties among the successful and distinguished members are stronger and more meaningful than their ties with other members of the community(Mulkay,1976:446). Thirdly, the concept of an elite implies the existence of an entity that has the ability to control and direct the activities of others; this representation invokes the notion of power, power in a tangible sense, as well as being able to define normative rules and values(Mulkay,1976:447). Lastly, members of a society who have acquired a social position of some distinction, can exert considerable influence over further recruitment into the elite strata(Mulkay,1976:447).

At first glance, the idea of an elite seems valid only if one were studying nation-states, rather than scientific enterprise. In part, that is because people have tended to view science as an egalitarian enterprise, conducted on a plane of reality that transcends the messy world of human politics and ideology. Yet, over the past forty-five years, in many ways commencing with the quantitative analyses of the origins of American scientists by Knapp and Goodrich (1952), and Knapp and Greenbaum (1953), sociologists of science have amassed a mountain of empirical data showing that the scientific community, like any other community, is indeed very highly stratified(Mulkay & Milic,1980:23).

In 1957, John I. Holland published an article in the prestigious journal *Science*, entitled "Undergraduate Origins of American Scientists". Within the pages of this paper, Holland set out to test the following hypothesis: "Are differential rates of college productivity a function of differential attendance rates by scholastically superior students"(Holland,1957:433).

Four large samples of senior high school students were obtained from the National Merit Scholarship program for the years 1955 and 1956(Holland,1957:433). The four samples had the following characteristics: (i) 556 winners of the 1955 National Merit Scholarship program; (ii) 430 students of the 1955 Certificate of Merit program; (iii) 3,000 of the 4,226 Certificate of Merit winners who replied to a questionnaire concerning present college attendance and scholarships; and lastly (iv) 750 Merit Scholars and Certificate of Merit Students¹. All these students ranked at least in the top five percent of their graduating class(Holland,1957:433).

Furthermore, the term college productivity was operationalized as "...the number of graduate fellowships and scholarships and of PH.D degrees awarded per institution in proportion to the total number of their graduates for the period 1946-51"(Holland,1957:433). It should be noted that this particular definition of college productivity was first designed by R.H. Knapp and J.J Greenbaum in their seminal text The Younger American Scholar: His Collegiate Origins(1953).

¹This sample was based on the 1957 results of the Merit Scholarship and Certificate of Merit programs.

Now, this sample set was quite large for a reason; Holland wanted to test four distinct hypotheses. However, for the purposes of brevity this section will focus on just the one hypothesis stated earlier in the paper.

Using the research findings of Knapp and Greenbaum (1953), and integrating his own empirical results, Holland made the following observations. For instance, based on the mathematics, only 7.3 percent of the Certificate of Merit students would be expected to attend the high productive colleges, whereas 92.7 percent would be expected to attend the low productive institutions(Holland,1957:434). Yet, their actual attendance rate was 42.8 percent for the high productive colleges and 57.2 percent for the low productive colleges(Holland,1957:434). Thus, the actual attendance of this group of students at high productive colleges was 5.86 times the expected rate(Holland,1957:434).

Similarly, the winners of the Merit Scholarship seemed to attend the high productive institutions at a rate 5.93 times that expected.

The above results applied only to male winners of the two prestigious secondary school awards. However, when Holland analyzed female Certificate of Merit Scholars, he found that they attended the high productive schools at a rate 10.13 times that expected; their colleagues who were the recipients of the Merit Scholarship, tended to join high productive institutions at a rate 15.44 times that expected. These results are significant beyond the 0.001 level of statistical significance(Holland,1957:434).

These results seem to give validity to the notion that differential institutional productivity is a function of differential attendance rates by academically gifted students(Holland,1957:436-437).

Thus, it would appear that a certain degree of inequality exists

even at the bottom rung of the academic ladder. Those universities fortunate enough to attract the top high-school students have a considerable advantage over their fellow institutions in making a significant contribution to the scientific landscape²

²It should be emphasized that more than 71 percent of the males in this study chose a career in the physical sciences; the proportion of female students that pursued a career in the natural sciences was approximately half that of the male sample, or about 35 percent (Holland, 1957:433).

4.3 The Distribution of Productivity and Resources

Holland was among the first researchers to investigate - in a quantitative sense - the social backgrounds of those who would one day be regarded as members of the scientific community, his analysis suggesting the shadow of something more mysterious, more enigmatic still. Indeed, what Holland had stumbled across in his exploration of future scientists, were the tenuous social threads of inequality, of the skewed distribution of resources and talent. According to Holland's study, gifted students did not randomly scatter to academic colleges across the continental United States, but instead, tended to cluster at a few elite institutions.

In many ways, Holland's research served as a catalyst for other sociologists who wanted to explore the social structure of scientific research.

What Holland's article implied - but did not explore - was the notion that attending a prestigious, or highly rated academic institution would facilitate ones climb up the scientific ladder. While this would seem to be a common sense expectation, empirical evidence to substantiate this claim was unavailable until 1967, when Lowell L. Hargens and Warren O. Hagstrom, of the University of Wisconsin, attempted to tackle this conceptual void. Using data originally published by Bernard Berelson in his text Graduate Education in the United States(1960), Hargens and Hagstrom proceeded to obtain correlation coefficients between specific characteristics of scientists' backgrounds, and the prestige of their current academic affiliation³(Hargens & Hagstrom,1967:29).

³ It should be noted, that for his study, Berelson

In their statistical explorations, Hargens and Hagstrom found a relatively strong correlation between the prestige of a scientist's undergraduate institutions and his or her current academic affiliation; the correlation coefficient for these two variables is 0.31. Furthermore, the correlation between the prestige of a scientist's doctoral institution and that of his or her current academic affiliation is 0.33(Hargens & Hagstrom,1967:29).

Not content with these correlational analyses, Hargens and Hagstrom proceeded to quantify the correlation between the prestige of a scientist's undergraduate and doctoral institutions, with that of his or her productivity rate. The results were surprisingly low; the correlation between the prestige of a researcher's undergraduate and doctoral schools with that of his or her academic productivity, was calculated to be 0.02 and 0.06, respectively(Hargens & Hagstrom,1967:29). However, a relatively strong correlation coefficient was found between the prestige of a scientist's current academic affiliation, and his or her productivity;

sent questionnaires to a representative sample of 4,400 faculty members of graduate institutions. Of the 4,440 scientists contacted, 1,821 responded to the questionnaire, a return rate of 41 percent(Berelson,1960:113-115; Hargens & Hagstrom,1967:26).

For the purposes of their study, Hargens and Hagstrom selected only those respondents who had backgrounds in the physical or biological sciences. The final sample size selected for this specific group of researchers, was 576.

Lastly, the operationalization of two terms must be discussed before proceeding further; these are prestige, and productivity. The definition of prestige was designed based on Berelson's own ranking system in which he grouped institutions into four general categories. Berelson addressed questions of the validity of his rankings by showing that the composition of the most prestigious category remained stable over the years during which the members of his sample obtained their degrees(Hargens & Hagstrom,1967:27).

Furthermore, the term productivity was operationalized as the "...number of publications of each respondent during the last five years"(Hargens & Hagstrom,1967:28).

the correlation for these two variables came to 0.32(Hargen & Hagstrom,1967:29).

Even when the effects of the prestige of scientists' doctoral institution were controlled for, there emerged a strong relationship between a researcher's productivity rate, and the prestige of their current academic affiliation(Hargen & Hagstrom,1967:31). For example, of those scientists who attended doctoral institutions of high prestige, 51% were found to have a high rate of productivity, and were located at elite institutions; in contrast, only 22% conducting research at a prestigious university had a low rate of productivity. Similarly, of those scientists who studied at a doctoral institution with a poor ranking, only 24% were located at an elite institution and possessing a high productivity rate; one the other end of the spectrum, only 10% of the scientists sampled obtained a PH.D from a lowly ranked doctoral institution, and were working at an elite institution with a low degree of productivity(Hargens & Hagstrom,1967:32). The full table from this study is reproduced below.

Table 2
Prestige of Scientists' Present Academic
Affiliations by the Prestige of Their Doctoral
Institutions and their Productivity Rates
[Source: Hargens & Hagstrom,1967:32]

Prestige of Present Academic Affiliation		Productivity High Low	
1(high)	[High Prestige Doctoral Institution]	51%	22%
2		16	15
3		14	23
4(low)		19	40
	Total	100%	100%
	(N)	(111)	(115)
1	[Low Prestige Doctoral Institution]	24%	10%
2		17	12
3		35	27
4		24	51
	Total	100%	100%
	(N)	(101)	(137)

As can be seen from this chart, scientific productivity is strongly correlated with the prestige of a researcher's present academic affiliation. As the authors of this study state, "...productivity rate and prestige of doctoral institution both affect placement in the academic stratification system"(Hargens & Hagstrom,1967:31).

These results do not, by any means, preclude the possibility that a very gifted student trained at a poorly ranked institution, will never enter the confines of the academic elite. Yet, what this research does show is that a student's scholarly affiliations, the social composition of the academic landscape one has been socialized into, does play a part in influencing an aspiring researcher's future academic opportunities. As Hargens and Hagstrom forcefully argue:

"...among those scientists who have just received their doctorates, placement in the system depends quite heavily upon the prestige of their doctoral institutions. One would expect this to be the case since these scientists have yet to display their scientific talents, leaving hiring institutions with few criteria upon which to judge their individual potentials"(Hargens & Hagstrom,1967:34).

Indeed, this comment is based on strong empirical foundations. Analysis was performed on the relationship between the prestige of doctoral institutions and the prestige of current affiliation for scientists who received their doctorates in the 1950's. Not surprisingly, 46% of those who were awarded a PH.D from an elite institution, obtained employment at a highly ranked university, whereas only 12% of scientists who graduated with PH.D's from poorly ranked institutions were hired by elite facilities(Hargens and Hagstrom,1967:35). In contrast, only 21% of those awarded doctorates from prestigious institutions were working in poorly ranked universities; and 72% of those who obtained doctorates from poorly ranked colleges, found employment at poorly ranked universities(Hargens & Hagstrom,1967:35).

Thus, in essence, the name and reputation of an academic institution seems to play an influential role in the lives of would be academics.

The patterns found by Hargens and Hagstrom were indeed abstract in a mathematical sense; they were encased in the famous statistical form of product-moment correlation coefficients. They implied a less than democratic and random nature to scientific socialization. But the patterns were real, not simply statistical coincidences, significant to the levels of statistical significance (Hargens & Hagstrom, 1967:29). These social patterns reinforced a relatively new realm of sociological analysis, they made legitimate the notion that the physical sciences were susceptible to quantitative and qualitative investigation.

While Hargens and Hagstrom were among the first - if not the first - researchers to perform statistical analyses on how the prestige of the institution where one studied affected one's eventual location in the scientific community, they were scholarly followers of another social researcher when it came to analyzing the role a scientist's current academic affiliation has on his or her intellectual performance.

In 1965, Diane Crane of Yale University, set out to test the notion of whether scientific productivity was solely a function of ability, or was it unduly influenced by the academic environment the scientist practiced in. Crane interviewed 150 scientists (eg. biologists, political scientists, and psychologists); due to funding and temporal constraints, she chose three distinct fields of study, representing both the social and natural sciences, in order to obtain a holistic picture of the scholarly landscape. The sample of scientists was drawn from three universities of varying prestige, universities classified as major, high minor, and low minor universities respectively (Crane, 1965:700-702).⁴ Then, an index of productivity was designed to measure a scientist's

intellectual contribution to his or her field; this specific index also distinguished between major and minor publications.⁵

Crane's analysis revealed a distinct pattern, a pattern Hargens and Hagstrom rediscovered two years later in their own publication. Based on her own independent data set, Crane found that of those scientists trained at an elite graduate school, 45% had high levels of productivity after graduation; only 18% of scientists surveyed accredited with high levels of productivity had attended a non-major, or non-elite graduate school(Crane,1965:703). Furthermore, 55% of scientists of low productivity had studied at an elite university, whereas 82% of non-productive scientists had recieved their advanced degrees from a non-prestigious school(Crane,1965:703). These results were deemed significant beyond the 0.01 level of statistical significance(Crane,1965:703). Thus, a scholar's academic training grounds has an influential affect on his or her scientific productivity after graduation(crane,1965:703).

The table below extends the above analysis to investigate how a scientist's current academic affiliation influences his or her productivity.

⁴ This ranking was based on Bernard Berelson's text Graduate Education in the United States(1960).

⁵ A book was considered a major publication, and a journal article was considered a minor publication. However, four journal articles, each of which explored a similar problem, was considered equivalent to a book(Crane,1965:701). In addition, productivity was measured relative to "professional age"(the number of years since obtaining the doctorate degree)(Crane,1965:702). Thus, high productivity was defined as the "...number of major publications achieved by approximately the top third of each 'professional age' group..."(Crane,1965:702).

Table 2
Productivity by Current Academic
Affiliation

	Current Academic Affiliation		
	Major University	High Minor University	Low Minor University
Productivity			
High	46%	39%	17%
Low	54%	61%	83%
Total	100	100	100
(N)	(72)	(36)	(42)

$$\chi^2 = 9.97, 2 \text{ df}, p .01$$

Source: Crane, 1965:704

As can be seen from the above table, scientists located at a major university appear to be more productive than their colleagues at poorly ranked institutions. But even if the effects of current affiliation are controlled for, scientists trained at a prestigious graduate school were likely to be very productive researchers, regardless of their place in the academic landscape (Crane, 1965:704). In addition, Crane found that scientists trained at a minor graduate school were unlikely to be productive unless they found employment at a prestigious institution (Crane, 1965:704).

These results substantiate Holland's early study of the origins of undergraduate students, and Hargens and Hagstrom's own analysis of the importance of educational prestige on a scientist's future scholarly career. Indeed, a student's choice of graduate school seems to have serious consequences on his or her scholarly opportunities, since many elite universities tend to hire their own graduates and graduates from similarly prestigious institutions (Berelson, 1960:109; Crane, 1965:704).

This concentration of scientific talent at a relatively few institutions, is a product of various social processes such as selective recruitment, and other administrative devices that tend to channel the most gifted men and women into a few select academic institutions(Mulkay,1976:451). In many cases, the best students tend to attract the attention of the top universities, which in turn provides these young scholars the opportunity to make contacts with the most productive and eminent researchers in their chosen field of study, researchers who will, in many instances, take a precocious student under their wing and train them in the art of scientific research, hence facilitating the preparation of the next generation of scientific explorers(Crane,1965:713).

Indeed, the tale of James D. Watson, co-discoverer of the structure of the DNA molecule, is a very pragmatic example of a talented student who had long since attracted the academic attention of a number of talented researchers in biology and molecular biology practicing their craft in the United States and Europe(Cole & Cole,1973:73-74). As Cole and Cole state, "...many of the world's leading biologists were familiar with his name and knew vaguely what he was working on. Even before his pathfinding work, Watson could be said to be travelling in elite circles..."(Cole & Cole,1973:74). Thus, the educational and academic reputation of a student, truly precedes him or her in the realm of scholarly investigation, and enables the aspiring academic star the ability to negotiate the stratified structure of the scientific landscape.

In an interesting analysis conducted on British university chemists by Blume and Sinclair (1973), it was found that even when the quality of published articles was held constant - quality as measured by peer group

assessment - scientists gained, in an academic sense, from being affiliated with an elite institution(Mulkay,1976:451; Blume and Sinclair,1973:135). As the authors explained:

"Among those whose work is of relatively low quality...54 percent of the Oxford and Cambridge chemists have received substantial recognition, compared to 17 percent of London University chemists, and only 12 percent of others. Among those of medium quality a similar differential is apparent, although it is less strong...At the highest level it is not certain that affiliation significantly affects recognition, although it must be borne in mind that the numbers here are rather small"(Blume & Sinclair,1973:135).

The above research seems to indicate that stratification in science is not exclusively an American phenomenon, but is a social shadow existing in other western, industrialized nation-states.

In essence, reputation is more than an intangible, abstract concept; notions such as prestige and eminence seem to manifest itself in pragmatic ways. Subjective interpretations of these variables seem to color a scientist's perception of his or her place in the scientific community, and influences the way he or she looks upon colleagues and peers. The research findings detailed in this section thus far, are by no means conclusive, or beyond question. Yet, they do lend credence to the argument that science is far from an egalitarian system governed by philosophical ideals. One could argue that science is a stratified culture, shaped and moulded by the winds of meritocratic anarchy, a realm where only a few, unique souls will ever claim victory(Greenberg,1967:5).

Thus, it seems that one's educational and institutional pedigree affects the cognitive perceptions of professional colleagues and the public; if you're a physicist, or chemist, or biologist working at an elite university, then it would seem inevitable that you will, one day, discover the answers to all of humanity's seemingly infinite list of questions; on the other hand, if you find yourself at a no-name

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institution, then the chances are good you will fade away into scholarly oblivion. These social images wrought within the scientific community, consciously or unconsciously, might seem unfair, but they are very real, images that ultimately "...affects the vision of scientists and influences the stances they adopt, both in relation to one another and in their dealings with nonscientists"(Greenburg,1967:5).

In the elitist terrain of science, there is one added benefit with being affiliated with a well respected academic institution, a benefit that turns the notions of prestige from an abstract discursive entity into a physical reality, tangible and measurable. In non-specialist jargon, that benefit is simply referred to as money.

According to Congressional records, in fiscal 1964, out of approximately 2,100 post-secondary institutions in the United States, ten universities received 38 percent of the government funds for research and development; these privileged institutions were, in no particular order, the University of California, MIT, Columbia, the University of Michigan, Harvard, Illinois, Stanford, Chicago, Minnesota, and Cornell(House of Representatives,1964:33-34; Greenberg,1967:19). This skewed distribution of resources appears to replicate itself on a geographical scale. For example, universities in the states of California, Massachusetts, and New York, received 48.8 percent of government funds for research and development. If seven additional states are included, these being Illinois, New Mexico, Maryland, Pennsylvania, Michigan, New Jersey, and Ohio, then the total accumulation of federal funds by these ten states amounts to 76 percent of the total funds handed out by the U.S. government for research and development purposes(House of Representatives,1964:33-34; Greenberg,1967:19).

The passage of time has done very little to alleviate this economic

inequality. In fiscal 1992, of the more than 2,000 colleges and universities in the United States, the top twenty universities received \$4.665520 billion dollars in federal science grants(cited in Science,1994:1669). The average grant to a university in this "population" of post-secondary institutions, was \$232.76 million, with a standard deviation of 103.77(cited in Science,1994:1669). This monstrous pattern of skewness in federal funding, reflects the presence of John Hopkins University which received a federal grant so large, it would make any academics jaw drop in disbelief; in fiscal 1992, Hopkins received a massive \$660.7 million dollars in federal science grants, approximately 4.12 standard deviations from the mean(Cited in Science,1994:1669). Indeed, if Hopkins were removed from this list, the average grant to the remaining 19 institutions would be, \$210.24 million dollars, and the deviation would fall to 34.47(cited in Science,1994:1669). With the inclusion of John Hopkins, the top ten universities on this list of top twenty institutions, received \$2.8036 billion dollars, or 60.23% of the total funds for this population of post-secondary institutions(cited in Science,1994:1669).

Below, the top ten universities from 1964 and 1992 are listed in alphabetical order. While some universities have been eliminated from, or added to the top ten institutions over the intervening twenty-eight years, a small, core group of institutions have held onto their privileged positions in the top ten list since 1964.

Federal Science Grants:
The Top Ten Universities
(1964)

1. University of California*
 2. University of Chicago
 3. Columbia University
 4. **Cornell** University
 5. Harvard University
 6. University of Illinois
 7. University of **Michigan**
 8. University of **Minnesota**
 9. **MIT**
 10. **Stanford** University
-

Federal Science Grants:
The Top Ten Universities
(1992)

1. U.C. Los Angeles*
 2. **Cornell** University
 3. John Hopkins U.
 4. University of **Michigan**
 5. University of **Minnesota**
 6. **MIT**
 7. U.C. San Diego*
 8. **Stanford** University
 9. University of Washington
 10. Wisconsin-Madison
-

Source: NSF/SRS, Survey of
Federal Support to Universities,
Colleges, and Non-profit Institutions in
FY 1992, cited in Science, vol:264, 1994:1669.

As indicated by the above two charts, five academic institutions (possibly six, if the University of California is included), have maintained their elite positions in the scientific community, at least where federal grants are concerned, for close to thirty years. In essence, it would be a fair comment, in light of the current data, to refer to these five schools as representing the elite of the elite universities; the cream of the scholarly crop. These universities and colleges have benefited from the cultural status scientific research has in the United States. Indeed, in 1950, this social emphasis placed on scientific research manifested itself in tangible fashion, when the United States Congress gave life to the now famous entity known throughout

* It is unclear whether the institution referred to as the University of California in 1964, later divided into the separate entities known today as UCLA and UCSD, respectively. Since the state of California has numerous institutions with the prefix University of California, and since it was unclear which specific institution the 1964 University of California title was referring to, all California state universities were unhighlighted in the above table. Yet, as one can clearly see, post-secondary institutions in California state have maintained their elite niche in the top ten list of universities for almost three decades.

the scientific community as the National Science Foundation.

The National Science Foundation was established, by an act of law, on May 10, 1950(Schaffter,1969:11). The mandate of the NSF was to stimulate, and support basic research in the physical sciences, to reinforce America's dominant position in the rapidly evolving technological world of the post war period. It was a vision that has been maintained and protected by the Foundation, and the U.S. Congress for nearly forty-six year(Lindberg,1970:vii; House of Representatives,1979:iii; Schaffter,1969:11). In the intervening four and a half decades since it was incorporated, the Foundation has become one of the single largest sources of federal funding for the scientific community(Palca,1990:541). For example, in 1988, NSF spent \$1.717 billion dollars on research related activities; in 1989, that figure jumped to \$1.886 billion dollars; and in 1990, the last year for which accurate figures are available, the Foundation spent \$2.122 billion dollars on research and development(Palca,1990:541).

In addition to its research grants, the Foundation also awards what are known as instrumentation and facility grants to academic institutions; these grants enable universities to purchase new equipment, or renovate deteriorating laboratories or research buildings(Mervis,1994:1517). Of course, winning these priceless financial awards is far from easy. As Mervis states, grants "...are awarded competitively, and applicants are required to document not only their need but also the project's likely contribution to science"(Mervis,1994:1516). Of course, like anything else in the realm of scientific research, the distribution of resources is far from egalitarian.

By the end of August 1994, the Foundation had handed out 168

facilities grants, amounting to \$92.5 million dollars, and 63 instrumentation grants, totalling \$29 million dollars(Mervis,1994:1517). Yet, the distribution of these awards among the countless universities and colleges in the United States, was somewhat skewed. For example, large universities, those that receive more than \$3 million a year in NSF research grants, obtained 47% of the facilities awards, whereas small institutions, those receiving less than \$400,000 a year in NSF grants, collected 29% of the total(Mervis,1994:1517).

As in the case of federal science grants documented earlier, there seems to be a scaling phenomenon in the sense that unequal grant distributions evident at the aggregate, continental level across the U.S., appear to replicate itself at smaller scales, at state and municipal levels. For instance, 53% of the facilities awards were collected by only ten states, and seven other states received no facilities grants whatsoever(Mervis,1994:1517).

While the Foundation has made attempts to alleviate these inequities by, for example, sending potential applicants to NSF funded workshops where they can learn the ropes of applying for grants from the Foundation(Mervis,1994:1517), it will take more than seminars to rectify the stratified fabric of scientific enterprise. Indeed, there must come to pass a dramatic change in the culture of science if the "have-nots" are to remain above the academic waters.

Of course, as anyone knows, social change, unlike technological change, is a very tedious, lengthy process; habits are hard to break, especially if they have a long, and distinguished pedigree.

Statistical data on the NSF clearly reveals an institution that spread its resources around quite selectively. From 1962 to 1966, the foundation spent a total of \$585.6 million dollars on basic

research(Schaffter,1969:63). Of this, the fields of mathematics, physics, and engineering were awarded a cumulative total of \$266.40 million, or 45.49% of NSF's total research expenditures for 1962 to 1966; the biological and medical sciences received a cumulative total of \$201.8 million; and the social sciences received a cumulative total of a mere \$47.9 million(Schaffter,1969:63; NSF,1966:118-121).

Paradoxically, or not so paradoxically, the National Science Foundation Act of 1950, did not include the social sciences in outlining areas of basic research to be supported. Although this oversight was corrected, funding for the social sciences remained at the discretion of the Foundation; the NSF was by no means obligated to support the "other sciences" as it was the physical sciences(Schaffter,1969:65). By the late 1960's this attitude began to change, and the social sciences were awarded sizable research grants, though they paled in comparison to the funds donated to the physical sciences. For example, the value of the research grant given to physics in 1969, was \$30.5 million; the amount received by the social sciences during this same period was \$15.2 million(NSF,1971:56,66). The fields of chemistry and engineering received grants valued at \$17.8 million, and \$19.3 million, respectively(NSF,1971:58,67).

Physics continued to be the discipline to beat in the early 1970's when it came to obtaining NSF grants. According to the Foundation's 1974 budget, the organization expended \$289.85 million dollars on basic research. Of this total, physics received \$36.73 million; chemistry, \$26.65 million, engineering, \$28.09 million, and the social sciences, a respectable \$24.92 million(NSF,1976:1).

Yet, even within the social sciences, the Foundation awarded more grants to specific disciplines. For example, of the \$15.2 million dollars

awarded to the social sciences,[¶] economics obtained \$4.289 million, anthropology, \$3.420 million, and the fields of sociology and social psychology, received a combined total of \$3.29 million(NSF,1971:66).

In essence, the purpose of this section was to show that certain universities are endowed with gifted researchers and generous sponsors, while others are not. Thus, some institutions have a competitive advantage over their rivals in making that revolutionary discovery , or winning the communities highest honors.

It is often said that no two human beings are created equal. This same basic observation can be applied to students of science, universities, and scholars. The cherished image of science, of a community of people living and practicing their craft in a fully democratic, and egalitarian environment, is, sadly, an image born of lofty ideals, and the web of illusion. As physicist Luis Alvarez once said bluntly, "There is no democracy in physics. We can't say that some second rate guy has as much right to [an] opinion as Fermi"(Greenberg,1967:43).

[¶] This refers, specifically, to funds awarded in 1971.

4.4 Of Nobel Prizes and Citations

In the previous section, it was argued that a small number of institutions receive an unfair share of research grants , and possess an envious pool of talented researchers. A good thing, too, these privileged halls of academia no doubt say to themselves in moments of scholarly tranquility, if they are to stand above their not so distinguished competitors, and produce the next generation of scientific leaders.

Indeed, a relatively small minority of graduate schools produce a large proportion of doctorates in the physical sciences. In the decades following the second World War, from 1950 to 1966, "...four to five percent of the [doctorate-granting] institutions supplied 25 percent of the doctorates during the entire period; eleven percent of the institutions supplied 50 percent of the doctorates; and twenty-four to twenty-six percent supplied 75 percent of the doctorates"(National Academy of Sciences,1967; Cole & Cole,1973:72).

Of course, closer inspection of the academic terrain reveals that the distinguished personalities of science, the stars of the scientific landscape, are products of a very select, elite group of graduate schools. These academic stars tend to be the winners of the communities highest scholarly awards, no award possessing greater prestige, or so coveted, as the Nobel Prize.

The concept of the Nobel Prize was founded by Alfred Bernhard Nobel, a Swedish chemist and engineer who died in 1896(Information Please,1996:708). The prize was to honor those individuals"...who have made the most outstanding contributions in the fields of physics, chemistry, and physiology or medicine, who have produced the most distinguished literary work of an idealist tendency, and who have contributed most toward world peace"(Information Please,1996:708).

The Nobel prize is perhaps the most prestigious award in existence in the scientific community. There is a body of empirical evidence to support this social perception. In the late 1960's, Cole & Cole asked a representative sample of 1,300 American physicists to rank the prestige of the Nobel prize among a series of scientific awards. All but 1% of the sample ranked it number one, ahead of such older, and in some cases, richer prizes as the Rumford Premium, the Enrico Fermi Award, and the Albert Einstein Medal (Cole & Cole, 1967:383; Zuckerman, 1967a:391-392; Zuckerman, 1967b:25).

Thus, the Nobel prize is perceived as an award of the highest caliber. As such, one would expect it to be won by the top researchers, working at the top universities, scientists endowed with strong intellectual talents, practicing in an environment rich in bright souls, and ample financial support. This appears to be the case.

Indeed, since 1901, when the first Nobel prizes were handed out, American researchers - those who did their prize winning research in the United States - have won a cumulative total of 71 out of the 251 Nobel prizes awarded for pioneering research in the fields of physics, chemistry and medicine for the period 1901 to 1967 (Zuckerman, 1967b:29,30). Of these 71 prize winners, 58 laureates received their Ph.D's from 16 American institutions; half were trained at only four: Harvard, Columbia, Berkeley, and Princeton (Zuckerman, 1967b:29).

This concentration of future laureates is a function of the concentration of doctoral training. As indicated earlier, a small minority of institutions is responsible for producing a relatively large percentage of doctoral graduates in the physical sciences. Indeed, only four institutions have graduated 20 percent of all doctoral candidates in

the physical sciences since 1920. These four are Chicago, the University of Illinois, Berkeley and the University of Minnesota(Zuckerman,1967b:29). These results seem to substantiate the mathematical correlation between scientific achievement and place of scholarly training, and helps to reinforce Holland's 1957 study that the best students tend to congregate at the top institutions(Zuckerman,1970:244).

The road leading to science's most distinguished award is highly competitive, but, as documented, studying at a top university facilitates the voyage considerably. It then comes as no surprise that more than half of the Nobel laureates produced in the United States from 1958 to 1963, were students of past prize winners(Cole & Cole,1973:74; Zuckerman,1967a:393; Zuckerman,1967b:29). To study under the shadow of an eminent researcher is a priceless opportunity, an opportunity to see up close how the art of scientific research is conducted, to watch the evolution of a research project as guided by the hand of a master. There are, obviously, other benefits to be accrued from working with a Nobel laureate. As Zuckerman states:

"Young men who take their degrees under distinguished scientists who themselves are concentrated at a few institutions are inevitably more visible to senior scientists who count, that is, the men who allocate research funds and facilities and who, indeed, participate in the selection of Nobel prizewinners. This hypothesis is consistent with the fact that the laureates who trained at the most prestigious institutions received the prize, on average, at the age of 47, more than 10 years earlier than men trained elsewhere; this difference holds within each field"(Zuckerman,1967b:29).

In addition, the research papers of laureates receive a higher citation rate than the scholarly works of non-laureates(Mulkay,1976:449). The basic assumption here is that there is a positive correlation between the number of citations a book or paper receives, and the perceived quality of those respective academic

contributions(Cole & Cole,1973:21). It can be argued that the "...measure of a scientists's contribution to his [sic] field is having other scientist's acknowledge its worth by using it"(Zuckerman,1970:250).

There is some empirical evidence to support this assumption. In a comprehensive study, Kenneth E. Clark asked a number of experts in psychology to list the psychologists who, in their opinion, had made the most significant contributions to their fields. He then calculated a number of correlational coefficients between the number of choices received by psychologists and other indices of prestige. The one index that correlated highly with the number of choices was the number of journal citations's to an individual's work; the correlation coefficient for this relationship was 0.67(Cole & Cole,1973:21-22).

In another study, researchers mailed out questionnaires to a sample of 282 psychologists working in the United States; 192 of the 282, or 68% of those contacted, returned completed forms. Analysis showed that 51% of the respondents rationalized citing a specific article because it reinforced their own line of research. Furthermore, the study found that while the quality of an article plays a part in the decision to cite a specific work, it is by no means the most important criteria when deciding which reference to cite, a finding which supports, in part, Clark's study(Shadish et. al,1995:481).

Indeed, when it comes to citation rates, Nobel laureates are in a league of their own. For example, one study found that the average number of citations in the 1961 Science Citation Index (SCI) to Nobel laureates who won the distinguished award between 1955 and 1965, was 58; in contrast the average citation rate of non laureates cited in the 1961 SCI, was 5.5(Cole &

Cole,1973:22). This result is all the more impressive when one realizes that "...only 1 percent of the quarter of a million scientists who appear[ed] in the 1961 SCI received 58 or more citations"(Cole & Cole,1973:22).

Furthermore, in a survey of 1,308 academic physicists, only a miniscule 2% had a total of 60 or more citations to their work in the 1961 SCI. Thus, a very small elite within the physics community can claim to have received a citation rate worthy of a Nobel laureate. In addition, 12% of the sample had between 15 and 59 citations, and the remaining 86% had fewer than 15 citation's to their life's work(Cole & Cole,1973:23).

This monopolization of honorific awards such as the Nobel prize by a small, elite group of scientists, this web of scientific inequality, becomes blatantly apparent at the international level. In the wake of the second World War, American scientists - those holding American citizenship, and who conducted their prize winning research in the U.S. - began to accrue the Nobel prize at a tremendous rate(Gray,1961:560). For example, in 1923, Germany possessed a total of $19\frac{1}{2}$ Nobel prizes, whereas the United States had amassed only four. But by 1960, the U.S. owned 37.33 Nobels; in contrast Germany had in its possession 35.83 prizes; America's lead at this stage was tenuous at best(Gray,1961:561). However, by the late twentieth century, America had, if you will, out-Nobeled every other nation on the planet.

By 1994, a total of 414 Nobel prizes had been given out over the intervening 93 years for the fields of physics, chemistry, and medicine. Of this population of 414 prizes, American researchers have won 172 Nobel prizes, or 41.55% of the total, by far the largest of any country; Germany with its cumulative total of 54 awards, comes a distant second (Information Please,1996:708-714). The top five Nobel prize winning nations are listed below.

Distribution of the Nobel Prizes:
The Top Five Nations, 1901-1995

Country	Physics	Chemistry	Physiology & Medicine
U.S.	58	39	75
Germany	17	22	15
England	17	19	11
France	9	7	8
Netherlands	5	2	3

Source: Information Please Almanac, 1996: 708-714.

This section on the Nobel prize seems to lend further credibility to the argument that the physical sciences are highly stratified along a number of social parameters. It is an empirical reality that challenges the popular perception that science is an egalitarian and highly democratic entity.

4.5 The Shadow of the Peer Review

The peer review system was born and perfected in the early years before the second World War. It is based on the notion that scientists are in the best position to judge the value of scholarly endeavors, and research projects. In pragmatic terms, this means that when a scientist applies for research funding, or submits a paper to a scientific journal, opinions are sought from other scientists acquainted with his or her field of specialization. They are asked to scrutinize the quality of the proposal or article, and in the case of a major project, whether it is soundly designed, financially realistic, makes an important contribution to the field in question, and, lastly, whether the person requesting financial assistance is qualified to carrying out the work(Greenberg,1967:16). Since it is unlikely that a used car dealer can outclass mathematical physicists in assessing the validity and quality of research proposals and journal articles in mathematical physics, the peer review process is considered a sound entity, founded on logical, common-sense principles(Greenberg,1967:16).

Yet, critics argue that the peer review encourages back scratching, facilitates the creation of an environment constrained by the intangible threads of ideology and orthodoxy, and discriminates against the obscure researcher(Greenberg,1967:17). Critics also contend that the peer review system poses a major obstacle to revolutionary ideas; furthermore, since peer reviews are not "blind", reviewers can play favorites, or be biased by his or her knowledge of the proposer(Mitroff & Chubin,1979:203). But are these criticisms based on empirical grounds, or are they the products of human perception?

One study conducted in 1975/76 by Deborah Hensler, attempted to answer this question. She sent a questionnaire to a random sample of

1,552 of approximately 31,000 persons who had served as reviewers of research proposals submitted to the National Science Foundation (NSF) during the fiscal year of 1974. An identical questionnaire was sent to a random sample of 3,256 applicants of NSF grants during the same time period; this random sample was representative of a population of 20,000 grant applicants. The response rate for both populations exceeded 80 percent, a phenomenal return rate for a social scientific study(Mitroff & Chubin,1979:208).

Among other things, the questionnaire included two equally innovative, and rigorous proposals, proposals which were similar on many counts except a few. In the first case, one of the proposals was designed and written by a well known researcher working at a distinguished institution; this proposal followed an orthodox algorithm, proposing experimental techniques and methodology that were consistent with mainstream research. The second proposal was written by a young, obscure researcher working at a lesser-known institution. This individual's project proposed somewhat unorthodox techniques, and challenged mainstream thought(Mitroff & Chubin,1979:208).

The responses to these proposals were as follows: 52% of the reviewers, and 61% of the applicants felt that the proposal from the well-known institution had a better chance of being supported; 29% of reviewers and 16% of the applicants felt both had an equal chance of being funded; and less than 3% of each group felt that the proposal from the less-distinguished institution had the upper hand when it came to winning a research grant. Furthermore, both groups felt that the more respected researcher and the orthodox proposal, had a very good chance of being supported(Mitroff & Chubin,1979:209).

Yet, Hensler's study is far from conclusive. As Mitroff and Chubin like to point out, her results simply reflect what former reviewers and

applicant believe would happen if these proposals had been sent to a real NSF peer review committee; it says nothing about how actual grant proposals from researchers of various levels of prestige, working at institutions of differential status, were received by a NSF peer review panel(Mitroff & Chubin,1979:213).

In October 1977, Cole, Rubin and Cole published an ambitious quantitative analysis of 1,200 applicants to the NSF in fiscal 1975. A series of multiple regression techniques were performed on nine stratification variables; these included: rank of PH.D department, current academic rank of the applicant, and various measures of publication and citation; the dependent variable in this analysis was the percentage of applicants receiving grants(Cole,Rubin & Cole,1977:36,37-39)⁶ At the end of their investigation, the authors made the following conclusion:

"The overall pattern of our data suggests that scientists with an established track record, many scientific publications, a high frequency of citations, a record of having received grants from the NSF and ties to prestigious academic departments have a higher probability of receiving NSF grants than other applicants do. Nevertheless, the granting process is actually quite open and there is nothing approximating a scientific caste system"(Cole, Rubin & Cole,1977:40).

Maybe so, but this study side steps the issue that 89% of the observed ratings given to proposals is left unexplained in the light of the nine stratification variables(Cole, Rubin & Cole,1977:38). Thus, it would be fair to argue that factors other than stratification variables are at play, such as perceptions of quality, ideological tensions, and other psychological variables(Mitroff & Chubin,1979:214-215). However,

⁶ In actuality, two dependent variables were analyzed. The first was the percentage of applicants receiving grants; and the second was the ratings received on proposals(Cole, Rubin & Cole,1977:37-39).

despite these flaws, the above study seems to reinforce the popular belief that the peer review system is far from flawless.

There is very little doubt that grant and journal reviewers are in a position of power within the scientific community; a research proposal, or an innovative journal paper can either prosper or wither into academic dust based on the recommendations of this select group of scholarly judges. From a sociological stance, empirical data suggests that a fair number of scientists on peer review panels are researchers of high distinction. For example, in mathematics, less than one-fifth of applicants and more than two-fifths of those reviewing funding proposals came from the 15 top ranked mathematics departments in the United States(Cole,1992:150). Similarly, in the publishing world, 32% of the reviews written for the elite physics journals were composed by the 5% of journal authors who were ranked in their highest prestige category(Abrams,1991:123).

This domination of review panels by elite scientists helps to promote orthodoxy, and forces many non-elite researchers to think twice before rocking the academic boat with a radical proposal, or line of research. Evidence seems to indicate that reviewers are more critical of research which threatens their own field of scholarly investigation(Cole,1992:151; Campanario,1993:343).

Indeed, prejudice in the evaluation of articles or proposals is one of the staple complaints of the peer review process, examples of which were documented in the preceding pages. The peer system has also been criticized as highly unreliable. For example, in one study, William Goffman, editor of The New England Journal of Medicine found that the probability of two different referees agreeing on the worth of a particular research article, was only slightly better than

chance(Campanario,1993:343). Indeed, research seems to indicate that "...there is much more agreement on rejection than on acceptance"(Campanario,1993:343).

In another study, a clever little social "experiment" was conducted. Authors Peters and Ceci obtained copies of twelve different psychology articles, and resubmitted these academic papers to the journals that had originally published them! It is important to note that the these articles had been written by prestigious authors from distinguished academic departments; obviously, for the purposes of this study, the names and affiliations were significantly altered(Campanario,1993:343). The results were, to say the least, amusing; of the twelve journals, three were detected by the reviewers as resubmits, eight were rejected, and, paradoxically, only one was accepted(Campanario,1993:343)!

Of course, as indicated earlier in the paper, one of the biggest criticisms of the peer review process is that it tends to reject revolutionary papers. Stephen Lock, editor of the British Medical Journal argues that the peer review system "favours unadventurous nibblings at the margin of truth rather than quantum leaps"(cited in Campanario,1993:344).

In order to test the above accusation, Campanario conducted a survey of Citation Classics, a database devoted to those papers which received an extraordinary number of citations since their initial publication, papers whose contents, in some cases, were quite revolutionary and unorthodox when they first hit the academic community; the cutoff mark was a cumulative total of 400 citations, though the criteria varies slightly depending on the size of the field in question. Yet, this operationalization is hardly a problem when one considers the fact that only 2% of over 32 million papers which were cited at least once between

1945 and 1988 were cited more than 50 times, and only 0.05% of all cited articles were cited more than 500 times(Campanario,1993:347).

It should be noted that when an article is chosen as a Citation Classic, authors are asked to write a small essay concerning the remarkable citation rate their papers have received over the years. These essays document any problems the authors might have experienced when they tried to publish their work; if the article was of a revolutionary nature, this, too, is dealt with in the essay; the essay is then recorded into the main Citation Classics database(Campanario,1993:347).

Using the Citation Classics database in conjunction with Current Contents, the author surveyed journals published in the fields of physics, chemistry, biology, agriculture, earth sciences, and the social and behavioral sciences. In the end, a sample of 316 papers was collected for the years 1989 and 1990⁷. Campanario found that authors of 19 out of the 316 papers surveyed, or 6.0%, that later went on to become a Citation Classic, encountered some difficulty when it came to publishing their results(Campanario,1993:348-349). Authors of papers that were highly cited, but did not make the Citation Classic list, and which experienced difficulty in the publication phase, amounted to only 3 articles(Campanario,1993:349). Indeed, 12 of the 19 Citation Classics papers which experienced scholarly resistance, "...reported innovative methods or theories, or presented new interpretations of previous data"(Campanario,1993:352). These same papers went on to become some of the most cited papers in their respective fields; the citation rates for this sample of Citation Classics ranges from 105 to 530; a mean of 253.33 was calculated(Campanario,1993:352).

This study lends some validity to the argument that new ideas face greater resistance in the scholarly world than their orthodox
⁷ Due to its unique selection method, articles in the Citation Classics database are neither random, nor representative of highly-cited papers(Campanario,1993:347).

counterparts.

As a personal, qualitative aside to what has, thus far, been a statistical discussion of the peer system, I wish to bring to light the case of Texas geologist, Jon Kalb.

Kalb discovered, much to his dismay, that after being denied a research grant from the NSF, he had been falsely labelled as a CIA agent in the Foundation's peer review meetings. Since he was never given an opportunity to respond to that charge, Kalb argued that it not only cost him his grant, but it destroyed his scientific career. With the assistance of a tenacious lawyer, Kalb was given access to NSF documents that clearly revealed that the CIA rumor was a pivotal issue in the peer review of his research proposal(Marshall,1989:250).

In late 1987, Kalb settled his legal battle with NSF, a battle that had lasted for 9 long years. In the wake of the settlement, NSF promised to make the review process more open and transparent(Marshall,1989:250).

Yet, investigations of three major funding agencies - the NSF, the National Institutes of Health (NIH), and the the National Endowment for the Humanities - by auditors of the General Accounting Office of the United States (GAO), found specific weak spots.

In their exploration, GAO investigators studied countless administrative documents, surveyed 1,370 reviewers, and interviewed a sample of 477 winners and losers in the grant awarding process(Marshall,1994:863). In their final report, GAO auditors concluded that the peer review system was, basically, sound. However, they noted that scores given to research proposals were correlated with gender, with women receiving lower scores than their male colleagues. Furthermore, over at the NSF, research proposals submitted by minorities seemed to score lower on average, though the poor scores were by no means extreme.

No one clear answer could be found to account for this pattern, though investigators assumed it was due to the poor quality of the proposals submitted to the organization; however, this is speculation on the part of the investigators(Marshall,1994:863).

Furthermore, the GAO discovered that judges at all three institution surveyed, seem to apply unwritten, informal criteria in reviewing research proposals(Marshall,1994:863). For instance, at NIH "...reviewers give better scores to applications that include preliminary results, even though NIH instructions do not say it is crucial to include such data"(Marshall,1994:863).

GAO analysis also revealed that young scholars, operationalized as assistant professors or other junior faculty, were underrepresented on peer review panels. Furthermore, a reviewer's personal knowledge or familiarity with an applicant tended to result in higher scores, and thus, a higher probability that a research proposal would be funded(Marshall,1994:863).

In essence, the road to obtaining research funding, or publishing an unorthodox article, is a hard and treacherous one; countless twists and turns, and ideological pitfalls must be carefully navigated if one is to have a successful career in the scientific community, a reality where "being first...is a major value and being second is a far cut below"(Zuckerman,1970:242).

4.6 Scientific Communication

The preceding sections have attempted to document, as explicitly as possible, the stratified structure and nature of scientific culture. In this process, the predictions of the elite model have been, thus far, validated by the light of empirical investigation. The scientific community, like the larger social reality in which it exists, is composed of an elite and non-elite strata, separated by an invisible, intangible wall that cannot be seen nor touched, like the wind, but which is, nevertheless, very real.

As demonstrated earlier in this section, the scientific elite tend to cluster within the rarefied atmosphere of a few select institutions. As such, we would expect them to interact with one another, formally and informally, at a higher rate than with their non-elite colleagues. Indeed, the evidence seems to suggest that various elite circles tend to overlap with a high degree of frequency. For example, elite students tend to cluster around elite researchers, and in rare cases, elite researchers tend to seek out gifted young scholars to train and supervise. In addition, elite researchers tend to cite articles written by other eminent scholars, and tend to maintain a high level of communication with their distinguished peers (Mulkay, 1976:453; Shadish et. al, 1995:483).

The fact that the scientific community is highly stratified, comes as no surprise to its countless members. Many researchers are of the view that the shadow of inequality which characterizes science, is a product of talent; some researchers are truly gifted, while others strive for mediocrity. It is a culture in which "...only a few scientists have the capacity to do great science and, in turn, be accorded great prestige" (Zuckerman, 1970:240), a social reality governed by the specter of a powerful ideology, a philosophy known as meritocratic

anarchy(Greenberg,1967:5). This cognitive belief is the conceptual clay upon which the scientific community rests. It is a vision which affects a scientist's perception of his or her place in the scholarly society, a vision which influences the interactions between elite and non-elite scholars(Greenberg,1967:5).

Like in any social community, normative prescriptions in science govern an individual's behavior and conduct. Indeed, within the confines of academia, a researcher's contribution to the scholarly waters is judged not only on its merits, but is scrutinized against the backdrop of scientific opinion, or what is commonly referred to as authority. Authority is founded on the abstract concept known as consensus, wrought from the discursive beliefs of those select few deemed worthy to judge what is proper and significant; authority flows from the web of power, power to define what is normal and logical, as opposed to the deviant and exceptional(Wetherell & Potter,1992:84; Zuckerman,1970:241). This notion of authority was summed up nicely when physicist Luis Alvarez said, "There is no democracy in physics. We can't say that some second rate guy (sic) has as much right to [an] opinion as Fermi"(Greenberg,1967:43).

The presence of authority within scientific discourse is seen as a logical by-product of conducting research, research that is often highly specialized and accessible to a few highly trained men and women. Since it is impractical to judge the validity and reliability of every new contribution to a particular field, it is comforting for the humble researcher to know that there exists an accepted and highly respected body of research against which one can evaluate one's own research, or a novel idea or theory. This pool of comforting data, referred to in academic jargon as authority, wrought on the accomplishments of generations of scientists long since passed into the pages of memory, acts as an intellectual barrier against cranks and other devious

creatures. As such, authority instills in many working scientists a deep suspicion of new paradigms or models, and creative interpretations of well worn data(Zuckerman,1970:242). This atmosphere of skepticism presumes that "...work which runs counter to currently accepted, useful ideas, and which is presented by unknown scientists, is probably trivial and possibly misleading"(Zuckerman,1970:242). It is a philosophical stance which explains a common phenomenon within the history of science, a phenomenon characterized by the rejection of research proposals or articles which run against the grain of "common-sense"(Cole & Cole,1973:79; Zuckerman,1970:242), articles which later resurfaced from the depths of scholarly oblivion to be hailed as works of genius.

Since the dawn of modern science, so many decades ago, the reins of power, and in effect, of scholarly authority, have rested within the hands of the scientific elite. As the academic stars of science, these men and women of eminence exert considerable informal, and formal influence upon the norms and values resonating within the academic community. Since scientific research is so specialized, the task of determining which ideas are acceptable and which are not, tend to be delegated to those who have made their mark, those who have been tested by the fires of scholarly examination time and time again, the veterans of countless intellectual battles. And so, the cloak of power is, for better or for worse, placed around the shoulders of the elite, the guardians of scientific excellence(Barber,1961:552; Cole & Cole,1973:79; Mulkay,1976:454).

As demonstrated earlier in this paper, by their very presence within the scientific landscape, elite researchers cannot but have a considerable effect upon their colleagues, and upon their community. They are the heroes of their respective fields, and as a such, are expected to

serve as authority figures in examining journal articles, in allocating scarce financial resources to their non-elite peers, in effect, to serve as intellectual gatekeepers for the community(Cole & Cole,1973:79; Griffith et. al,1972:960).

Whether one perceives this social arrangement as just or not, is purely academic; the entity known as human culture cares little for the beliefs of its inhabitants, even though, paradoxically, those very same inhabitants are ultimately responsible for weaving the reality in which they exist. What is, is; what should be is an abstract conceptual painting without substance.

Thus, given the stratified nature of science, and the fact that the privilege to weave and reinforce the web of norms and values, is entrusted to an elite few, non-elite researchers must negotiate their passage within this competitive environment with care. Those scientists who dream of one day joining the elite, "...must comply with the cognitive standards set and exemplified by these leaders"(Mulkay,1976:454), and learn not to stir the academic waters before its time.

The accrument of recognition and honor by a few select scientists is a fact of scholarly life, and there is very little the academic rebel can do about it except to sail along with the prevailing current as so many have done before.

This complex social phenomenon, this shadow of inequality so characteristic of the scientific community, was first systematically analyzed by Robert Merton of Columbia University. Grippped by the spirit of inspiration, Merton dubbed the phenomenon "the Matthew effect," after the famous verse found in the biblical book of Matthew: "Unto every one that hath shall be given...but from him that hath not shall be taken away

even that which he hath"(Merton,1968:58; Gibbs,1995:98).

The stage is now set to analyze one of the most fascinating paradigmatic debates of our time. It is a debate that seeks nothing less than to understand the origin of the cosmos, a debate that has the capacity to demonstrate the often political and ideological practice that is scientific investigation.

Chapter 5: Cosmology

This chapter documents the origin of the Big Bang model in theoretical cosmology. The section then proceeds to outline the essentials of this paradigm, including its predictions concerning the structure of the cosmos, predictions that have been strongly supported by empirical evidence. The final part of the Chapter deals with the numerous attacks launched against the Big Bang theory in recent years, attacks emanating from a small, marginal group of plasma physicists. These plasma cosmologists, as they call themselves, believe that the Big Bang theory is wrong, and that the current structure and evolution of the heavens can best be accounted for within the realm of plasma physics.

5.1 Introduction

In 1905, Albert Einstein submitted a most extraordinary paper to the prestigious German periodical Annalen der Physik. The paper was simply entitled "On the Electrodynamics of Moving Bodies", a paper that would revolutionize the way physicists conceptualized the physical world, a paper that would come to be known by scientists and non-scientists alike as Einstein's special theory of relativity(Clark,1972:101; Hawking,1988:20).

Within the pages of this nine-thousand word thesis, Einstein argued that the laws of physics should be identical for all observers, regardless of their motion. This theoretical constraint had a number of consequences, not the least of which was that notions such as absolute space and time had to be abandoned. To Einstein, motion was a relative phenomenon, as was time; one person's description of the physical world was as good as another's; there was no such thing as an absolute measuring device, or timepiece. As Einstein's biographer Ronald W. Clark states, "Just as beauty lies in the eye of the beholder, so does each man (sic) carry with him his (sic) own time"(Clark,1972:121).

The remarkable predictions wrought by the special theory have been tested countless times over the intervening decades. Indeed, as the 90th anniversary of the special theory came and went, each of its predictions has been verified to countless decimal places(Pool,1990:1207).

Ten years after introducing the special theory, Einstein again rocked the scientific establishment with yet another remarkable paper, published, as was his previous article, in the Annalen der Physik, and entitled "The Foundation of the General Theory of Relativity"(Clark,1972:252; Hawking,1988:29; Lindley,1993:79).

Within this now legendary paper, Einstein reworked scientist's understanding of gravity, constructing the most sophisticated mathematical model of gravity ever devised. Like the special theory, every prediction of the general theory has been verified by countless experiments(Clark,1972:261; Kaufmann,1988:471).

Indeed, it was within the abstract logic of general relativity that the idea of a dynamic, expanding universe was first conceived, a universe wrought at a finite point in time(Hawking,1988:33; Kaufmann,1988:563). In many ways, Einstein is considered the founding father of cosmology, the inspiration behind the paradigm known as the Big Bang.*

* For a detailed account of the special and general theories of relativity, please see Appendix D.

5.2 The Origin of the Big Bang

Two years after he constructed the most sophisticated theory of gravity ever devised, Einstein embarked on yet another courageous, intellectual expedition. In 1917 he published a controversial paper entitled, "Cosmological Considerations on the General Theory of Relativity." Within the pages of this article, Einstein wielded the field equations of his general theory to construct a mathematical model of the structure of the universe, an act that, in essence, founded the modern discipline of theoretical cosmology(Clark,1972:264-266).

The mathematics of the general theory made it clear that if the universe contained an infinite number of stars, even at infinite distances, an infinitely strong force would manifest itself, propelling the stars through the cosmos at a very high velocity. However, observations showed that the velocities of stars, relative to the speed of light, was quite small. This fact, Einstein argued, made it reasonable to postulate that the number of stars in the universe was finite(Clark,1972:267).

The conclusion that the universe contained a finite number of stars was disturbing for a number of reasons. For example, the general theory stated that mass curves the fabric of space-time; the greater the distribution of mass in a given region, the greater the curvature. Thus, in Einstein's model, a universe containing a finite number of stars would turn space back on itself. In this sense, the universe had a finite dimension, but was unbounded, similar to the structure of the planet Earth, whose surface area is finite, but has no discernible beginning or end(Clark,1972:268). In essence, this conceptualization of the cosmos conformed to Einstein's belief "...that just as the laws of nature must be the same for all observers, so must the view of the

universe"(Clark,1972:268). Thus, in observing the universe, every place is as good as every other place; there are no privileged frames of reference(Sagan,1980:200).

Drawing on the general theory, Einstein made the following comment on the structure of the universe:

"The whole universe has a diameter of about 100 million light years, in round numbers. That amounts to about 700 trillion miles [this is the British trillion of 10^{18}]. It follows from the mathematical calculations which I have presented in "Cosmological Considerations Arising from the General Theory of Relativity," in which the figure I have just quoted is not given. The exact figure is a minor question. What is important is to recognize that the universe may be regarded as a closed continuum as far as distance measurements are concerned"(Moszkowski,1921:127).

This theoretical construct of the universe was based on the assumption that the curvature of space was independent of time; that is, the universe as a whole must be unchanging(Gamow,1956:139-140). Yet, the equations composing the framework of the general theory refused to yield a static universe. Einstein was so convinced of the idea that the universe was a static entity, that he engaged in some, uncharacteristically, mischievous mathematical juggling. Thus, into the field equations of the general theory, he introduced a term known as the cosmological constant, a constant that represented a repulsive force which increased in strength with the distance between objects. In his 1917 paper, Einstein justified the addition of this term by stating:

"In order to arrive at this consistent view, we admittedly had to introduce an extension of the field equations of gravitation which is not justified by our actual knowledge of gravitation....That term is necessary only for the purpose of making possible a quasi-static distribution of matter, as required by the fact of the small velocities of the stars"(Moszkowski,1921:127).

Einstein's model of the universe was challenged by the Dutch mathematician Williem de Sitter, who argued that the curved fabric of

space-time was continually decreasing(Clark,1972: 269; Gamow,1956:140). Thus, in de Sitter's cosmos, the universe was constantly increasing in size; space was becoming less curved and more in line with Euclidean geometry(Clark,1972:269; Gamow,1956:140).

Indeed, another voice echoed de Sitter's critique of the cosmological constant. In 1922, a Russian mathematician by the name of Alexander A. Friedmann noticed a small, but serious error in Einstein's proof of a static universe. In the words of one of Friedmann's most famous students, George Gamow:

"It is well known to students of high-school algebra that it is permissible to divide both sides of an equation by any quantity, provided that this quantity is not zero. However, in the course of his proof, Einstein had divided both sides of one of his intermediate equations by a complicated expression which, in certain circumstances, could become zero.

"In the case, however, when this expression becomes equal to zero, Einstein's proof does not hold, and Friedmann realized that this opened an entire new world of time-dependent universes; expanding, collapsing, and pulsating ones. Thus Einstein's original gravity equation was correct, and changing it was a mistake. Much later, when I was discussing cosmological problems with Einstein, he remarked that the introduction of the cosmological term was the biggest blunder he ever made in his life"(Gamow,1970:149-150).

Thus, the field equations of the general theory insisted that the universe was not static; it was evolving, changing with the passage of time. But Einstein refused to withdraw his cosmological constant, abandoning it only in 1930 when a young astronomer by the name of Edwin P. Hubble proved that the universe was indeed expanding(Clark,1972:270; Gamow,1956:145). Thus, for the first time in many years, Einstein's famous intuition had been neutralized at the hands of nature.

5.3 The Hubble Expansion and the Beginning of Time

In the late seventeenth-century, Isaac Newton discovered that if sunlight passes through a three-dimensional glass triangle, known as a prism, it breaks up into its basic, constituent colors, called a spectrum, identical to the spectrum of colors one would see in a rainbow(Hawking,1988:37). This same principle can be used to analyze the light coming to us from stars, or galaxies, located millions of light years away. By studying the spectrum of a star, scientists can estimate the stars surface temperature and chemical composition(Hawking,1988:37; Sagan,1980:254). Indeed, spectrographic analysis was to play a large role in founding modern day cosmology.

In the 1920's, shortly after World War I, a young astronomer by the name of Edwin P. Hubble arrived on the doorsteps of the Mount Wilson Observatory in Pasadena(Clark,1972:523; Gamow,1956:145; Sagan,1980:254). Using the Observatory's hundred-inch telescope, one of the most powerful light collecting instruments at the time, Hubble probed the enigmatic, cosmic night. In time, Hubble made an astonishing discovery: according to his data, the spectra of a large majority of the galaxies visible to the human eye, appeared red-shifted; the more distant the galaxy, the more red-shifted were its spectral lines(Sagan,1980:254).

Before this finding, many scientists believed that the galaxies were moving through the universe in a purely random fashion, and thus, expected to find as many blue-shifted spectra as red-shifted ones(Hawking,1988:39). Yet Hubble shattered this expectation with his detailed observations of the night sky. Furthermore, Hubble also discovered that the size of a galaxy's red-shift could not be attributed to random factors; it appeared that the size of a galaxy's red-shift was directly proportional to the galaxy's distance from the

Earth(Hawking,1988:39; Sagan,1980:254).

In order to fully comprehend the implications of Hubble's findings, a brief discussion must be undertaken on the phenomenon known as the Doppler effect.

The Doppler effect is a common fact of everyday life. An ambulance driver speeding past you turns on the siren. Inside the vehicle, the driver hears a steady sound at a fixed pitch, or frequency. But outside the ambulance, the pedestrian perceives a steady change in pitch over a period of time; that is, as the ambulance approaches you, the sound of its siren seems to increase steadily with each passing second. When the ambulance just passes you, the sound of its wail is quite intense. But as the vehicle moves away, the sound of the siren begins to decrease in intensity, until it fades into silence(Sagan,1980:252).

Since sound is simply a succession of waves travelling through air, the closer the spacing of the waves, the higher the frequency, or pitch; the farther apart the waves are, the lower the frequency, and hence, the lower the pitch perceived(Hawking,1988:38; Sagan,1980:252).

As we have discussed in earlier sections, light can also be thought of in terms of a wave function. For example, if our ambulance were emitting a beam of white light from its front and back, instead of sound, the frequency of the light would increase by a small amount as the ambulance approached us. Since each successive wave of light is emitted from a point slightly closer to you with each passing second, you detect a shorter wavelength than you would if the ambulance were at rest(Hawking,1988:38; Kaufmann,1988:96-97; Sagan,1980:253). If you were to analyze the spectrum of this light, you would see that it was shifted toward the blue (short-wavelength) end of the spectrum. This is referred to as a blue-shift(Kaufmann,1988:97).

Conversely, the frequency of light emitted by the ambulance would

decrease as it receded from you; all the light waves would be stretched out, like a rubber band. Hence you see a slightly longer wavelength than you would if the ambulance were at rest. Since all the spectral lines are shifted toward the red (longer-wavelength) end of the spectrum, you would say that the light was red-shifted(Hawking,1988:39; Kaufmann,1988:97; Sagan,1980:253).

By calculating the spectral shift of light, scientists can calculate how fast a galaxy is moving relative to the Earth.

In fact, in the pragmatic, everyday world, the Doppler effect is used by police officers to compute the speed of cars by measuring the frequency of radio waves reflected off them(Hawking,1988:39; Kaufmann,1988:98).

Hubble's analysis indicated that there is a direct correlation between the distance to a galaxy and the size of its red-shift. Thus, nearby galaxies are moving away from us at a relatively slow pace, whereas distant galaxies are speeding away from us at a very high rate. Since no other logical explanation could account for the galaxies' red-shift, Hubble interpreted the red-shift as a manifestation of the Doppler effect(Gamow,1956:145; Kaufmann,1988:518).

Indeed, Hubble calculated the distances to a number of galaxies. Then, drawing upon the Doppler formula, he calculated the speed with which each galaxy is receding from us. Plotting this data on a graph of distance versus speed, a very strong linear relationship appeared; Pearson r for this data is around the + 0.9 level. This relationship between a galaxy's distance and its red-shift is known as the Hubble law(Kaufmann,1988:518). The Hubble law is symbolized by the following formula:

$$v = H_0 r$$

where v is the recessional velocity, r is the distance, and H_0 is a constant called the Hubble constant (Kaufmann, 1988:519). Recent calculations put the Hubble constant at:

$$H_0 = 50 \text{ km/sec/Mpc};$$

this expression is read, fifty kilometers per second per megaparsec; a parsec is equivalent to 3.26 light years, and one light year is approximately 9.4×10^{12} kilometers (Kaufmann, 1988:346, 519).

In essence, Hubble's discovery that we live in an expanding universe represented nothing less than a conceptual revolution within physics. It catapulted the general theory from the realm of abstract thought into the pragmatic, everyday world.

Yet, upon closer examination, theorists realized that Hubble's remarkable finding had one serious implication. According to Einstein's special theory of relativity, space is not a solid, rigid entity, but can change over a period of time (Kaufmann, 1988:551). In order to better understand this phenomenon, imagine that you are blowing up a balloon. Now suppose that one-cent coins, each coin representing a galaxy, are attached to the surface of the balloon. As the balloon expands, the amount of physical space between the coins grows with each passing second. This is roughly analogous to what is happening in the cosmos; the amount of space between the galaxies is increasing with the passage of time. Thus, the expansion of the universe represents the expansion of space itself (Kaufmann, 1988:551).

In the mid 1920's, Hubble gave a lecture on his findings at a meeting of the National Academy of Sciences in Washington (Clark, 1972:524). In the audience, listening with great interest to Hubble's speech, was a young Belgian priest and astrophysicist by the name of Abbé Lemaitre. In time, Lemaitre published

a paper analyzing Hubble's findings from a purely theoretical perspective. In the 1927 article, Lemaitre argued, as did Friedman in 1922, that the general theory demanded a non-static, evolving universe. However, Lemaitre went one step further in his thesis and proposed that the universe had started from a highly compact and extremely hot state he entitled the "primeval atom"(Clark,1972:524; Gamow,1956:145).

And so, at the hands of a humble priest turned mathematician, one "...for whom symmetry was nearly important as truth"(North,1965:118), the idea of a universe born at a finite time in the past, was given academic life. In time, Friedman embellished upon Lemaitre's theoretical model of the cosmos, and thus, forever reinforced the notion that the universe was not an entity of infinite age, but one that had come into existence in an age so ancient that even the cycle of time had not yet begun.

In essence, while Einstein did not explicitly create the paradigm of a universe born from the chaotic waters of a "primeval atom", his general theory did. And thus, from the field equations of an abstract model, the metaphysical idea that time had a definitive beginning, rushed like a torrent across the rational landscape of theoretical physics.

5.4 The Big Bang

The empirical evidence seems to suggest that the universe is in a state of expansion. If this is indeed an accurate interpretation, then it would imply that at some point in the ancient past all the matter and energy in the cosmos was concentrated in a state of infinite density; indeed, at this very early stage in its history, the universe mimicked the center of a black hole, an entity referred to as a cosmic singularity(Kaufmann,1988:552).

It is assumed that some primeval explosion ruptured this singularity and initiated the expansion of space and time, an explosion dubbed the Big Bang. Using Hubble's law, and employing a certain degree of algebraic dexterity, one can estimate the time elapsed since the Big Bang; recent estimates put it at about 20 billion years, give or take a few billion(Kaufmann,1988:552-553).

It should be noted that the colorful title of the Big Bang is very misleading. For instance, the ancient explosion which created the cosmos we see today, was not an explosion in the literal sense of the word; to compare it to an exploding bomb would be an inaccurate representation. When a bomb explodes, pieces of shrapnel and debris accelerate into space from a central, fixed location at various speeds, at specific angles. Thus, in theory, you should be able to trace all the pieces back to their initial location, to their origin, and estimate where the bomb had been placed. This procedure is pragmatically impossible when studying the structure of the universe, because the universe is nothing less than the embodiment of space itself; the universe has no physical boundary; by definition, it cannot have a physical edge(Kaufmann,1988:554; Gamow,1956:146). In essence, the Big

Bang represents nothing less than the expansion of space itself at the dawn of time(Kaufmann,1988:554; Mather,1993:28).

The Big Bang theory is quite abstract, and its tale of the origin of the universe is, at times, hard to digest, partly because it deals with a reality that will forever stand beyond the grasp of human experience. However, from a purely mathematical perspective, the Big Bang makes perfect sense.

Of course, the value of any paradigm rests in its ability to explain a large class of phenomena, and to make solid predictions about the physical world, predictions that are susceptible to empirical verification. While the original version of the Big Bang model had been born in the gifted mind of a humble Belgian priest, the modern, polished descendant of Lemaitre's framework was crafted at the hands of George Gamow and his merry band of graduate students working at George Washington University(Kaufmann,1988:555; Peebles et. al,1994:56).

In the wake of World War II, George Gamow and his cluster of young scholars, argued that the universe immediately following the Big Bang looked like a primordial fireball with temperatures so hot that thermonuclear reactions could have occurred easily throughout space. Their calculations showed that as a result of the Big Bang, the mass of the present day, visible universe should be approximately 75% hydrogen, 24% helium, and the remaining 1% consisting of heavier elements such as carbon. This quantitative prediction has since been validated by astronomical observations to a high degree of accuracy, and is now one of

the empirical pillars of the Big Bang model(Gamow,1956:152; Gribbin,1993:25; Peebles et. al,1994:56; Kaufmann,1988:556; Mather,1993:28).

Gamow's Big Bang theory made another definitive prediction. Gamow argued that when the universe was in its infancy, radiation could not have propagated very far without being absorbed and emitted by at least some atomic particles. This constant absorption and emission of electromagnetic radiation facilitated a state of thermal equilibrium; that is, the probability of any one particular region of the early universe being hotter or colder than the mathematical average, was quite small. In such a physical reality, the intensity of radiation at each wavelength is a discrete function of the temperature. Thus, radiation born during the fiery first microseconds of the Big Bang can be detected today, in the twentieth century, by its thermal signature(Gamow,1956:152; Mather,1993:28; Peebles et. al,1994:56).

Gamow postulated that as the universe expanded from its state of infinite density, the radiation field of the Big Bang began to cool and atrophy at a constant rate. Since the universe has expanded to such a phenomenal size since its birth, this primeval radiation has, as a consequence, now been so stretched (eg. red-shifted) that its effective temperature should be around 3 to 5 degrees Kelvin⁸. Of course, at the time Gamow made his prediction, the technological equipment of the day could only test this hypothesis to crude levels of accuracy. But since those pioneering times, the theoretical radiation field of the Big Bang

⁸ Zero degrees Kelvin equals -273.16 degrees Celsius. This temperature is known as absolute zero, the point at which all molecular motion stops; it is the lowest possible temperature(Kaufmann,1988:610).

has been conclusively documented(Gamow,1956:152; Gribbin,1993:27; Kaufmann,1988:556; Mather,1993:28; Peebles et. al,1994:56).

In the 1960's, two engineers, Arno Penzias and Robert Wilson, working for Bell Telephone, were testing a new microwave antenna that was supposed to relay telephone calls to orbiting communication satellites. To their annoyance, the two researchers discovered that it was detecting unexpected radiation, radiation that appeared to be coming from all directions in the sky. This radiation was so uniformly distributed about the heavens that it could not have possibly been generated by the solar system or our galaxy. Penzias and Wilson concluded that they had detected the primordial radiation of the Big Bang(Kaufmann,1988:556; Mather,1993:28; Peebles et. al,1994:56).

Since those exciting days, scientists have made countless measurements of this radiation, known today as the cosmic background radiation because of its fairly long wavelength(Mather,1993:28). Indeed, preliminary analysis conducted in the 1970's and 1980's revealed that this radiation possessed a temperature of approximately 3 degrees Kelvin, in excellent agreement with Gamow's predictions.

Yet, there was a serious problem. Scientists realized that the background radiation field was too smooth, too perfectly uniform. If the radiation emanating from all parts of the sky is incredibly smooth, or isotropic, that implies that the early universe was perfectly smooth; all the matter and energy in the cosmos was evenly distributed throughout space at one point in the distant past. But present day observations reveal that we live in a very clumpy universe, a universe in which hydrogen and helium are squashed into stars, which in turn are squeezed into gigantic clusters known as galaxies, and even galaxies tend to merge together into superclusters. So how could a very smooth pool of hydrogen

and helium and radiation have evolved into the uneven universe we see today(Gribbin,1993:xi,35).

Mathematical models based on the Big Bang theory postulated that the early universe was not perfectly uniform, that indeed there were tiny inhomogeneities in the infant cosmos, slight concentrations of matter, cosmic "seeds" from which evolved the universe we know today, a universe dotted with planets, stars, galaxies, and globular clusters(Gribbin,1993:xi,41).

Of course, technological limitations prevented scientists from determining how smooth the radiation really is. But fortunately for all concerned, in late 1989, NASA launched COBE (Cosmic Background Explorer), a satellite specifically designed to measure the background radiation to unprecedented levels of accuracy. Preliminary results registered a universe too uniform to allow the evolution of galaxies, let alone other large scale structures. But since the theoretical concentrations of matter required to validate the Big Bang were so incredibly small, it would take some time - perhaps months, or years - before COBE could detect them with any degree of accuracy(Gribbin,1993:xiii; Mather,1993:28-29).

Then in April of 1992, NASA announced the astonishing news that COBE had indeed discovered the predicated inhomogeneities in the early cosmos. COBE's sophisticated sensors registered deviations from unity amounting to one part in a 100,000, deviations representing primeval density fluctuations in the early universe just as predicted by theory. COBE also calculated the temperature of this ancient radiation to unprecedented levels of precision; analysis has revealed that the background radiation has a temperature of 2.726 ± 0.01 degrees Kelvin(Peebles et. al,1994:56; Turner,1993:861).

Naturally, cosmologists were thrilled with COBE's measurements. At long last, here was the empirical evidence scientists had been searching for, evidence that suggested that the universe had indeed been born in violence, born from an ancient, cataclysmic explosion known as the Big Bang.

As a theoretical model, the Big Bang is compelling: it explains the Hubble expansion, the abundance of hydrogen and helium in the universe, and the cosmic background radiation(Peebles et. al,1994:57). As P.J.E. Peebles, one of the most eminent cosmologists working today writes, "Whatever developments the coming decades may bring, cosmology has moved from a branch of philosophy to a physical science where hypotheses meet the test of observation and experiment"(Peebles et. al,1994:57).

5.5 The Plasma Alternative

While COBE's results sharpened many cosmologists belief in the validity of the Big Bang theory, these same results strengthened the convictions of a small group of plasma physicists - or plasma cosmologists as they refer to themselves - who believe that the Big Bang model represents an inaccurate description of the cosmos. From the point of view of these physicists, empirical observations of the universe are far more consistent with plasma cosmological models, models based on electromagnetic theories, and the philosophical belief that the universe has existed for an infinite length of time(Lerner,1991:4).

Perhaps the most vocal plasma cosmologist , is a young researcher by the name of Eric J. Lerner, whose first book The Big Bang Never Happened (1991), intensified the cosmological debate and exposed it to a broad audience of both physicists and non-physicists alike(Lerner,1991:xxii).

Although Lerner is a plasma physicist, he does not possess a doctorate in physics. He is a prolific researcher, but is not associated with any scholarly institution. Nevertheless, Lerner is a scientist of some distinction. He is an award winning science writer with numerous publications to his credit, and the electronic editor of Aerospace America, a monthly journal devoted to covering issues within the aerospace engineering community.

While he majored in plasma physics at university, he has always had an interest in cosmology, the study of the origin and evolution of the cosmos. Even as a student, Lerner found the theoretical assumptions of the Big Bang hard to accept from both a philosophical, as well as an empirical stance. The abstract notion that the universe came into existence from an entity smaller than an atom, seemed hard to reconcile with known laws of physics. From Lerner's point of view, the Big Bang theory is nothing more

than a mathematical abstraction, a conceptual framework that bears little resemblance to the physical world. Its highly theoretical argument that the universe had emerged from a cosmic singularity smaller than atom, and had miraculously expanded a trillion-trillion fold in a trillion-trillionth of a second, seems not only strange, but physically impossible(Lerner,1991:11). Yet, it is one of the most revered models in theoretical physics, and represents a single shared paradigm within cosmology, a standard model by which scientists can study the cosmos, and seek solutions to specific problems, problems that take on a unique significance in the light of such a communal model(Brush,1990:48).

Lerner believes that this devotion to the Big Bang is misplaced. Cosmologists are in a state of denial, he argues, overlooking evidence that has accumulated over the years that clearly shows that the Big Bang is highly flawed(Lerner,1990:39).

The main problem with the Big Bang, according to Lerner, is that it argues that the universe has a finite age; approximately 20 billion years have elapsed since that primordial explosion, so long ago. Thus, the theory predicts that there should be no objects in the cosmos beyond a specific size, around 100 million light-years across(Lerner,1990:39). However, in the 1970s, scientists detected the presence of entities known as superclusters spanning the heavens, long strings of clusters of galaxies so large that they were posing a serious challenge for cosmologists. Then, in 1986, R. Brent Tully of the University of Hawaii, showed that the superclusters were grouped into

even larger structures. These massive super-superclusters represented ribbons of galaxies about one-billion light years in length, 300 million light-years wide, and 100 million light years thick, separated by empty voids approximately 300 million light-years across(Lerner,1990:39).

Based on empirical observations, scientists can estimate how fast galaxies are moving through space; velocities are, at most, approximately 1,000 kilometers per second. Given this reality, it would take time about 80 billion years to weave Tully's massive superclusters, or four times as long as the time since the Big Bang explosion(Lerner,1990:40; Lerner,1991:12).

At first, theorists rejected Tully's observations, arguing that the conglomerations he detected were statistical aberrations. Yet, in 1989, astronomers Margaret J. Geller and John P. Huchra of the Harvard-Smithsonian Center for Astrophysics, amassed enough data to prove conclusively that these vast tendrils of luminous matter were indeed enormous structures bound together by the force of gravity(Lerner,1990:40; Lerner,1991:13).

The discovery of the supercluster was cause for concern within the cosmological community. Since the Big Bang model states that all the matter and energy in the universe had at one time been concentrated at a dimensionless, mathematical point, the cosmos must have been, before its birth, perfectly smooth and homogeneous(Lerner,1991:13; Gribbin,1993:37). If this was indeed the case, then it begs the following empirical question: How do you go from the perfectly smooth universe of twenty-billion years ago, to the clumpy, uneven universe of today(Lerner,1991:13).

According to theory, cosmologists believe that approximately

300,000 years after the Big Bang, inhomogeneities began to materialize in the distribution of matter in the primordial sea, with hydrogen and helium gas interacting with dark matter to weave ancient "seeds", entities that would eventually blossom into the stars and galaxies we see today (Gribbin, 1993:37; Mather, 1993:29). Physicists argued that if these density perturbations had formed in the very early universe - that is, before the estimated time of 300,000 years - then they should show up as very hot and bright spots in the famous cosmic background radiation (CBR); if the structures were created around 300,000 years after the Big Bang, then the energy to accelerate the matter and then halt its progression through space, would materialize as distortions in the CBR (Lerner, 1990 :41).

When NASA launched the COBE satellite, cosmologists predicted that the distribution curve of the CBR would mimic a blackbody spectrum. The term blackbody refers to a theoretical entity that is in perfect thermal equilibrium, neither emitting nor absorbing energy from its surroundings. Since the CBR was born in an "explosion" involving the entire cosmos, it must have been, by definition, in a state of thermal equilibrium; there were no surroundings for the Big Bang singularity to get energy from or give it to (Lerner, 1990 :41; Lerner, 1991:29).

In 1992, COBE signalled its human makers and reported that the CBR mimicked the blackbody curve like a glove, deviating from unity by one in a hundred thousand (Lerner, 1990 :41; Lerner, 1991:30; Peebles et. al, 1994:56).

Now, cosmologists were obviously thrilled with COBE's performance. The fluctuations observed in the background confirmed - to scientists, anyway - that the early universe was not perfectly homogeneous, that it did contain pockets of non-uniformity. But Lerner argues that the CBR

measurements are too perfect. For example, dissipating the energy from the formation of Tully's superclusters would create a 2% distortion in the CBR. The COBE results ruled out such massive energy releases. In addition, theoretical predictions concerning the size of the CBR fluctuations were far from solid; estimations ranged from deviations of a few parts per hundred thousand to a few parts in ten million. This erratic pattern of predictions almost guaranteed that predictions of the background radiation would be validated by COBE(Lerner,1991:xxi,31).

Yet, cosmologist P.J.E Peebles argues that the CBR predictions are not in any serious trouble. Mathematical modelling predicts that irregularities in the CBR, or anisotropies, should be seen down to levels of less than one part in one-million; if no anisotropies are detected at this level, then the Big Bang is in serious trouble(Peebles,1991:774). But, for the moment, COBE has only detected variations of one in a hundred thousand, lending weight to Lerner's argument that the CBR is not the echo of the Big Bang.

Lerner's attacks on the COBE background results do not sit well with some physicists. Peebles, for one, thinks Lerner's comments concerning the CBR are far from air tight(Peebles,1991:775). Theoretical physicist, Peter J. Watson, chair of the physics department at Carleton University, makes the following rebuttal:

"It's partly true. As I've said all along, that I think, it's perfectly possible the standard Big Bang, is wrong. But the point is, it's testable. And it's perfectly reasonable to attack it. The attack you're getting here is simply wrong, I mean it's factually wrong. [Quoting from Lerner's text] Dissipating the energy from the Great Wall's formation in twenty-billion years would create a 1% distortion in the background spectrum. Now, it depends entirely how you create galaxies. If you create galactic clusters by just gravitational forces, then that's true; you don't have enough time since the Big Bang essentially to form them. Since no one knows how those structures are created, for certainty, it's not an argument against the Big Bang; no one can mimic the production of superclusters"(Watson,1995).

Yet, George Smoot of the University of California at Berkeley, one of the many scientists who worked on the COBE mission, states, "Using the forces we now know, you can't make the universe we know now"(cited in Lerner,1991:32). His colleague, John Mather, remarked, "If these theories are right, we shouldn't be here"(cited in Lerner,1990:42).

Lerner next aimed his verbal arrows at another conceptual pillar of the Big Bang theory. One aspect of the Big Bang that draws considerable admiration from cosmologists, is its ability to predict the relative abundances of the light elements such as helium, deuterium, and lithium; these elements compose about 24% of the visible universe, with hydrogen and other heavier elements composing the remaining 76%(Peebles et. al,1994:56). However, Lerner argues that this statement is misleading. The Big Bang, he states, predicts the various elemental abundances as a function of density, density as measured by the number of protons per ten billion photons. From Lerner's point of view, no one density accurately fits all three abundances, thus indicating another conceptual flaw in the theory(Lerner,1991:xx).

But cosmologists P.J.E Peebles strongly disagrees. He argues that the density of protons and neutrons in the universe, a value computed from empirical observations of the cosmos, predicts the relative abundances of the elements quite nicely. For example, the model predicts that helium should compose approximately 24% of the mass of the universe, a prediction that had long since been validated. Of course, if strange entities such as dark matter do indeed exist, then these predictions will have to be modified, along with assumptions concerning the density of matter in the universe(Peebles et. al,1994:56).

In time, new observations, on another empirical front, once again challenged the Big Bang. In 1995, two young scientists, Tod Lauer and

Marc Postman, of the Space Telescope Science Institute, in Baltimore, Maryland, made an exciting discovery. After a year's worth of celestial stargazing, the two researchers found that rather than expanding outward into the cosmic abyss like the rest of the universe, a few thousand galaxies, including our own Milk Way, spanning about a billion light years, were racing through space toward a point in the general direction of the constellation Virgo(Lemonick & Nash,1995:37).

This observation was initially greeted with suspicion, mainly because it contradicted conventional cosmological wisdom. However, even to this day, no one has been able to detect a flaw in Laure and Postman's methodology(Lemonick & Nash,1995:37).

To compound the problem, astronomer Wendy Freedman and her colleagues at the Carnegie Observatory in Pasadena, California, threw yet another boulder into the now intensifying Big Bang debate. Using the resuscitated Hubble Space Telescope, Freeman calculated that the age of the universe is between 8 to 12 billion years old, in effect, making it about 2 billion years younger than some of the stars it contains. Of course, one must take these results with a grain of salt; Freedman herself acknowledges that her analysis could be off by as much as 20 percent(Lemonick & Nash,1995:37,41). Yet, this very strange observation is being taken seriously because of the reputation of Freedman and her associates, and because her analysis is based on the powerful vision of the Hubble Space Telescope. In addition, her conclusion that we live in a relatively young universe, validates other studies that have emerged in recent years arguing for a young cosmos(Lemonick & Nash,1995:40).

Yet, some astronomers find Freedman's results a little hard to

swallow. Christopher Impey of the University of Arizona's Steward Observatory, made the following humorous comment, "You can't be older than your ma"(cited in Lemonick & Nash,1995:38).

For their part, cosmologists have taken the recent attacks on their theory in stride. While they find Freedman's analysis cause for concern, they point out that her measurements are fraught with potential errors, as Freedman herself points out. Furthermore, her estimates concerning the age of the universe is based on the assumption that the Hubble constant is fairly high. Yet, the fact remains that there is as much support for low values of the constant as for high ones(Powell,1995:19). As Bradley E. Schaefer of Yale University states, "There ain't no consensus out there"(cited in Powell,1995:19).

While acknowledging the many observational problems currently plaguing the Big Bang, cosmologist P.J.E Peebles argues that it is the best model available with which to study the cosmos. He argues that, "Most cosmologists would be delighted to abandon the standard model for something new to think about if only the alternatives looked reasonably promising"(cited in Wade,1994:38).

One of these alternatives is the plasma cosmological model of cosmic evolution, a model Lerner designed in conjunction with other plasma physicists. The plasma model draws upon electromagnetic theories to explain the large scale development and structure of the universe. A brief discussion of the physics behind plasma cosmology will now be presented.

Plasma physics concerns the study of one of the most energetic and spectacular entities of the cosmos, entities referred to as plasmas. A plasma is a hot, electrically conducting gas. In ordinary gases

circulating within the Earth, electrons are tightly bound to their individual atoms, thus, severely restricting their degree of freedom, or motion. However, in a plasma, the temperature is so hot - reaching into the millions of degrees Celsius - that the electrons are literally ripped off their atomic hosts, free to wander where they will, elevating the gas from an inert substance, into an entity capable of conducting electricity and susceptible to magnetic fields(Lerner,1991:14).

In many ways, plasma can be conceptualized as the "oceans" of the universe, the most abundant force permeating the fabric of space. Approximately 99% of the visible matter i., the universe is plasma(Alfvén,1986:26; Lerner,1991:14). Plasma physicists believe the cosmos is bathed in vast electrical and magnetic fields, fields that might have played a crucial part in the evolution of the universe as we know it today(Alfvén,1971:993; Lerner,1991:14). Empirical data gathered by the Hubble Space Telescope seems to confirm plasma physicists' belief of the importance of electromagnetic forces in the cosmos. This finding has convinced many plasma cosmologists like Lerner, that plasma processes might serve as a worthy opponent to the Big Bang(Lerner,1991:38-39).

As an independent researcher with no academic affiliation, Lerner could not circulate his plasma model among departmental colleagues or graduate students for the purposes of obtaining constructive criticism and helpful suggestions. Yet, despite this drawback, Lerner was fortunate enough to have friends within the plasma community, researchers who were in fact associated with the realms of academia and the scientific establishment, and who were sympathetic to his views. Before long, his professional associates introduced him to a living legend within plasma physics, a researcher named Hannes Alfvén.

Hannes Olof Gosta Alfvén is considered by his peers as the virtual founder of modern plasma science(Lerner,1991:40). In 1970, Alfvén was awarded the Nobel prize for his pioneering work in plasma physics(American Men & Women of Science,1993:80). While this most prestigious of elite awards assured his eminence within the plasma community, Alfvén discovered that his title as a Nobel laureate did little to impress his colleagues in cosmology, a field he touched upon numerous times in his career.

While the bulk of Alfvén's academic and professional career was devoted to investigating traditional issues in plasma physics, his personal interest in cosmology caused him to enter the field for brief instances during the course of his scholarly tenure. Although Alfvén found cosmology a fascinating endeavor, he has always viewed the Big Bang theory with suspicion. To Alfvén, the notion that the universe emerged from an "explosion" twenty billion years ago, seems to contradict everything that is known about the observable universe; we don't see stars, planets, matter and energy in the present day cosmos emerging from mathematical points(Lerner,1991:56). In his own words:

"...the present is the key to the past. In other words we should not approach a historical problem in science by making a guess about how the conditions were in a certain region several billion years ago because the probability that such a guess is correct is close to zero. Instead we should start from the present conditions"(Alfvén,1988:394).

But Alfvén's attacks on the Big Bang did little to unnerve theoreticians in cosmology. From their point of view, Alfvén's ideas were bereft of empirical evidence. To suggest as Alfvén was doing that electromagnetic forces could explain the structure of the universe with greater accuracy than Einstein's general theory of relativity, was nonsense. As most cosmologists point out, there is no solid evidence that supports the notion that electromagnetic forces are strong enough on cosmological scales to influence the evolution of large scale structures(see Watson interview,1995:Appendix A).

To Alfvén, the cosmological community's response to his beliefs were far from democratic. In many ways, cosmologists reacted to Alfvén's strange ideas like any social group confronted with the new and strange. It was like, 'My grandpa played with the Big Bang, my pa played with the Big Bang, and none of them would buy what you're selling'(Gleick,1987:305).

In essence, the attitude of most cosmologists to Alfvén was, he may be a legend within plasma physics, but he was not a cosmologist and never would be one in their eyes.

In the end, Alfvén's critiques hardly mattered. At the time Alfvén was attacking the Big Bang, technological limitations prevented accurate testing of the Big Bang's predictions. By the time the Big Bang model had passed from the realm of philosophy into that of a physical science, Alfvén had effectively retired from the academic scene. Now, at the age of 88, Alfvén spends much of his time guiding a new generation of anti-Big Bangers like Eric Lerner who wish to topple cosmology's orthodox paradigm.

Lerner believes that while the Big Bang has serious difficulty in

explaining the clumpy structure of the cosmos, this observation can be reconciled within a plasma model. For example, currents flowing through plasma tend to surround themselves with a cylindrical magnetic field; this field in turn attracts other flows of electrical current. The currents then come together, drawing the plasma with them. Over time, the plasma evolves into long, threadlike filaments of glowing gas(Lerner,1990:42).

According to Lerner, computer simulations seem to suggest that plasma processes alone can, in a few hundred billion years, form the cosmos and its massive inhabitants we see today. Since the plasma model does not assume a Big Bang, time is not a concern(Lerner,1990:43; Lerner,1991:49).

Of course, if Lerner's model was to pose a serious threat to the Big Bang, it had to grapple with one of the main pillars of theoretical cosmology, namely the cosmic background radiation, or CBR. The paramount challenge, as Lerner saw it, was to account for, not only the CBR, but also its very isotropic nature. In time, Lerner began to develop an alternative explanation for the background radiation.

In his investigation, Lerner recalled the work of Martin Rees of Harvard University who, in 1978, proposed that the CBR had been wrought by massive stars in the early stages of galactic creation. The radiation generated by these stars could have been in the form of ultraviolet radiation and visible light, radiation that could have been absorbed by clouds of interstellar dust and re-emitted as infrared radiation. Empirical data gathered by the IRAS satellite (Infrared Astronomical Satellite), indicates that the early galaxies appear to shine about 500 times as brightly as our own galaxy in the infrared, lending weight to this argument(Lerner,1990:43;Lerner,1991:268).

While this provided an alternative explanation for the origin of the CBR, a more imaginative analysis would have to be undertaken in order to explain its very smooth spectrum. Thus, with the assistance of fellow plasma physicist, Tony Peratt, Lerner constructed a working model that seems to explain the CBR's uniform structure without invoking a Big Bang scenario.

Lerner argues that when electrons become trapped in the intangible web of magnetic field lines, they tend to emit radio waves and microwave radiation. In the vast stretches of space, electrons and powerful magnetic fields interact vigorously within the jets emitted from the nuclei of galaxies(Lerner,1990:43). These jets are simply filaments of gas thousands of light years in length, luminous ribbons of matter that often stretch from the galactic nucleus to the depths of space, like some ghostly arm(Kaufmann,1988:528,537). However, according to a fundamental law in physics, any object capable of emitting radiation of a specific frequency, has the capacity to absorb the same frequency(Lerner,1990:43; Lerner,1991:269). Thus, in essence, photons resonating within the CBR could be absorbed by electrons trapped in galactic jets and re-emitted in different directions. A large number of these filamentary jets would scatter the CBR into a smooth spectrum, similar to the process by which water droplets in fog scatter visible light into a uniform, greyish glow(Lerner,1990:43; Lerner,1991:269).According to Lerner, this model can also account for the temperature of the background radiation. In Lerner's words, "The effective temperature of the electrons in the direction perpendicular to the lines of force is...the same as the background radiation"(Lerner,1990:43).

Lerner contends that theoretical analysis, in conjunction with

experimental data supports his alternative explanation of the background radiation(Lerner,1990:43).

This debate may seem somewhat paradoxical - with both plasma physicists and cosmologists arguing that their individual theories stand up to empirical observation, and attacking one another's models as flawed. Yet, in many respects, it validates Kuhn's thesis of scientific change. Indeed, Kuhn argued that two different groups of researchers, analyzing the same problem from different theoretical perspectives, tend to see evidence that supports their specific paradigm(Kuhn,1970:150). As Kuhn states, "Both are looking at the world, and what they look at has not changed. But in some areas they see different things, and they see them in different relations one to the other"(Kuhn,1970:150).

Not surprisingly, a number of cosmologists objected to Lerner's statements concerning the microwave background. P.J.E Peebles, for one, argues that if Lerner's model is correct, it would generate large anisotropies in the CBR, in direct violation of COBE's measurements(Peebles,1991:775). Peter Watson, on the other hand, offers a more sophisticated rebuttal:

"I believe this is technically wrong, and the reason it's technically wrong is because, if you do something for microwaves, you do the same thing for all other photons. And you know that you get light from distant galaxies. I mean, on page 270 [looking at Lerner's text], there's a perfectly good picture, it's a radio picture, but you can see that galaxy in the middle in optical radiation. Now, how come it scatters microwaves so efficiently and doesn't scatter optical photons at all; the absorption is tiny for optical photons. The second objection to this is that if you produce large random magnetic fields - firstly, there are no large magnetic fields around because I've measured the magnetic field in the galaxy and it's a microgauss; that's measured directly. So now you've got to say, well, for some reason, there are large magnetic fields around - we can't see them; they must be somewhere else. [Laughs] I don't like that sort of theory. But secondly, if they're large and random - large, random things don't produce very, very smooth effects. The scatter analogy is a very bad one, because fog is a very uniform phenomenon. It's like saying, you've got a thunderstorm in one direction and you've got light drizzle in the other direction, and we should be able to see equally in both directions"(Watson,1995).

Yet, Lerner argues that the CBR could not have possibly been generated by some form of primordial explosion.

Lerner analyzed a collection of 237 galaxies, originally compiled by Nicholas Devereux of the University of Massachusetts. His research showed that there was a positive, inverse correlation between the radio luminosity of a galaxy - how "bright" a galaxy is in radio waves - and its distance relative to our planet. The correlation coefficient for this relationship is approximately -0.95 ; the probability that this correlation is due to random factors, is two-in-one-trillion(Lerner,1991:276). Thus, the radio brightness of a galaxy appears to fade rapidly with distance, suggesting that radio waves are being absorbed by some medium. This result implies that radiation born twenty-billion light-years away, could not have reached the Earth without being severely distorted; yet, COBE found only infinitesimal fluctuations in the background radiation. It would appear that the CBR is generated by some physical phenomenon with the capacity to absorb and emit radiation, generated within close proximity to our galaxy, the Milky Way(Lerner,1991:51,276-277; Lerner,1990:63,66-67).

Lerner and his colleagues next set out to explain the abundance of light elements without invoking a Big Bang scenario. For Lerner, existing stars could not have produced the 24% helium found in the universe. Lerner argues that "At the rate they currently produce energy from fusion, only 1 to 2 percent of their hydrogen should have been burned to helium in the twenty-billion years that our galaxy has existed. Therefore, say Big Bangers, the rest derives from a primordial explosion"(Lerner,1991:266). However, Lerner believes there is an alternative explanation.

Research conducted by astrophysicist Martin J. Rees of Cambridge

University in 1978, suggests that the 24% helium now present in the universe, was generated by massive stars, far larger than our sun, in the early stages of galactic creation. In a few hundred million years, these gas giants would have exhausted their fuel supply, leaving the cosmic night in a spectacular supernova, their helium forms now scattered across the vast stretches of space and time(Lerner,1991:50,266).

A more complicated version of this model seems to give a logical explanation for the relative abundances of not only helium, but deuterium, lithium, carbon, and oxygen. According to Lerner, his so called plasma model agrees nicely with empirical observations, thereby fueling his belief that the Big Bang theory is a relic of a by gone era(Lerner,1991:267).

Of course, not all physicists like Lerner's plasma theory. Professor Watson, for example, believes Lerner's explanation of elemental abundances is pure nonsense. In Watson's words:

"Okay. Now again, anyone who knows anything about stellar modelling knows that this is nonsense. Here he's saying that you can have a star that will very cleverly produce 25% helium in its outer layers, blow it off, and retain the heavy elements as part of the seed material. It's just nonsense. I mean, the stellar modelling programs runs very well, and you can predict stars extremely accurately; and what you find is that you start with a star entirely made out of hydrogen, say a hundred times the mass of the sun, and what you'll find is that in a few million years, it will evolve so that it's got a heavy core - those are the heavy elements - around that there will be a thin layer of helium, a few to maybe 10,000 kilometers thick, and it doesn't get mixed up. You don't create 25% helium. It's nonsense"(Watson,1995).

Watson's comments further highlights the Kuhnian notion that what may seem obvious and logical to one group, is not accepted by another. Logic alone cannot convert the opposition to a particular theoretical model, to a specific way of seeing the physical world(Kuhn,1970:150).

The final hurdle in Lerner's quest to undo the Big Bang, was to offer an alternative explanation for the Hubble expansion. Alfvén himself had tackled this question decades ago, and Lerner drew on his theoretical work in this field.

From Alfvén's point of view, a Big Bang would clearly produce an expansion of the cosmos, but an expansion need not be caused by a Big Bang(Alfvén,1988:395; Lerner,1991:51-52). To Alfvén, the apparent expansion of the universe does not necessarily prove that it was caused by a primordial explosion. As Alfvén states, with regard to the Big Bang, the logic that "All dogs are animals' does not prove that 'all animals are dogs'"(Alfvén,1988:395).

Long ago, Alfvén and his former teacher, the late Oskar Klein, attempted to explain the Hubble expansion by another theoretical route. They hypothesized that many billions of years ago, a small corner of the infinite universe - about a billion light years in diameter - had once been a writhing sea of plasma, matter and anti-matter. In time, a massive physical explosion occurred that sent the plasma rocketing through space, plasma that would one day evolve into the galaxies we see today racing across the landscape of infinity(Alfvén,1988:395-396; Lerner,1991:52). Alfvén admits that this cosmic tale is far from perfect, but it allows him to demonstrate to cosmologists his belief that there are alternative ways of conceptualizing the universe apart from the Big Bang(Lerner,1991:52).

Of course, Alfvén's alternative model has no empirical validation to date, and thus, is viewed by many physicists as mere conjecture. Yet, despite this drawback, Alfvén still believes his theories have more credibility than the Big Bang(Lerner,1991:52). In this respect, he is guilty of what he accuses his opponents of doing - constructing wildly speculative models of the cosmos that bear little resemblance to the physical world, a fact cosmologists like P.J.E Peebles and Jeremiah Ostriker are quick to point out.

Chapter 6: Revolutions

This chapter documents in an empirical, quantitative fashion, the difficulties faced by plasma cosmologists in their attempts to challenge the Big Bang theory. The predictions of the Elite-Kuhnian model will now be explicitly tested against the empirical evidence.

6.1 Kuhn and Gramsci

According to the Kuhnian theory of paradigmatic change, new models of knowing are often invented and endorsed by very young scientists, or those new to a particular field. Since these researchers have little or no intellectual investment in the traditional, orthodox paradigm, they are more willing to take a second look at alternative perspectives(Kuhn,1970:90; Stewart,1986:263). Those new to a field of inquiry, having arrived from a different theoretical camp, tend to bring their unique training and paradigms to their adoptive communities, new tools and styles with which to attack an old conceptual problem(Kuhn,1970:90,150-151). Not surprisingly, those who were socialized in the old ways, having built their careers upon the traditional paradigm, will inevitably resist change. This resistance is born of the belief that the older paradigm is a reliable one, having survived years, if not decades of empirical testing. To give up such a well worn model for something new and untried, is a cause for concern, and understandably so(Kuhn,1970:151).

Yet, the Kuhnian model does not predict that all orthodox scientists will resistance alternative explanations in the face of conceptual and empirical anomalies, or will never change their minds in the light of persuasive arguments for paradigmatic change. What it does predict is that conceptual revolutions take time, with conversions to a new model happening in discrete steps(Kuhn,1970:151-152). As Kuhn states, "Conversions will occur a few at a time until, after the last holdouts have died, the whole profession will again be practicing under a single, but now different, paradigm"(Kuhn,1970:152).

From Kuhn's point of view, paradigmatic resistance is intertwined

with orthodoxy, which in turn is born of academic specialization. Indeed, from the moment new recruits to science open their textbooks, and begin to attend classes, they have, in many respects, entered through the doors of scientific socialization. From day one, these future scholars are taught the age old art known as problem solving. These problems represent the kinds of cognitive brain twisters that scientists often encounter under "real" working conditions. The solving of such mathematical problems usually follow a conceptual algorithm, a step-by-step methodology by which a solution can be discovered. Indeed, problem solving initiates students in an accepted style of achievement, the normative rules one must follow in order to climb the academic ladder(Kuhn,1970:165-166; Gleick,1987:37). As Kuhn writes:

"Under normal conditions the research scientist is not an innovator but a solver of puzzles, and the puzzles upon which he concentrates are just those which he (sic) believes can be both stated and solved within the existing scientific tradition"(Kuhn,1977:234).

Thus, intellectual specialization dictates a proper way of conducting scientific research. It represents a conceptual map of the scientific landscape, delimiting the areas that are considered safe and proper, and those that are considered cognitively problematic.

In the context of theory change, academic specialization and socialization, forces the proponents of competing paradigms, to view the same conceptual problem from different points of view, from different theoretical perspectives. This reality further impedes the process of communication, and reinforces the convictions of both groups that their opponents are attacking a specific scientific problem with the wrong conceptual tools and models. As Kuhn states:

"Practicing in different worlds, the two groups of scientists see different things when they look from the same point in the same direction. Again, that is not to say that they can see anything they please. Both are looking at the world, and what they look at has not changed. But in some areas they see different things, and they see them in different relations one to the other"(Kuhn,1970:150).

Kuhn's comments above, resonates nicely with the Big Bang, plasma debate. Cosmologists and plasma physicists both exist in highly specialized fields, their training emphasizing specific theories and conceptual problems. In one group, Einstein's general theory of relativity constitutes a standard, conceptual model; in the other, theories of electromagnetism and plasma. For one, the universe was born in violence at a finite point in time; in the other, the universe has neither a beginning nor an end(Kuhn,1970:150; Lerner,1991:53).

Indeed, as if to highlight Kuhn's argument that two different theoretical groups tend to view the physical world from different conceptual perspectives, Princeton cosmologist, Jeremiah Ostriker, made the following comment concerning plasma cosmology: "There's no observational evidence that I know of that indicates that electrical and magnetic forces are important on cosmological scales"(cited in Lerner,1991:53). This is a comment many plasma cosmologists would undoubtedly dispute.

In essence, cosmologists and plasma scientists represent Kuhn's two conceptual communities, groups that "...see different things, and...in different relations one to the other"(Kuhn,1970:150). Both theoretical camps exist in different worlds, attend specific conferences, meet with their intellectual stars, and publish in journals that are group specific(Lerner,1991:53). Indeed, as Eric Lerner states, "...plasma physicists...publish in electrical engineering and related journals, not

the magazines that most astronomers read"(Lerner,1991:53). As such, it is not surprising that the two groups would study the same topic from different points of view, and inevitably come to conflicting conclusions with respect to one another.

Of course, the value of a new paradigm is its ability to solve questions which the older paradigm has difficulty addressing. If the new model can give precise, quantitative predictions that are better than the old, predictions that can explain a broad range of phenomena on the basis of a few conceptual elements(Hawking,1988:9), then it is likely to succeed(Kuhn,1970:154).

Yet, the claim by a new paradigm to have solved the crisis-provoking problem which demanded its creation in the first place, cannot always be honestly made. Indeed, the new paradigm may create more problems than not(Kuhn,1970:154). This observation is further compounded by the defenders of the orthodox theory who will "...point to problems that its new rival has not solved but that for their view are no problems at all"(Kuhn,1970:157).

In the end, the choice between competing paradigms does not so much revolve around which is validated by empirical evidence, for what is or is not considered evidence, is influenced by one's theoretical outlook, one's accepted paradigm(Kuhn,1970:157; Stewart,1986:263). Instead, the decision of whether or not to abandon the old theory for the new, is a very personal one, a decision that "...can only be made on faith"(Kuhn,1970:158).

If the new paradigm is to grow and survive, it must be rigorously developed by its supporters, moulded and shaped in the face of both theoretical and experimental analysis; it must be willing to adapt, open

to suggestions calling for improvement. If the empirical evidence supports the unorthodox theory, its arguments will grow in persuasion and conviction. In time, many traditional scientists will come to accept the new theory, not all together, to be sure, but a few individuals at a time. Before long, even the most orthodox researcher cannot deny the validity and legitimacy of the new paradigm, though a few may still cling to the old ways(Kuhn,1970:158-159). As Kuhn states:

"Though the historian can always find men - Priestly, for instance - who were unreasonable to resist for as long as they did, he (sic) will find a point at which resistance becomes illogical or unscientific. At most he (sic) may wish to say that the man (sic) who continues to resist after his whole profession has been converted has ipso facto ceased to be a scientist"(Kuhn,1970:159).

In the context of the current paradigmatic debate occurring in cosmology, a paradigm shift has not occurred, and may not occur for years, if not decades. Whether the plasma model can reconcile empirical observations that have troubled the Big Bang model, is a point of heated debate within the astrophysical community. Lerner's claim that the Big Bang is wrong, and the plasma model, right, may or may not be legitimate(Lerner,1991:276). A. Kuhn has so often pointed out, only years of theoretical development and testing will determine the validity and reliability of a new paradigmatic contender(Kuhn,1970:156). In its earliest stages of development "...a new candidate for paradigm...has seldom solved more than a few of the problems that confront it, and most of those solutions are still far from perfect"(Kuhn,1970:156).

Indeed, the plasma model is a relatively new paradigm, and its future depends, to a large part, on how successful its supporters are in developing and refining its framework so as to be able to compete with the Big Bang on theoretical and empirical grounds. It may be years before this debate is finally resolved.

In the light of Kuhn's thesis of traditional and new paradigms, it is clear that the plasma model is the unorthodox theory attempting to dislodge its more established counterpart, the Big Bang. The plasma challenge has faced considerable resistance, for social and political reasons outlined in the previous pages. It attempts to attack a framework that represents not just a traditional theory, but also an acceptable method by which to study the cosmos, not just a conceptual image of space and time, but also an ideology (Kuhn, 1970:10; Gleick, 1987:38). As such, the Big Bang theory enjoys a hegemonic status within cosmological circles.

A long time ago, Antonio Gramsci argued that hegemony was effectively tied to the exercise of leadership, and that it was only through the effective emulation of leadership that power was eventually obtained (Gramsci, 1971:57; Perry, 1992:24-25). Indeed, hegemony is effective because it cloaks the interests of the elite as that of the non-elite community, articulating the will of the people as its own (Gramsci, 1971:181-182; Perry, 1992:25).

Socially, cosmology, like the scientific community itself, contains an elite, and a non-elite mass. The elite researchers exert considerable influence upon the norms and values of their community. In many respects, these scholars represent authority figures, the masters of their specific craft, researchers others turn to for advice and counseling (Cole & Cole, 1973:78).

The fact that the elite are showered with a disproportionate amount of financial and honorific awards is seen as legitimate, because success in science has, and always will, be correlated with intrinsic talents and

abilities; it is after all a meritocratic reality where the best and brightest will undoubtedly survive. In this sense, the hegemonic status of the elite researchers is seen as the natural by product of talent, and not the product of the socio-political structure of the scientific community. It highlights the notion that talented researchers can, with hard work, enter the elite stratum in time.

In the case of the Big Bang, its hegemonic status is a product of tradition and history. It is a model that has been refined by the scientific elite for generations, and has come to represent what Kuhn calls, normal science(Kuhn,1970:10). That is, the orthodox nature of the Big Bang model was born of "...research firmly based upon one or more past scientific achievements...that some particular community acknowledges for a time as supplying the foundation for its further practice"(Kuhn,1970:10).

In addition, the Big Bang draws upon the eminence of one of the most revered and respected physicists of all time: Albert Einstein. It was Einstein's general theory that gave life to the Big Bang paradigm. From day one, students of cosmology are taught the elegance of Einstein's theories; this in turn prepares them to appreciate the aesthetic nature of the Big Bang model.

During the course of their study, these future theoreticians must adopt a body of facts and figures and mathematical methodology; they are repeatedly subjected to questions that sharpen their skills as problem solvers, socialized from the beginning on the proper techniques of scientific research and exploration. In the end, unconsciously, they would give up much freedom to question the foundations of cosmological

analysis, for it would be tedious, after a point, to question every facet of one's field of study(Kuhn,1970:42; Gleick,1987:36).

In this sense, the hegemonic position of the Big Bang model is not imposed from on high, but is an entity negotiated within the intricate social terrain of the cosmological community(Gramsci,1971:161,181-182; Perry,1992:26). In order to survive and thrive within the context of the social community, hegemony must acknowledge the existence and demands of the subordinate masses. In this way, consent for the prevailing power structures is generated since the non-elite masses feel that they are effectively negotiating the system, participating in the social arena as empowered citizens(Gramsci,1971:160-161; Perry,1992:25-26).

So, within cosmology, alternative models are, in fact, heard and studied. Thus, Fred Hoyle's steady-state model, Mandelbrot's fractal theory, and lastly, Eric Lerner's plasma model are given their day under the spotlight of conventional wisdom(eg. Peebles,1991:775). Yet, in the end, they are discounted as conceptually and empirically flawed. As P.J.E Peebles states, "Though some of the alternative cosmologies are elegant and theoretically compelling, it is the original relativistic expanding universe that so far best fits the observations"(Peebles,1991:775).

Yet, despite its adaptive qualities, hegemony is not an absolute force, but an entity often swayed by philosophical beliefs emanating from the non-elite masses, ever susceptible to the threat of counter ideologies. Thus, hegemony is always in a state of perpetual tension, negotiating its passage between the twin towers of force and consent(Gramsci,1971:80,183; Perry,1992:27).

In actual practice, hegemony is articulated through the social

instrument of ideology. As stated earlier, the Big Bang is more than a simple model; it represents a body of beliefs, an ideology of the origin of the universe. But this ideology is not absolute. Instead, it is a conceptual view that is constantly being crafted through elite/non-elite interaction, between supporters of the Big Bang and their opponents, between cosmologists and plasma physicists (Gramsci, 1971:377; Perry, 1992:29). Thus, ideology is a presence that emerges and is given life by the social landscape, in time permeating human negotiations, "...which in turn provide a system of explanation and orientation which directs the activities of people" (Clement, 1975:271).

If ideology can be viewed as a terrain upon which social contests are waged, then it is clear that ideology is not a cohesive, monolithic entity to which all members of a community pledge allegiance. Ideology is the product of human communication, of discourse that is constantly engaged in constructing a particular conceptual image (Perry, 1992:30).

Plasma physicists' attacks on the Big Bang is one representation of how the ideological terrain is negotiated, its abstract configuration slowly altered through elite/non-elite interaction.

In essence, ideology cannot be traced to a single, solitary social pool, for its actions do not manifest themselves in a linear, rational manner, but in a non-linear, systematic fashion. The threads of ideology are entangled with the elite, and with many members of the non-elite who have grown up and been socialized in its presence (Perry, 1992:30; Clement, 1975:271).

For instance, the Big Bang is viewed with admiration by elite, as well as many non-elite scientists working within cosmology, and in related fields such as nuclear and particle physics. Thus, it is a view, a conceptual outlook that cannot be attacked at any one specific

location; nor can the attack be directed at any one specific social group or community. Paradigmatic change ultimately requires attracting new converts from among the elite and non-elite strata. Yet, "...no single argument can or should persuade them all. Rather than a single group conversion, what occurs is an increasing shift in the distribution of professional allegiances"(Kuhn,1970:158).

6.2 The Evidence

From the perspective of the Elite-Kuhnian model, science is a creature of stratification; but it is also an entity of communication. Given this reality, a researcher's professional standing within the scientific community, and his or her links with other eminent scholars, tends to facilitate the social pooling of knowledge and resources among a select few academics, at the expense of creative, yet, non-elite scientists(Duncan,1974:110). As such, elite scientists have a higher probability of making a significant discovery, and having that pioneering research accepted by his or her professional colleagues than if he or she had been an unrecognized theorist or experimentalist. Since researchers tend to spend a good portion of their time discussing their work with peers of equal academic standing, personal contacts become crucial when it comes to developing new ideas and theories. This social condition makes it difficult for the non-elite researcher to interject his or her ideas into this elite circle, especially if those ideas deviate from mainstream research(Duncan,1974:120).

The Elite-Kuhnian model suggests that Eric Lerner's negotiation of the ideological landscape of cosmology has been difficult, partly because of his non-elite status within the community, and partly because he had entered cosmology from a different discipline, namely plasma physics, a field of study that is quite unique from theoretical cosmology.

The scholarly work of his academic hero, Hannes Alfvén, has also been, for the most part, ignored by cosmologists, despite his status as a Nobel laureate, and his prominent reputation in plasma physics(Brush,1990:92). This social shunning rests, in part, on Alfvén's theoretical claims. His belief that electromagnetic forces can account

for the structure of the universe with greater accuracy than the general theory, has long been attacked by cosmologists as unsound, mainly because his plasma theories do not stand up to the empirical data (Brush, 1990:92; Peebles, 1991:775).

Furthermore, many physicists question the validity of Alfvén's methodology of extrapolating from laboratory results to the universe as a whole, a jump of countless orders of magnitude (Brush, 1990:92; Lerner, 1991:45-46). Alfvén's assumption that such a quantum leap can be undertaken in the development of plasma cosmological models, has been attacked on a number of theoretical and empirical grounds (Brush, 1990:92). Yet, Alfvén argues "If we can extrapolate from the laboratory to the solar system, which is a hundred trillion times larger...then why shouldn't plasma behave the same way for the entire observable universe, another hundred trillion times larger?" (cited in Lerner, 1991:45).

While some cosmologists agree that Alfvén's plasma model is elegant in some respects (eg. Peebles, 1991:775), they point out that it does not explain the universe we see today.

So, while Alfvén may be a star within plasma physics, his ideas and models are seen as conceptually flawed from the vantage point of theoretical cosmology; and Alfvén himself is seen as somewhat of a maverick.

In their battle for recognition, Lerner and Alfvén had to contend with the formidable presence of the elite cosmologists, researchers whose pioneering works in cosmology have cast a long shadow over the entire community. But who are these respected scholars? A brief, biographical picture of four of the most famous cosmologists working today, will be

highlighted below. These theoreticians are not representative of all elite cosmologists, but they are four of the pioneering stars with the community.

Stephen W. Hawking is probably the most famous scientist alive today, the only scientist since Einstein to command enormous media attention. He is considered a celebrity both within cosmology and the general public. His first book for the public, A Brief History of

Time, a text devoted to cosmological issues, has sold over a million copies in hard cover alone. He is presently the Lucasian Professor of Mathematics at Cambridge University, a position once held by Sir Isaac Newton over three centuries ago. He has received numerous awards for his theoretical work, including the Eddington Medal of the Royal Astronomical Society, the Dannie Heinemann Prize of the American Institute of Physics and the American Physical Society, the Maxwell Medal and Prize of the Institute of Physics, and the Einstein Medal awarded in Berne, Switzerland in 1979. His specialty is in the areas of general relativity, gravitation, and quantum mechanics as it relates to black holes (Cambridge Biographical Dictionary, 1990:680; Hawking, 1988:x; Kaufmann, 1988:600).

Joseph Ivor Silk is a professor of astrophysics and theoretical cosmology at the University of California at Berkeley. He has held various distinguished positions during his career. He was the Alfred P. Sloan Foundation fellow from 1972 to 1974; the John Simon Guggenheim Foundation fellow from 1975 to 1976. He was a member of the Institute for Advanced Studies at Princeton University from 1975 to 1976. He is a principal investigator at NASA, NSF, the Department of Energy and CalSpace. Silk is also a member of the American Astronomical Society; the Royal Astronomical Society; the International Astronomical Union; and fellow of the American Association for the Advancement of Science. His research interests include theoretical cosmology, particle physics as it applies to cosmology, and galaxy and star formation and evolution (American Men & Women of Science, 1993:794).

Steven Weinberg is professor of theoretical physics at the University of Texas. He has received honorary doctoral degrees from a dozen other universities. In 1979, he shared the Nobel prize for physics for his research in elementary particle physics. In addition to the Nobel

prize, Weinberg has received numerous other awards, including the National Medal of Science; the J.R. Oppenheimer Prize; the American Institute of Physics-US Steel Foundation Science Writing Award; the Dannie Heinemann Prize; the Elliot Cresson Medal; the Madison Medal from Princeton University, among others too numerous to mention here. He was also a consultant at the Institute of Defense Analysis, and the Smithsonian Astrophysical Observatory. Weinberg's research interests include particle physics, cosmology and field theory(American Men & Women of Science,1993:531; Weinberg,1994:45).

The last physicist to be discussed is Phillip J. Peebles, a Canadian born cosmologist. Peebles is the Albert Einstein Professor of Science at Princeton University. Like his colleagues, Peebles has won numerous awards. These include the A.C. Morrison Award in Natural Science, from the New York Academy of Sciences; the Eddington Medal, from the Royal Astronomical Society; and the Heineman Prize, from the American Astronomical Society. He also holds a number of fellowships at the following societies and institutions: the American Physics Society; the Academy of Arts and Sciences; the Royal Society; the American Astronomical Society; and the American Association for the Advancement of Science. His research interests include cosmology and gravitational physics. His pioneering work in cosmology has earned him numerous awards and honors(American Men & Women of Science,1993:992; Peebles et. al,1994:53).

Indeed, of all the cosmologists mentioned in this brief biographical sketch, Peebles is the only researcher to explicitly criticize the works of Hannes Alfvén and Eric Lerner. The others have either ignored the research of plasma cosmologists, or have brushed it aside, arguing that plasma cosmology is too speculative to afford serious discussion.

In essence, all these cosmologists believe in the validity of the Big Bang, and are doubtful that there exists any alternative model that can effectively compete with it in cosmological research.

According to Robert Merton (1968), the phenomenon known as the "Matthew effect" facilitates the establishment of an orthodox environment, and acts as an obstacle to new ideas, or theoretical models. It predicts that those with unorthodox notions will have a hard time making headway in their chosen discipline if they possess little prestige within that discipline (Duncan, 1974:130). One way to test this hypothesis is to measure the prestige of Alfvén and Lerner's scholarly works within cosmology, relative to that of the elite cosmologists. For such an analysis, citation counts prove to be one of the best empirical indicators, partly because of their reliability, and partly because they are easy to obtain. Citation counts provide one quantitative indicator with which to measure prestige. The research of Cole & Cole (1973) and Shadish et. al (1995), seems to demonstrate that citation counts are positively correlated with perceptions of quality, originality, and scholarly importance.

In order to test the "Matthew effect", a survey was conducted of the Science Citation Index from 1989 to 1993, the time period when the Big Bang debate was at its fiercest within cosmology (see Section 3.2). It should be emphasized that the SCI registers citations made in a given year to a scientist's lifework. That is, if you were to look up Hawking's citation counts in the 1989 SCI, it would tell you the citation frequencies for almost every article Hawking has ever published, and which are covered by the SCI, during the course of his career. For example, in 1989 a scientist might have cited Hawking's 1969 article on black holes, x number of times; this would be listed in the SCI. It is essential that this observation is kept in mind when studying the table on the page following the next.

In table 1, on the following page, the citation rates for scholarly works written by our select group of elite cosmologists on articles related to cosmology, are illustrated. The first column gives the name of the respective researcher; the second, that academics' cumulative citation rate for his life's work from 1989 to 1993; the third column gives the mean number of citations for the five years surveyed, $(\bar{x})$; the fourth column gives the standard deviation for the "population" surveyed (δx) ; and the fifth column represents a ratio of the standard deviation to the mean $(\delta x/x)$, a term officially referred to in statistics as the coefficient of variation(Allison,1980:164). A brief discussion of this concept will now be presented.

The coefficient of variation effectively controls for the various mean citation rates of the theorists in our sample, and allows the reader to compare variances on a standardized level. Since the coefficient of variation is scale invariant, it allows one to compare "...relative differences among individuals rather than...absolute differences"(Allison,1980:166). By employing the coefficient, scale effects are cancelled, and allows for a more insightful analysis of the data, permitting the analyst to say whether one data set is more consistent, or experiences less fluctuations over a period of time, relative to another(Allison,1980:165-167).

Table 1
Elite Citation Rates for Works in Cosmology
1989 to 1993

Name	Citation Rate 1989-1993	Mean ($\bar{x}$) 1989-1993	Standard deviation (δx) 1989-1993	Coefficient of Variation ($\delta x/x$) 1989-1993
S. Hawking	3,085	617.00	38.70	0.063
S. Weinberg	4,663	932.60	51.29	0.055
P. Peebles	2,133	426.60	66.05	0.155
J. Silk	828	165.60	9.65	0.058
Total	10,709	535.45	283.55	0.530

Source: Science Citation Index, 1989 - 1993.

As can be seen from Table 1, these four theoreticians have a cumulative citation rate of almost eleven-thousand for the years 1989 to 1993. Even within this elite group, there is a certain degree of inequality. For instance, 72% of the total citation rate for this group can be attributed to just two scientists: Hawking and Weinberg.

What is important to note in this first table, is the column designated coefficient of variation; this term will be referred to as COV from now on. As can be seen, the COV is relatively small for the listed cosmologists. This implies that the citation rates for the theorists were fairly consistent for the years surveyed; their scholarly contributions were cited at approximately the same level from 1989 to 1993. This degree of consistency implies that the above four cosmologists' works are perceived by their colleagues as relevant and important enough to be consulted and used in other scholarly endeavors from year to year. Thus, the COV suggests that citations made to these theorists did not fluctuate wildly for the time period surveyed. Of course, Peebles' COV

displays a relatively large value of 0.155. This can be accounted for by a fairly strong citation count for Peebles in 1993 that was 1.26 deviations above the mean.

While the citation rates for the orthodox cosmologists can be described as large in an absolute sense, the purpose of this analysis is to analyze the relative differences in citation frequencies between the cosmologists and the plasma physicists. Table 2 below, documents the citation rates for Alfvén and Lerner's alternative cosmological paradigm.

Table 2
Non-elite Citation Rates for Papers on Alternative Cosmological Model
1989-1993

Name	Citation Rate 1989-1993	Mean ($\bar{x}$) 1989-1993	Standard deviation (δx) 1989-1993	Coefficient of Variation (δx) 1989-1993
H. Alfvén	46.00	9.20	3.76	0.409
E. Lerner	17.00	3.40	1.85	0.546
Total	63.00	6.30	4.15	0.658

Source: Science Citation Index, 1989-1993.

As Table 2 clearly shows, the academic writings of both Alfvén and Lerner on the plasma model - the alternative paradigm to the Big Bang - were very poorly cited for the survey period, relative to the orthodox works of the elite cosmologists. Indeed, as a group, the cosmologists had a cumulative citation rate that was 170 times greater than the combined citation frequencies of both Alfvén and Lerner.

It appears that the plasma cosmological model is not getting a lot of attention from the scientific community, which supports the Elite-Kuhnian argument that scientists new to a field, possessing little

prestige or recognition in their adoptive community, will encounter difficulties in their attempts to articulate an unorthodox paradigm. The extremely low citation scores for papers written by Alfvén and Lerner, seems to underscore their non-elite status within the realm of cosmological research. Indeed, the physics community as a whole appears to have given the plasma model very little consideration. This lack of attention makes it very difficult for the plasma model to gain new adherents, or generate wide spread debate, factors crucial to the future of any new paradigm. For it is only through the medium of academic argument that the potential of a new theory can be fully appreciated, and judged by elite and unknown theorists alike; only through the process of communication, of persuasion can paradigmatic conversion be possible(Kuhn,1970:158-159).

Lastly, not only are the citation frequencies of Alfvén and Lerner extremely low, they appear to display a relatively large degree of skewness as indicated by the COV, in contrast to the fairly consistent citation rates of the elite cosmologists. This empirical observation seems to suggest that the articles by Alfvén and Lerner are not only poorly cited, they are cited inconsistently. This inconsistency further reinforces the observation that the alternative paradigm of these researchers has a low visibility within physics, a paradigm that is cited modestly in one year - though still very poorly relative to the works of the elite cosmologists - and extremely poorly in other years.

But the question remains: in which journals do Alfvén and Lerner publish their unorthodox views, and who cites their work, and in which journals do the citing articles appear?

In the tables below, a survey was conducted of SCI between 1989 to 1993 to ascertain the scholarly distribution of Alfvén and Lerner's articles on plasma cosmology. The table shows the name of the journal in which the original articles appeared, the citation rate of the journal which allows us to determine whether the journal in question is prestigious, semi-prestigious, or non-prestigious, and the number of plasma articles published in each of the listed journals.

Table 3
Hannes Alfvén's Publication Distribution
1989-1993

Journal Name	Citation Rate JCR 1993	No. of Articles Published In
Ark Fys	unavailable	1
IEEE Transactions in Plasma	1,124	2
Physics Today	1,109	3
Astrophysics & Space Science	1,636	1
Laser and Particle Beams	251	1
Annals of the New York Acad.	19,890	1
Space Science Reviews	1,148	1
Total		10

Source: Science Citation Index, 1989-1993; Journal Citation Reports, 1993.

Table 3 shows that Alfvén's cosmological articles tend to cluster overwhelmingly within the low semi-prestigious and non-prestigious journals; this is, of course, assuming that the journal Ark Fys, is also a semi or non-prestigious journal. Yet, even if we ignore this specific periodical, 80% of Alfvén's papers articulating his alternative theory, are located in modestly cited journals.

This empirical finding has two potential interpretations: one, that Alfvén had tried to get his unorthodox views published in the elite

periodicals, but was rejected because his beliefs contradicted conventional wisdom. As was argued in section 4.5, elite journals generally attract articles from the brightest stars of a particular discipline, stars whose reputation as scholars and researchers endow their work with a certain measure of academic authority, the standard against which all other research is judged. This authority, in effect, defines what is considered mainstream research. Given this reality, and given the fact that the academic elite predominant the peer review boards of prestigious journals, research which contradicts conventional wisdom will face considerable difficulty in getting published. The fact that one of Alfvén's unorthodox paper was published in a relatively prestigious journal, specifically, The Annals of the New York Academy of Sciences, lends empirical credibility to the notion that he has submitted his papers to elite journals. The fact that only one such periodical published his views suggests that elite journals do not tend to embrace controversial papers.

A second interpretation of this data suggests that Alfvén may be purposely seeking those journals which are sympathetic to his views; the evidence suggests that these periodicals are those which exhibit modest citation rates, and which do not typically attract researchers from cosmology. This selective targeting of journals also implies that Alfvén is trying to reach a particular group of researchers, researchers whose thinking is similar to his own. Indeed, past research seems to indicate that authors primarily select journals on the basis of the audiences they reach, rather than the social rewards they confer (Gordon, 1984:27,34-35). Thus, by publishing in the non-elite journals, which also tend to be plasma physics journals in particular,

such as IEEE Transactions, Alfvén is trying to reach fellow plasma physicists and other modest researchers who have very little investment in the orthodox cosmological paradigm.

These results increase the plausibility of Kuhn's notion that paradigmatic resistance is, in part, due to theorists in two different conceptual camps trying to understand the same phenomenon with different cognitive tools(Kuhn,1970:150). The publication record of Alfvén tends to reveal a researcher whose articles are published in what can be considered "family" journals, journals which are reviewed by plasma physicists and not cosmologists. It highlights Kuhn's comment that "...the proponents of competing paradigms practice their trades in different worlds....Practicing in different worlds, the two groups...see different things when they look from the same point in the same direction"(Kuhn,1970:150).

Further analysis reveals this communal behavior. Table 4 shows the journals that published articles citing Alfvén's work.

Table 4
Journals that Published Articles Citing Alfvén's Work
1989 - 1993

Journal Name	Citation Rate 1993 JCR	No. of Times Journal Cited Alfvén's Work
IEEE Transactions	1,124	13
Earth Moon Planets	166	7
Journal Plasma Physics	649	1
Planetary & Space Science	2,686	2
Astronomy Nachr.	303	2
Astronomy Space Science	1,636	3
USP FIZ NAUK+	2,092	1
Physics Reports	7,273	3
Rech. Aerospace	86	1
IAU Symposia	1,987	2
ZH EKSP TEO	9,804	1
Nature	226,827	1
Ann. NY. Ac. Sc	19,890	6
Laser Particle Beams	251	1
RIV NUOV CI.	278	1
Spacecraft Rockets	547	1
Total		46

Source: SCI, 1989-1993; JCR, 1993.

Table 4 shows that Alfvén received most of his citations from IEEE Transactions, one of the main plasma journals of the plasma physics community. Indeed, IEEE Transactions alone, accounted for 28% of Alfvén's total citation frequency for the years 1989 to 1993. This further reinforces Kuhn's notion of academic specialization and communal behavior. Alfvén published a good number of his anti-Big Bang articles in IEEE Transactions, and similarly, a majority of his citations came from the same journal, from fellow plasma physicists and others interested in his views. It should be noted that 83% of Alfvén's cumulative citation

rate came from semi and non-prestigious journals. For the most part, these citations were positive. However, the one citation he received in the elite journal Nature, came from his rival in cosmology, P.J.E. Peebles, who was criticizing Alfén's alternative cosmological model.

It is important to note, that due to SCI's tabulation methodology, authors citing their own work, x number of times, tend to inflate their own citation frequency, a phenomenon that is common with Alfén. For example, Alfén received 6 citations in The New York Academy of Sciences for his unorthodox views. While this may appear to be significant, closer examination of the SCI database shows that these 6 citations were the result of Alfén citing his research from six different articles published over the years in one article published in this specific journal in 1989. Similarly, of the 13 citations Alfén received in IEEE Transactions, 5 came from Alfén himself, citing past research in one article he published in this journal in 1990.

This tendency to self-cite is curious, and can be interpreted as evidence of the pioneering nature of Alfén's work. Since plasma cosmology is a relatively recent theory, having emerged in its present form in the late 1980s, a theory, as we have seen, that is pretty much ignored by most physicists, the only ones who would be willing to expend time in moulding its theoretical form, arguing on it behalf in conferences and in journal articles, would be Alfén and Lerner, the theory's initial supporters, those willing to "...develop it to the point where hardheaded arguments can be produced and multiplied"(Kuhn,1970:158).

Since the plasma model is so new, and since Alfén and Lerner are

its two main creators, it would be hard to find existing articles that could be used as references, other than the pioneering articles written by Alfvén and Lerner themselves articulating their new paradigm. While the SCI does not indicate it, Lerner does cite Alfvén countless times in his articles and his first book The Big Bang Never Happened (1991), further reinforcing the communal image of the plasma cosmological community.

Table 5, below, further emphasizes Alfvén's prodigious self-citation rate.

Table 5
The Distribution Of Authors Citing Alfvén
1989-1993

Total No. of Authors Citing Alfvén	Average No. of Times Citing Authors Cited Alfvén	Standard Deviation (ox)	Names of Highest Citing Authors	No. of Times Cited Alfvén	Deviations Above Mean
25	1.84	2.22	Alfvén	11	4.12
			Papaelia	7	2.32

Source: SCI, 1989-1993.

In essence, of the 46 citations Alfvén received from 1989 to 1993, 11 or 24% of those citations came from Alfvén himself. As Table 5 shows, Alfvén cited himself more frequently than any other scholar, lending empirical credibility to the arguments set forth in the preceding pages that the plasma model is a young one, with very few supporters, and very little clout within the scientific community. This resonates with Kuhn's arguments that:

"At the start a new candidate for paradigm may have few supporters, and on occasions the supporters' motives may be suspect. Nevertheless, if they are competent, they will improve it, explore its possibilities, and show what it would be like to belong to the community guided by it"(Kuhn,1970:159).

The next three tables on the following pages, illustrates Lerner's publication history and distribution.

Table 6
Eric J. Lerner's Publication Distribution
1989-1993

Journal Name	Citation Rate 1993 JCR	No. of Articles Published In
IEEE Transactions	1,124	3
Laser and Particle Beams	251	2
Discover	unavailable	1
Astrophysical Journal	57,088	1
Total		7

Source: SCI, 1989-1993. JCR, 1993.

Like Alfvén, a majority of Lerner's anti-Big Bang articles, 86%, are found in low semi-prestigious and non-prestigious journals; this is of course assuming that the journal Discover is a modestly cited journal. This assumption is credible because this particular periodical is a popular science magazine, and as such would not be consulted by practicing scientists in search of technical data. Thus, even if its citation had been made available in the JCR, it would have undoubtedly been low, low enough to place it in the non-prestigious category.

To his credit, Lerner managed to get one of his unorthodox articles published in a relatively prestigious journal, namely The Astrophysical Journal. But, like Alfvén, most of his research articles are located in modestly cited journals. Indeed, the publication data of Alfvén and Lerner correlate nicely, reinforcing the arguments made earlier in this

section concerning the social status of the alternative Big Bang paradigm, and its creators within the scientific community, and specifically, within cosmology.

Table 7 shows the distribution of articles citing Lerner's unorthodox research.

Table 7
Journals that Published Articles Citing Lerner's Work
1989-1993

Journal Name	Citation Rate 1993 JCR	No. of Times Journal Cited Lerner
IEEE Transactions	1,124	8
Reviews of Modern Physics	8,850	1
Astrophysical Journal	57,088	2
Physical Review A	38,123	1
Physical Letters A	10,413	1
Applied Mathematics Com.	249	1
Chaos Sol.	unavailable	1
Astrophysics Space Science	1,636	1
Nature	226,827	1
Total		17

Source: SCI, 1989-1993; JCR, 1993.

As Table 7 shows, a majority of the articles citing Lerner's research appears to be published in IEEE Transactions; indeed, 47% of all articles citing Lerner's work were published in this journal. However, closer examination reveals that 6 out of the 8 citations, or 75%, were made by Lerner himself; the remaining two citations can be accounted for by two other authors who cited Lerner's work once each during the scope of the survey.

In addition, Lerner's unorthodox research was cited twice in the prestigious Astrophysical Journal. Interestingly enough, both these

citations were made by Lerner, citing work from two different articles in the one paper he had published in this specific journal in 1990.

As with Alfvén, most of these citations were positive. However the one citation he received in Reviews of Modern Physics, was merely a footnote in which the author of the article, Stephen Brush, suggested readers study Lerner's controversial book for more information regarding Alfvén's unorthodox cosmogonic views. As such, this citation cannot be classified as either positive or negative.

Yet, the one citation Lerner received in the prestigious journal Nature, was negative. The article in which Lerner's work was mentioned was written by cosmologist P.J.E Peebles who was criticizing Lerner's plasma cosmological model which appeared in the Astrophysical Journal.

The fact that Lerner, like Alfvén, tends to cite himself prodigiously, can be seen in Table 8, below.

Table 8
The Distribution of Authors Citing Lerner
1989-1993

Total No. of Authors Citing Lerner	Average No. of Times Citing Author Cited Lerner	Standard Deviation (ox)	Names of Highest Citing Authors	No. of Times Cited Lerner	Deviation Above Mean
8	2.125	2.62	Lerner	9	2.63

Source: SCI, 1989-1993.

Thus, of the 17 citations Lerner received from 1989 to 1993, 9, or 53% of those citations came from Lerner himself. As Table 8 shows, Lerner's citation rate of his own work, is statistically, very high relative to the population authors citing his research. In contrast, the next highest citing author after Lerner, is Werbos, who cited Lerner twice over the five year period; all other authors cited him only once.

The empirical data on Lerner's citation and publication history, parallels Alfvén's. The above results resonate nicely with Kuhn's argument that a new candidate for paradigm has, in the beginning, very few supporters. As a result, the small number who do believe in the unorthodox model, must rely on their own unconventional research, and the research of their likeminded peers in order to keep the new theory afloat within academic circles(Kuhn,1970:158-159).

The SCI allowed us to explore the scholarly backgrounds of both Alfvén and Lerner with some degree of intensity. Unfortunately, the same could not be done with the elite cosmologists. The citation frequencies of these prominent scholars were so large, that a similar citation analysis would have consumed far too much time. Yet, an approximate survey of the SCI database reveals that our small group of cosmologists cite one another's work quite regularly, and are themselves cited by talented peers publishing in elite journals. In addition, the works of the four cosmologists are, not surprisingly, mostly found in the top periodicals of the scientific community, journals like Physical Review Letters, Nature, and The Astrophysical Journal.

Furthermore, the elite cosmologists, unlike their unrecognized counterparts, have very low self-citation rates. For example, of the 3,085 citations Stephen Hawking received from 1989 to 1993, only 17 of

those citations, or 0.6%, were made by Hawking himself. In the case of P.J.E Peebles, his self-citation rate was 2%; for Steven Weinberg it was 0.6%; and in the case of Joseph Silk, it was 3% (SCI,1989-1993).

These low self-citation rates can be accounted for by various factors. Firstly, unlike plasma cosmology which is still in its infancy, theoretical cosmology has been around for over sixty-years, its analysis guided by a standard model, a single shared paradigm that has been tested and refined for about as long, a paradigm known as the Big Bang relativistic model(Peebles,1991:775). Countless researchers from within cosmology, and the related fields of nuclear and particle physics, have contributed, in some fashion, to the Big Bang theory. Thus, there is a prodigious body of work cosmologists like Hawking et. al can draw upon in the course of their investigations.

From the point of view of the Kuhnian framework, cosmological science is normal science, science based on a well-worn paradigm and past scientific achievements(Kuhn,1970:10). As such, there is a body of legitimate problems that require solving, problems that can be solved, it is believed, within the context of the existing theoretical framework(Kuhn,1977:234). Given this reality, Hawking and his colleagues need not develop a model from scratch as Alfvén and Lerner are doing; there is so much research being conducted in cosmology that one is not limited by a narrow body of data. In an environment guided by a standard framework, there is, in all probability, some body of knowledge, some researcher whose research interest parallel your own.

In essence, the elite cosmologists have a greater supply of research to choose from relative to their plasma counterparts, research produced by their prominent colleagues, as well as from thousands of others in

cosmology and related fields. This is, of course, one explanation for the elite theorists low self-citation rate; other possible explanations should be pursued in future academic endeavors.

In Kuhn's scheme, revolutions are born at the hands of the young or the new, born of researchers "...little committed by prior practice to the traditional rules of normal science"(Kuhn,1970:90). Thus, those researchers who have very little investment in the old ways are more likely to embrace new, innovative ideas. While it is difficult to quantify the degree to which scientific resistance is a product of self-preservation on the part of the traditional scientists, and how much is a product of a genuine belief that the new model is conceptually flawed, Kuhn's interests hypothesis is susceptible to empirical analysis.

In his writings, Kuhn argues that resistance to a new model of knowing is partly a product of having spent many years, if not decades, building a career on the older paradigm, convinced that "...the older paradigm will ultimately solve all its problems, that nature can be shoved into the box the paradigm provides"(Kuhn,1970:151-152).

This interests hypothesis predicts that cosmologists who have practiced their craft for many years, and have acquired an elite status within their community, would have left a considerable paper trail of a scholarly nature. In this case, it would be relatively simple to assess how much intellectual investment our elite theorists have placed in the Big Bang paradigm.

In order to obtain the publication history of the theoreticians, a survey was conducted of the Author Index of Physics Abstracts, one of the most comprehensive reference databases in physics. An arbitrary population of years was constructed, spanning from 1970 to 1994(see

section 3.2). From this "population", a random sample of ten years was selected and subsequently surveyed. An estimate was then calculated of the number of journal articles, paper, monographs, and conference letters a researcher had produced over this twenty-five year interval.

In addition to Physics Abstracts, a survey was conducted of the literary publications of the cosmologists. Using the American and British reference sources, Books in Print (1995), and Whitaker's Books in Print (1995), a list of popular and technical books on cosmology written by the physicists was produced.

In the end, a fairly comprehensive publication trail was compiled. This is illustrated in Table 9.

It should be noted that the heading summarizing a cosmologists's publication history, includes articles and papers written by the respective scientist on his own, or in conjunction with other scientists as part of a multiple author team, where the cosmologist was simply one among many researchers, and not necessarily the main contributor to the article in question.

A similar situation exists for the theorists's book publishing career. However, in this case, where the cosmologist is not the sole author, there is, at most, only one other collaborator.

Table 9
Publication History of Elite Cosmologists
1970-1994

Name	Age as of 1996	Years Practicing Physics Since Obtaining Ph.D, up to 1996	No. of Cosmological Journal Articles, Monographs, Papers, and Conference Letters Published from 1970-1994	No. of Books Published on Cosmology During Career
Hawking	54	27	68 $\pm$ 11	7
Peebles	61	34	105 $\pm$ 5	5
Silk	54	28	175 $\pm$ 18	4
Weinberg	63	39	38 $\pm$ 6	9

Source: Physics Abstracts, 1970-1994; Books in Print, 1995; Whitaker's Books in Print, 1995; American Men & Women of Science, 1993.

Table 9 shows that the above four theoreticians have left a considerable paper trail over the course of their careers, with numerous journal articles and books expounding upon the Big Bang theoretical framework. Since obtaining their doctorates in physics, these researchers have worked with the relativistic Big Bang theory, using its abstract insights, refining its mathematical composition, for close to, and in some cases, over three decades. Scholarly careers have grown around the Big Bang; countless awards and prizes have been accrued by these physicists for their contributions to theoretical cosmology. The Big Bang has been part of their collective lives for so long, that it seems probable that they would feel at least some hostility towards outsiders like Alfvén and Lerner, scientists whose aim is to replace the Big Bang theory with one of their own. Indeed, the above results seem to increase the plausibility of Kuhn's interests hypothesis, and casts some small degree of doubt upon Peebles' comment that, "Most cosmologists would be delighted to abandon the standard model for something new to think about if only the alternatives looked reasonably promising"(cited in Wade, 1994:38).

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Of course, this does not mean that researchers who have invested a lot of their time and energy in a particular paradigm will never become convinced of the validity of a new candidate for paradigm. If the new model stands up to empirical testing, and is gradually improved over time, its theoretical assumptions and designs strengthened, then some of the traditional scientists will eventually come on board, "...because scientists are reasonable...one or another argument will ultimately persuade many of them"(Kuhn,1970:158).

But such a conversion takes time, and very few researchers will desert a well worn theory for a new one right away. The new paradigm must be seen as a worthy heir to the old, and only years of testing and argument will cause allegiances to gradually shift toward the new model(Kuhn,1970:158).

In the light of the above comments, the evidence presented in Table 9 suggests that some part of the elites resistance to the plasma model is born of uncertainty, of having practiced the traditional paradigm for so long, a paradigm that, despite its flaws, is still seen as a better theoretical representation of the physical world. For the plasma model to gain converts, it must convince the traditional researchers that it can do a better job than its older rival in explaining the nature of the cosmos. And at the moment, it has done very little to persuade the cosmological community that it has any real insights to give.

Of course, academic resistance to new paradigms manifests itself in various forms, and one arena where it can be quite intense is on the peer review boards of scientific periodicals and funding agencies.

In section 4.5, evidence was brought to bear which suggested that the peer review process is less than democratic. Indeed, the empirical data suggests that the review panels of distinguished journals, and other respectable periodicals, as well funding agencies, are dominated by elite scientists, the academic stars of the scientific community, individuals whose research credentials and past achievements facilitates the construction of what Kuhn calls, normal science which constitutes a body of accepted facts and theories (Kuhn, 1970:10; Cole, 1992:150; Abrams, 1991:123).

Of course, the biggest complaint of the peer review process is that it tends to reject revolutionary ideas. Evidence compiled over the years seems to suggest that prominent scientists who propose new models of knowing, or ideas, have a higher probability of having their concepts studied and given the benefit of the doubt, than if the unorthodox proposals had been submitted by an unrecognized researcher (Campanario, 1993:349-352). Indeed, as the editor of the British Medical Journal remarked, the peer review process, "favors unadventurous nibblings at the margin of truth rather than quantum leaps" (cited in Campanario, 1993:344). This social attitude to new ideas is seen as a form of academic protection against cranks and other devious creations. It presumes that "...work which runs counter to currently accepted...ideas, and which is presented by unknown scientists, is probably trivial and possibly misleading" (Zuckerman, 1970:242). While this cognitive outlook is, to an extent, understandable, it has resulted in the rejection of

papers that went on to become classic works of scholarly research(Campanario,1993:352).

Kuhn's interests hypothesis can be brought to bear to test whether or not there is a differential acceptance rate of anti-Big Bang and plasma cosmology articles among journals of varying levels of prestige. In the light of the above comments and Kuhn's theory, one would expect to see pro-Big Bang articles dominating the pages of the prestigious periodicals, and very few, if any, articles outlining the alterative cosmological paradigm.

To test Kuhn's interests hypothesis as it relates to journals, a population of 24 journals dealing with cosmological issues was compiled. Based on the citation rates these journals received in the 1993 JCR, they were divided into three categories of journals, labelled: prestigious, semi-prestigious, and non-prestigious, respectively(see Appendix B). Then, three of the highest ranked journals in the prestigious and semi-prestigious categories, and three of the poorest cited journals in the non-prestigious category, were surveyed. The survey was non-random, investigating each article published in the respective journal from 1989 to 1994. Unfortunately, due to unforeseen circumstances, the contents of two journals, Annals of Physics, and Physical Review Letters, had to be randomly surveyed(see Appendix B).

The results can be seen in Table 10A, on the next page. While the headings are self-explanatory, one category needs to be clarified, specifically, the category labelled, Big Bang Ratio. This ratio simply tells the reader how often cosmological articles were published in the respective journals during the years surveyed.

Table 10A
Distribution of Pro, Anti, and Inconclusive Big Bang
Articles by Prestigious Journal
1989-1994

Journal Name	Citation Rate 1993 JCR	Total Articles Published	Total Articles Big Bang	Big Bang Ratio
Nature	226,827	12,133	104	0.009
Science	170,514	9,049	57	0.006
Physical Review	103,790	11,560 $\pm$ 73	133 $\pm$ 6	0.011*

No. Articles Pro.	No. Articles Vs.	No. Articles Inc.
76	1	27
46	0	11
114 $\pm$ 6	0	19 $\pm$ 3

Source: JCR, 1993; Nature, 1989-1994; Science, 1989-1994; Physical Review Letters, 1989-1994.

The empirical data in table 10A seems to validate Kuhn's interests hypothesis, as it relates to the publication of orthodox and unorthodox articles concerning cosmology. Of the three elite periodicals listed above, only Nature published an anti-Big Bang article during the scope of the survey, and only one such article. Yet, 73% of the cosmological articles published in this periodical, were supportive of the theory, while the remaining 26% were inconclusive; these articles tended to take on a neutral stance with respect to the Big Bang paradigm, highlighting the theory's strengths and weakness; no ideological orientation could be discerned. Furthermore, not one plasma cosmology article - Alfven and Lerner's alternative cosmogonic theory - was discovered during the survey.

The above results increase the credibility of the interests perspective. The elite journals, and those on their peer review panels

* The error bar for this figure was so small as to be negligible.

seem unwilling to publish articles that attack the standard model of cosmology, articles that would disrupt the accepted practice of "normal science". These findings seem to lend empirical weight to the comment made earlier in this section that the peer review process "favors unadventurous nibblings at the margin of truth rather than quantum leaps"(cited in Campanario,1993:344).

The absence of many anti-Big Bang articles, and no plasma cosmology papers within the above journals, may be a product of ideology and orthodoxy, of papers being "...reviewed by the very people whose pet theories are being challenged"(Lerner,1991:374).

Yet, this resistance may also be born of the simple fact that the alternative paradigms to the Big Bang, do not meet the standards of the empirical data, or are flawed on theoretical grounds. As Kuhn argued, only when the supporters of a new candidate for paradigm refine their theory, explore its possibilities, and attract followers, will it achieve the academic clout to be given a second look by the traditional scientists who grew up on the old paradigm(Kuhn,1970:158-159).

Table 10B shows the distribution of pro, anti, and inconclusive Big Bang articles within the three highest cited semi-prestigious journals.

Table 10B
Distribution of Pro, Anti, and Inconclusive Big Bang
Articles by Semi-Prestigious Journal
1989-1993

Journal Name	Citation Rate 1993 JCR	Total Articles 1989-1993	Total Articles Big Bang 1989-1993	Big Bang Ratio
Annals of Physics	6,410	662 $\pm$ 12	28 $\pm$ 4	0.04*
Scientific American	4,194	590	17	0.03
Astronomy & Astrophys.	3,161	919	2	0.002
No. Articles Pro.		No. Articles Vs.		No. Articles Inc.
20 $\pm$ 4		0		8 $\pm$ 2
13		0		4
0		0		2

Source: Annals of Physics, 1989-1994; Scientific American, 1989-1994;
Astronomy & Astrophysics Supplement Series, 1989-1993.

Table 10B shows that not one anti-Big Bang article appeared during the five year survey period; furthermore, not one plasma cosmology article was published during this time frame. The lack of such alternative scholarly works within the pages of the above journals, once again suggests the presence of an orthodox environment within the peer review process among the above listed periodicals. The above results also suggests how formidable a paradigm the Big Bang is within the scientific community, how strongly it represents, or is synonymous with the concept of normal science, that alternative paradigms are virtually non-existent within the pages of the elite and semi-elite academic journals.

* Once again, the error rate was negligible.

Of course, once again, these results do not prove the existence of selective bias among those reviewing articles submitted to the above 3 journals; it only suggests a possibility that such a bias may exist. The plasma model, and other alternative models to the Big Bang, may be scarce among the top journals because of their novelty and low profile within the community; or, as is the case with the plasma model, it may be a product of theorists coming into cosmology from a different field of specialization, employing theoretical concepts and tools most cosmologists are not familiar with. As Kuhn once remarked, "Something must make at least a few scientists feel that the new proposal is on the right track..."(Kuhn,1970:158). Such feelings only emerge after a long period of exposure to the would be paradigm, after many months and years of looking at the empirical evidence. Perhaps then, plasma cosmology, and other alternative models, will share the same amount of attention within the scientific community's elite periodicals.

Table 10C on the next page, shows another distribution chart, but this time for non-prestigious journals.

Table 10C
Distribution of Pro, Anti, and Inconclusive Big Bang
Articles by Non-Prestigious Journal
1989-1993

Journal Name	Citation Rate 1993 JCR	Total Articles Published	Total Articles Big Bang	Big Bang Ratio
Aerospace America	41	1,090	6	0.006
J.R. Astron. Soc.	87	299	13	0.040
B.J. Philo. Sci.	204	230	3	0.010

No. Articles Pro.	No. Articles Vs.	No. Articles Inc.
1	1	4
5	2	6
2	0	1

Source: Aerospace America, 1989-1994; Journal of the Royal Astronomical Society of Canada, 1989-1994; British Journal for the Philosophy of Science, 1989-1994.

As Table 10C shows, the non-prestigious journals tend to publish a larger proportion of anti-Big Bang articles than their elite counterparts. In fact, one journal, Aerospace America published a plasma cosmology article by Eric J. Lerner. This comes as no surprise, since Lerner's is employed by the journal as an electronics editor and would be in a position to get some of his views published.

Interestingly enough, Aerospace America published a total of six articles related to the Big Bang during the survey period. One of these articles was against the Big Bang - Lerner's paper, and another was supportive of the model; the remaining 4 articles, or 67% of the total, were inconclusive.

In the case of the Journal of the Royal Astronomical Society of Canada, 38% of its cosmological articles held the Big Bang in a positive light, 15% were against it, and the remaining 46% were inconclusive.

The Big Bang was treated favorably within The British Journal for the Philosophy of Science. Interestingly, this journal published not one anti-Big Bang article during the five year scope of the survey.

These results are as predicted by the interests hypothesis. Since the brightest academic stars tend to referee at the elite periodicals, reinforcing the conventions of mainstream research (Abrams, 1991:123), the low number of anti-Big Bang articles within these journals is not surprising, and is consistent with the interests hypothesis, since reviewers at these journals are more critical of research which threatens their own field of scholarly investigation, and which is outside the scope of conventional wisdom (Cole, 1992:151; Campanario, 1993:343).

In contrast, the non-elite journals are very poorly cited, suggesting that they are not seen as possessing the kind of material demanded of high quality research, and thus, are referenced only slightly. They do not generally attract the scientific elite, or the best research. As such, one would assume that these periodicals have less to lose, than their elite counterparts, in publishing an unorthodox piece of research. Indeed, the results documented in Table 10C, while not conclusive, suggests that the non-prestigious journals are more flexible when it comes to unorthodox cosmological models than their elite cousins.

The empirical data shows that, as a group, the elite journals published only 1 anti-Big Bang article out of the 294 cosmological articles produced between 1989 to 1993; in other words, only 0.3% of their cosmological papers were against the orthodox model.

In contrast, as a group, the non-elite journals published 3 anti-Big Bang papers out of the 22 articles produced during the survey period;

thus, 14% of all the cosmological papers published by the non-elite journals, were against the orthodox paradigm.

While these results seem to increase the validity of Kuhn's interests hypothesis, and the Elite-Kuhnian model which articulates the notion that scientists who have built their distinguished careers upon the older paradigm, and have invested heavily, intellectually, in the traditional ways, will tend to resist conceptual change(Kuhn,1970:151), closer examination of the data reveals that, even among the non-elite journals, the number of pro-Big Bang articles, out weighs those against.[¶]

Indeed, in two out of the three journals, pro-Big Bang articles outnumber those opposed to the paradigm; in the third journal, the number of articles for the model, equal those against. This finding suggests that the Big Bang's range of influence is vast within the scientific community, its theoretical framework embraced by many researchers within the elite, as well as non-elite circles. This result is probably the strongest evidence to date that the Big Bang represents a powerful conceptual model within cosmology, an ideology that is intertwined with both the elite and non-elite strata, one which cannot be traced to a single, solitary social group(Perry,1992:30).

In essence, while the results in this section seem to support the Elite-Kuhnian model, and Gramsci's work on hegemony and ideology, they are far from conclusive. Ideology, and the desire of the elite to protect their traditional paradigm, are potential factors that seem to play a role in hampering the academic diffusion and acceptability of Alfvén and Lerner's plasma cosmological model. But there are other variables at play in this social conflict. Resistance to the plasma model may have nothing

[¶]Please refer to footnote on the next page.

to do with ideology, or self-preservation on the part of the traditional scientists. It may be a genuine belief, born of intense scrutiny, that the new candidate for paradigm does not stand up to empirical testing; it may not be falsifiable, or perhaps causes more problems than it solves, a characteristic which history shows is true of many new ways of knowing(Kuhn,1970:156).

Whether the plasma model is indeed a worthy opponent of the Big Bang will take years to decide. Often, the most demanding task asked of those who believe in the validity of a new, unorthodox theory, is to be patient, to develop the model further, to be willing to take criticism for the purposes of increasing the perceived potential of the new theory. "And as that goes on, if the paradigm is one destined to win its fight, the number and strength of the persuasive arguments in its favor will increase"(Kuhn,1970:159). After many years of trying, a new candidate for paradigm may well replace the traditional conceptual framework, and when that time comes, a new standard model, a new form of normal science will have been born.

¶Continued from page 194.

It should be noted that in all the three journal categories, the inconclusive articles outnumbered the anti-Big Bang articles. For example, as a group, 19% of all the cosmological articles published in the prestigious journals from 1989 to 1994, were inconclusive; this figure was 30% for the semi-prestigious journals, and 50% for the non-prestigious journals. These relatively large figures can be partly explained by the advent of new technologies. The launching of COBE and the Hubble Space Telescope near the end of the 1980s, allowed cosmologists to test, in an explicitly empirical sense, the predictions of the standard Big Bang model. While these new technological apparatuses reinforced cosmologists' faith in the standard paradigm, they also raised more questions than they solved. Indeed, throughout the history of science, the instruments of scientific investigation have often played a not insignificant role in paradigmatic change(Kuhn,1970:58-59). In the context of cosmology, the empirical anomalies discovered by COBE and the Hubble Telescope, caused many cosmologists to write articles demanding further research on the findings, articles which did not articulate the writers' own ideological stance with respect to the Big Bang; instead, these scholarly papers simply cited the need for an intensified analysis of the empirical results in order to determine their implications for cosmological research. It is unknown why the number of inconclusive articles increases as we move from prestigious to non-prestigious journal.

Chapter 7: Conclusions and Suggestions for Further Research

This thesis has attempted to study a paradigmatic debate within the realm of theoretical cosmology. It represents an effort to map the social and political forces which manifest themselves during times of perceived crisis, when the standard model of a community, a model that has guided the research efforts of a particular discipline for so many years, is faced with an anomalous discovery that it cannot easily explain.

According to Kuhn's thesis of scientific change, empirical anomalies force researchers to modify their single shared paradigm in light of the new findings, a retooling process that strengthens the existing paradigm, but only at the cost of discarding long standing beliefs and assumptions(Kuhn,1970:66). Thus, in the Kuhnian scheme, novel discoveries can be perceived as constructive as well as destructive events(Kuhn,1970:66).

Empirical findings are not the only sources of paradigmatic change, however, but are, in fact, complemented by the invention of new theories which claim that they can address conceptual concerns that the old model is incapable of doing(Kuhn,1970:66,153). In most cases, novel paradigms are born from the imagination of researchers either very young or new to the field whose standard model is perceived to be in a state of crisis(Kuhn,1990:90). Since these researchers have very little commitment to the traditional ways of knowing, they are more willing to embrace new conceptual frameworks, and have a higher probability of designing alternative paradigms(Stewart,1986:263).

Of course, the emergence of a new candidate for paradigm inevitably leads to social tensions between the supporters of the novel paradigm, and those whose distinguished careers have been inextricable linked to the older tradition of normal science, a tradition based on the achievements of the orthodox theoretical model(Kuhn,1970:10,151).

But, as Kuhn repeatedly points out in his thesis, the new candidate for paradigm may or may not be legitimate. Its success rests upon attracting a small group of supporters who believe in its conceptual worth, a belief that is, more often than not, born of subjective and aesthetic considerations(Kuhn,1970:158). It is up to these few supporters to develop the novel paradigm, to refine it, to explore its potential, and articulate to the community why it is important to consider. If the new candidate for paradigm is valid, and has strong intrinsic possibilities, then over time, it may come to represent the new norm of scientific investigation(Kuhn,1970:158-159). But such change takes time. As Kuhn states, "... a generation is sometimes required to effect the change..."(Kuhn,1970:152).

This thesis has articulated the argument that the resistance to the plasma cosmological model by mainstream cosmologists, is a resistance born of orthodox ideology, a resistance born of conservatism. It was argued that this conservative outlook is a product of the highly stratified structure of the scientific community, a social realm where a select few hold the reins of power and influence, researchers whose past scientific achievements resonate with social perceptions of authority and distinction. It was argued, that resistance to the plasma model is a function of stratification, of elite theorists within cosmology wishing to protect the paradigm which made possible, careers that are both prestigious and highly productive in academic circles.

It was also argued that resistance to the plasma paradigm is further compounded by the lack of prestige and visibility possessed by the plasma model's chief supporters, Alfvén and Lerner, within theoretical

cosmology, a social status made all the more acute by the fact that both these scientists are from a field of study outside the normal parameters of cosmological research. These social factors make the diffusion of the plasma model all the more difficult, a cause of considerable concern, for it is only through the process of communication that a new candidate for paradigm is exposed to a wide audience. Only then, can it hope to attract followers willing to invest their time in articulating the novel theory, expounding its strengths and attenuating its flaws. Only then, can a new candidate for paradigm hope to survive into the future, and replace the older tradition of normal science.

In order to test the above arguments, the theoretical framework known as the Elite-Kuhnian model, was first developed to map the social and political forces interacting within the context of the Big Bang, plasma debate. Then, hypotheses constructed from this general theory was applied to the debate to measure the social visibility of the plasma paradigm and its main supporters, Hannes Alfvén and Eric J. Lerner, relative to the traditional Big Bang model, and its chief proponents, a sample of four distinguished physicists drawn from the cosmological community.

In addition to the quantitative, empirical results, excerpts from interviews conducted with physicist, Dr. Peter J. Watson, were incorporated into the body of the thesis in order to highlight this debate from the perspective of someone who is presently conducting research within cosmology. It allows for a personal interpretation of the cosmological debate which is beyond the scope of an abstract, theoretical study.

As demonstrated in Chapter 6, the predictions of the Elite-Kuhnian

framework resonate, to an extent, with the observed empirical evidence. Analysis shows that the forces of stratification, ideology and conservatism, seem to play a role in hampering the diffusion and acceptability of the plasma cosmological model, but these results are far from conclusive.

In truth, the present study cannot state, in a quantitative sense, how much of the resistance faced by the plasma paradigm is a product of the above social variables, and how much is the result of other factors. This comment highlights the dichotomy between social and physical theories of knowing.

In the physical sciences, one can conduct experiments under tightly controlled conditions, holding all other variables constant while manipulating the independent variable to see its effects on the dependent variable. In such settings, for the most part, the outcome of such experimental manipulations are evident to the senses. For instance, in the classic physics experiment where a professor drops a bowling ball and a feather at the same time, the observer can see for him or herself, that the bowling ball hits the ground ahead of the feather. This result is a function of the intervening action of air resistance; however, if air resistance is controlled for, the ball and the feather hit the ground at the same instant, and at the same velocity. This result can be seen by all observers, and ones political or ideological views in this instance, has no bearing on the outcome of the experiment.

Yet, for the most part, physics styled experiments are impossible in the social sciences, a realm where the chief object of study is a sentient entity whose composition is too complex to be manipulated, the various facets of its nature, too varied to be controlled.

A further impediment to social analysis is that, social theories, in most instances, cannot be translated into a rigorous mathematical framework capable of making precise predictions; no social equivalent exists to Einstein's special and general theories. In this respect, social models are crude approximations to their physical science counterparts.

In the case of the Elite-Kuhnian model, its predictions are descriptive in nature rather than quantitative. It attempts, with respect to this thesis, to understand the social and political forces which interact during paradigmatic debates. And while its predictions are testable, and falsifiable, they do not propose precise numerical predictions; the Elite-Kuhnian theory cannot state how much of the resistance to the plasma model is a product of the "Matthew effect", and how much a function of the interests hypothesis; such a quantitative model may well be beyond the scope of social investigation.

In essence, the Elite-Kuhnian paradigm attempts to understand the complex interaction of social and cultural forces permeating the lives of countless thousands of researchers who compose the scientific community. As such, it is too much to ask of any model to disentangle the myriad of social variables interacting within the context of a theoretical debate. And since paradigm shifts take years to come to fruition, it is difficult to say exactly what variable was responsible for its occurrence. Thus, to test a social theory, is not as explicit as testing a physical one; there are too many factors one can not control for or foresee during the course of social analysis.

Given the inherent limitations of the Elite-Kuhnian model, the

analysis of the data articulated in Chapter 6, can only be viewed as one interpretation among many, an educated opinion to be debated in future discussions. While the evidence suggests that the Elite-Kuhnian framework has some degree of validity, it is important to keep in mind that there are other, more complex factors involved in this paradigmatic debate.

For instance, the resistance to Alfvén and Lerner's plasma paradigm may have nothing to do with protecting the status quo, but may be intertwined with more subtle reasons.

In the case of Hannes Alfvén, resistance may be a function of personality. Indeed, one main criticism of Alfvén by his peers in the physics community, is his very personal, combative nature, his confrontational interaction with other scientists (Brush, 1990:92). Hannes Alfvén's attitude of ignoring constructive criticism, refusing to admit the conceptual flaws in his own theory, and refine his model in the light of subsequent empirical results, may explain in part, the cosmological community's unwillingness to accept his cosmogonic theory (Brush, 1990:92).

In the case of Eric Lerner, resistance to his work may stem from his association with Alfvén, and adopting Alfvén's style of research and combative nature. But, it may also be partly due to his lack of academic credentials. Lerner does not possess a doctorate in physics, and is not associated with an academic institution. This serves as an obstacle on one front : the Ph.D degree is usually the most basic requirement for careers in academia and specialized research. It designates one as a professional, a full fledged member of the particular community in question. It allows other scientists to view you as an equal, one who has

paid his or her dues and is capable of rigorous scientific research. Social perception of the degree is, in some cases, more valuable than the degree itself.

On another front, since Lerner is not a university professor, he cannot talk about his unorthodox model with colleagues in an informal fashion, colleagues who may have similar interests as his own, peers who may be able to provide valuable commentary. Furthermore, his lack of institutional affiliation means he cannot attract graduate students, the next generation of scientists, into his fold who have similar views, and supervise their training in the unorthodox paradigm. This is an important point, because as Kuhn often remarked in his thesis, the future of a new candidate for paradigm rests in its ability to attract supporters who will develop it to the point that its influence will gradually grow within the scientific community(Kuhn,1970:158).

Lastly, another possible reason the plasma model has not been accepted, may rest on factors that have nothing to do with the forces of ideology and orthodoxy; resistance may be born of a belief that the new theory is theoretically and conceptually flawed. As was documented in Chapter 5, Dr. Watson's opposition to the plasma model revolved around technical and observational grounds. As Watson often commented, Lerner's arguments against the Big Bang may be valid on some conceptual fronts, but he tends to give only one side of the picture, ignoring other factors which may potentially hurt his argument.

Given the above comments, further research on the Big Bang, plasma debate is suggested, research which attacks this paradigmatic debate from a different theoretical and empirical angle. This study described the experiences of unorthodox researchers who had entered cosmological

research from a different field of specialization. It would be instructive to see how alternative models to the Big Bang, proposed by elite and unknown researchers from within cosmology itself, are greeted by the cosmological community.

Furthermore, it is suggested that future research on this topic attempt to explicitly test the interests hypothesis on a large sample of prestigious and unknown theorists within cosmology. Such a large study would be able to determine if elite researchers are in fact more likely than their unknown counterparts, in a statistical sense, to resist alternative cosmogonic theories.

In addition, a future research project could explicitly test another Kuhnian hypothesis in the context of this debate, one that is known as Planck's Principle. This notion holds that younger scientists are more willing to accept new scientific theories than their older counterparts (Hull et. al, 1978:717; Levin et. al, 1995:275). Of course, this study could be integrated with the interests analysis for the purposes of seeing interaction effects among the variables being analyzed.

This study was the first attempt to amalgamate the Elite theoretical framework, Kuhn's thesis of scientific change, and Gramsci's work on ideology and hegemony for the purposes of investigating the socio-political structure of a paradigmatic debate, a debate that has, thus far, not been studied by social scientists. The absence of any scholarly analysis of the Big

Bang, plasma debate, may be due to the unresolved nature of the debate, and highlights another important contribution of this thesis.

This dissertation is unique in the respect that it has attempted to study a paradigmatic debate that is still in progress. As stated earlier in the study, whether the plasma model is a legitimate heir to the Big Bang theory is unknown, and will not be known for years to come. Whether the plasma model will achieve its goals or not, or has the potential to do so, was not the concern of this paper; such a question can be more appropriately addressed within the pages of a physics dissertation. The objective of this study was to analyze the Big Bang, plasma debate from a sociological perspective, an analysis that was non post-hoc in nature, something that has not been seen before in the literature.

Despite the inconclusive nature of the results documented in this thesis, it would be unfair to ignore the hypotheses developed in this study. The social world is far too complex to be subjected to the kind of rigorous analysis found in the physical sciences, where precise quantitative values can be computed. Yet, the Elite-Kuhnian model has facilitated the study of the current cosmological debate in a way that would have been difficult, if not impossible without its theoretical insights. The limitations of the Elite-Kuhnian model highlights the fact that it is a model; it is an approximate representation of reality and not reality, a fact that must be kept in mind at all times.

In essence, despite its less than conclusive results, this study should stimulate future research on the sociological structure of the cosmological community. The results of parallel academic endeavors would, as Kuhn would say, refine and sharpen the conceptual paradigm

developed in this dissertation, a retooling that will inevitably sharpen the theoretical arguments articulated within the pages of this study and allow for a more comprehensive explanation of the complex, intricate social phenomena that are scientific revolutions.

Appendix A:
Interviews with Dr. Peter J. Watson

AI: First of all, thank-you for doing this interview. It seems, from my--being in sociology, there's a lot of articles on the sociology of science. And, one sociologist at UCLA, by the name of Harold Garfinkel, came out with a theory called ethnomethodology which he--I'll just say....What ethnomethodology is, is that human beings are constantly searching for patterns in the world, and this search for patterns forms a crucial component in how people make sense of the world around them; and he calls this, the documentary method of evidence. And what he did was, he used this theory to analyze tape recordings made by astrophysicists on the night of January 16th, 1969 when a pulsar was discovered in the heart of the Crab Nebula. And what he did was, he argued that the physicists were trying to impose a pattern on the recordings they were receiving, trying to convince themselves of the existence of the pulsar. And, I'll just give you a quote of what he says; he says, quote "many different underlying patterns could be proposed to account for these details, with...pulsars only among one of them....Perhaps if the shoptalk had gone differently, the conclusions drawn...would have been different, and pulsars would not have been discovered at all."

And, my question is, what do you think of these philosophical debates which sort of argue that there are no real physical, physical laws out there, but are just only human cognitive projections?

PW: I think, firstly that, that particular thing is complete rubbish. There are two separate things going on there: the first was, pulsars had actually been discovered about two years earlier by...well...Hewitt and...Jocelyn Bell. What that observatic was, was the first optical observation of a pulsar, and actually, I've listened to the tape myself, and it's kind of amusing that, on a...it's on a...movie education we use to, to...give to students. The point is, that there were about, I think, probably 15 observations of pulsars before that. What was critical about this one was that it was the first time that it had ever been observed at optical wavelengths; previously, it'd always been observed in the radio.

AI: Right.

PW: Now, people were expecting to see it in the optical wavelengths, but...it's a--it requires a different experimental technique. And, actually, the people who did that particular experiment weren't astrophysicists, believe it or not.

AI: Hmph.

PW: They were actually particle physicists, because the techniques they used were particle physics techniques. And, so, it was--and it's ironic because it was the only astronomical observation they ever did. They went there a few nights before, got an astrophysicist to help them, did the observation, and never did another one.

AI: Hmph.

PW: So, yeah, I mean, they expected to find it pulsing but, nevertheless, when they actually did, did find it pulsing, it was quite a surprise to them.

AI: I, I used this article in a presentation I had to give, and I--my comment was, there's a limit to the art of convincing yourself of something that doesn't exist. The way he was writing it up--.

PW: Hmph-hmph.

AI: --it seemed to me that you could, sort of, look at anything and convince yourself of seeing something that doesn't exist, that....He just sort of went....

PW: I can give you a nice counter example. You know there was a supernova...about 1987A?

AI: Right.

PW: Yeah. People were absolutely convinced there should be a pulsar at the center of that. And so, people looked for the pulsar for about 8 months after the explosion, and someone found it; and they found it, it was pulsing at...2700 hertz, which is far faster than a pulsar has ever gone. And these people became famous, almost overnight, for discovering the pulsar. Everyone knew it was there, but everyone was satisfied. And then, no one else could find it. And they searched for this pulsar for months afterward. And then, the same people went back and looked again, and they found it's nothing to do with the pulsar at all; it was a glitch in the video camera which happened to have an internal frequency of 2700 hertz.

AI: Oh(laughs)!

PW: So, I mean(laughs), there really was an objective reality there, but the objective reality was a video camera; it wasn't a pulsar.

AI: So, these basic issues seem to always revolve around....When sociologists are talking about the nature of truth--.

PW: Hmph-hmph.

AI: --they always talk about....So, what does truth mean, really, in physics?

PW: Well, there it means repeatability.

AI: Right.

PW: I mean, anyone can do it. You have a prescription of how to go and look at the Crab pulsar; you can use exactly the same technique to look at 1987A. In one case you'll see pulsars, in another case you won't. It's as simple as that.

AI: Well....So, in terms of the, the whole notion of truth being applied to physics as a whole, where does--how is that defined?

PW: Oh, that's far too big a question.

AI: Okay.

PW: I mean, repeatability and falsifiability. Repeatability--.

AI: Right.

PW: --for an experiment, when you're talking about theories, you usually__pay

at least lip service to the idea of testability and falsifiability.

AI: Right.

PW: I mean, in practice, they're much sloppier than that. And it, it really comes down--in the ultimate__does it work.

AI: Okay. It's interesting that--'cause in sociology/anthropology, there's always these philosophical debates going on, within those disciplines, about epistemology, objectivity, the limits of deterministic description, and so forth. And it, and it goes on all the time, and is seen as natural. And it's interesting that physics was taking on these issues at the end of the 19th century, when someone like Ernst Mach wrote a book called, *THE SCIENCE OF MECHANICS: A CRITICAL AND HISTORICAL ACCOUNT OF ITS DEVELOPMENT*; and Henri Poincaré challenged Newton's concept of absolute space and time, and so forth. And I was wondering, what, you know, what have these philosophical debates evolved into in physics in 1995?

PW: Well, the irony of all this is of course, I think, the guy who probably said it best is...Michelson, when he said the future of physics is measuring the fourth decimal place, and this was about two years before the whole structure of physics collapsed with Relativity and Quantum Mechanics. And, I mean, we all have to pay for hubris. Not often does it--that things collapse around us as badly as that. The real thing, and I think this is perhaps the most ironic, is that Poincaré...was right, Ernst Mach was wrong, and Ernst Mach was wrong in the one science he understood best, namely mechanics, because we now know about chaotic systems, and chaotic systems are intrinsically, well, they're deterministic, but not predictable.

AI: Right.

PW: And...it--that, that's an a--really is one of the most amazing, if you like, philosophical discoveries of the last twenty years in physics: that we've known about quantum mechanics limiting predictability, but no one ever dreamed that classical mechanics, simply because everything is deterministic, no one ever dreamed that it's going to be unpredictable.

AI: I was reading...a thing on a...what Einstein wrote--a friend, a friend of his; his name was Dr. Philipp Frank. And, he wrote a paper called, *CAUSAL LAW AND EXPERIENCE*, and he sent it to Einstein. And, he argued that the law of causality, and this is a quote, "can be neither confirmed nor disproved by experience; not, however, because it is a truth known a priori but because it is a purely conventional definition." And, Einstein agreed with this view, but argued that this accounting only showed that there exists a conventional element in the law. And Frank stated, and I quote again, "he agreed with me that, whatever may happen in nature, one can never prove that a violation of the law of causality has taken place."

And how do you respond to this--how does physics respond to these comments?

PW: Firstly, causality is much more...vaguely defined than it used to be in those days. Again, one has this sort of 19th century concept that any cause necessarily has an effect, and it was always the same effect. I mean, Quantum Mechanics blew that away completely, and now Chaos theory has done it again.

AI: Right.

PW: It--I mean, it, it is no longer true an experimental fact that effect follows cause in a naturally predictable fashion; there's a more, there's a much more subtle point here and that is that, whether...whether we would notice if causality broke down. I mean, causality in Quantum Mechanics is actually quite well defined; it's, it's defined in different ways than in Classical Mechanics, but nevertheless, it's well defined. Now, you can think and--for example, John Bell at CERN came up with various possible ways in which causality could be violated, and in fact...it is possible to think a phenomena in which causality could be violated even in the quantum mechanical sense; they haven't shown up yet.

AI: Okay.

PW: So, it's a testable statement, which is what makes it interesting.

AI: Moving into the social realm of physics, there's this...popular perception of physicists, sort of, looking down upon their social science colleagues with academic...well, disdain, or whatever. And, I'm reminded of a poster, I believe here in the office, of Rutherford and his comment, "Physics is the only true science, everything else is..."[Dr. Watson points to the poster in question which is hanging from the wall directly behind me, and I turn to read, aloud, the remaining portion of the quote]. All the rest is stamp collecting! Okay! So, I was wondering if this perceptual stratification exists within physics, and I ask that because of...this book[I open Sharon Traweek's text] in which, I'll just give you a brief quote of what she says; she says, "One rarely sees experimentalists in the offices of theorists. These people do occasionally discuss physics together, but their meetings typically occur on the second floor. Several theorists told me that an experimentalist would probably feel awkward among the theorists, who have more status."

And...so, I mean, does this really exist in physics? I mean, do physicists consider themselves academically, or intellectually superior to chemists, biologists, and, you know, the old punching bag, social scientists?

PW: I, I suppose...as a joke, yes, because jokes probably reveal something about the way one really thinks; and probably is some truth at the bottom of this. I think a lot of the point is that, it's quite easy if you're brought up in a rigorous field to see flaws in a non-rigorous field. For example, I have an issue with quite a lot of work with psychologists, here. And, it's very easy for me to instantly see what is sloppy about an experiment, whether an experiment really does test what they're claiming to test. But, I think....As I've said in more than one talk, in fact, the most embarrassing part of this particular collaboration was to discover that psychologists knew a hell of a lot that I didn't know.

AI: I'm surprised that there are so many people in the department of sociology who have a background in...in physics or science. And, it's dangerous to come up to them with a presumption that they don't know anything

about this, 'cause then--.

PW: It's certainly dangerous to come up to Charlie Gordon with the idea he doesn't know about things.

AI: That's true.

PW: He's one of the smartest guys I know.

AI: That's true. Does he have a background in physics?

PW: No. He has done some science. In fact, I think what he told me was, he went through some first year science at Amherst.

AI: Okay. He's a--.

PW: He's extremely well informed.

AI: Right. And....This thesis, though, and I want to clarify it, is in sociology, not in physics. My, my objective is not to prove or criticize the Big Bang; I just want to look at the, the nature of paradigm shifts within science; the social foundations upon which it occurs. And, it's interesting, in my readings, I've come across research by plasma physicists, by the nobel laureate, Hannes Alfvén--.

PW: Yeah.

AI: And, you know, he came up with a theory of looking at the evolution of the universe using electro-magnetic theories--.

PW: Hmph-hmph.

AI: --which he says does a good job of explaining things. And...the funny thing is, you can't find, really, his work in the mainstream physics journals, and I was--they usually end up in electrical engineering, or aerospace engineering journals, which is interesting. And, I'm saying, you know, why does this occur, why is there a reluctance to, to publish his stuff in the mainstream journals?

PW: Actually, I've never--I mean, I, I don't know whether it's true that he was rejected by the mainstream journals. I think he may simply have published in the journals he was happy with, mainly the plasma physics ones. There are a couple of points here: one is, there is definitely passions in physics, as in any other subject. The second thing is that, we're at the stage, particularly in cosmology, where there is--we've gone from a stage of understanding nothing thirty years ago, to actually having theories that largely work as of today. So, therefore, there's this usual reluctance to look at anything beside. Now, Alfvén's...work, which I must admit I have not looked at for a while, is actually...technically, wrong. I mean, it's not--I'm sorry, not wrong; it doesn't describe the universe as we see it. And...it's the following observation that makes it wrong. He needs to have a lot of turbulence, a lot of...inhomogeneity in the very early universe, because you want to produce large electric and magnetic fields. If you have an absolutely uniform universe filled with hydrogen, you can't do that.

AI: Right.

PW: You've got to have a tremendous amount of turbulence. Now, there's this experiment that was done with the COBE satellite--well, not exactly an experiment--observation that was done with the COBE satellite, perhaps three years ago, that actually looked back to the universe 500,000 years after the Big Bang. And, at that stage, the universe is almost totally uniform, it's incredibly uniform; to one part in ten-thousand. Now, that observation alone is incompatible with what Alfvén claims the early universe should look like. So, therefore, I think Alfvén is wrong. I mean, it's not--I'm not saying he doesn't have a good idea, and I'm not saying it's not an alternative theory to the Big Bang; I'm just saying it's not right.

AI: That's interesting, 'cause this follows up to my second question which is, I haven't had a chance to look at the COBE results, but it's interesting that in my readings, depending on what camp you're in, whether you're for the Big Bang, or against the Big Bang, you can look at the COBE results and say that it supports your...your argument. Have you had a chance to--?

PW: I don't think anyone now seriously claims that COBE is supportive of arguments against the Big Bang. For example, Hoyle is one of the...he strongly opposes the Big Bang on, on partly philosophical grounds. He argued that, you could get a microwave background, which is what COBE measures, you could get, you would get--expect to see a microwave background in virtually any model. The problem is, you don't get a uniform one, and that's what COBE found, that it's so perfectly uniform.

AI: Okay.

PW: And so, not only did COBE kill Alfvén's theory, it killed the Steady-State model of the universe.

AI: That--.

PW: And several others.

AI: Is that referred to as isotrophy, the--?

PW: Yeah, yeah. Perfectly isotrophic.

AI: I also read that...an article in TIME magazine, dealing with scientists Laurer and Postman at the Space Telescope Science Institute in Maryland, they announced that, this is based on their observation, that our galaxy along with a few thousand others, are moving toward the constellation Virgo--.

PW: Yeah.

AI: --and--in violation of the expanding universe model. And, a scientist, astronomer Wendy Freeman and her colleagues at the Carnegie Observatory, using the Hubble Space Telescope, argues that the universe is 8 to 12 billion years old, while at the same time, acknowledging that there are stars that are 14 billion years old. And...does this empirical observation suggest that cosmology is on the brink of a scientific revolution?

PW: No. TIME always does that; TIME misses out the error bars. If you look at what Wendy Freeman actually measures, she measures the Hubble constant to be,

well, 87, but it's 87 plus or minus 20.

AI: Okay.

PW: Now, that means, the age of the universe is...by my reckoning, somewhere between 8 and 15 billion years old. Now, if you talk to the people who actually measure the measured ages of the oldest stars, which, by the way, I mean, it sounds a trivial thing to do, but it's not; because you can measure the age of young stars very accurately, because young stars evolve fast, you can watch them in all stages. But, to some extent, there's guess work in measuring the age of old stars. And, I forget who the woman is, someone from Waterloo, she came up here ten or nine years--couple of years ago, because she's one of the people who've done this very seriously. And, she says, yes, you look at the old globular clusters, the stars are 14 billion years old; 14 billion plus or minus 5. So, if these two numbers get their error bars down by another factor of ten, then you can kill the Big Bang. You know, if not 14 plus or minus 5, it's 14 plus or minus point 5, then the--and it's not...it's not between 8 and 15, it's 8, then the Big Bang is dead.

AI: Okay.

PW: So, it's an absolutely testable theory, which is what's nice about it.

AI: Fourteen plus or minus five billion; does that indicate that the stars are anywhere--there's a, what, roughly 70% probability that the stars are anywhere from 9 to 19 billion years?

PW: Yes.

AI: That's a pretty big range!

PW: Yes. Yeah. Fourteen is our best estimate. They're honest. I mean, they do the measurements quite honestly; TIME would take the error bars off.

AI: Yeah, they didn't mention the error bars in the article.

PW: Yeah.

AI: They just said that...nobody can find anything wrong with their...methodology in terms of doing the observation. But they ignored the error bars in the actual article, so, you didn't get an idea of how accurate or far off they were.

PW: I mean, I'll tell you how the observation is done; in principle it's very simple. You look at clusters of stars which you believe are old, and as...what happens is the hot, blue stars go supernova, and so, you can trace down to what is the oldest stars that has not gone--what is the brightest star that has not yet become a supernova. And that--you now have to believe you understand the theories of solar models, or stellar models, very well. And, if you understood the theory of stellar models exactly, that would tell you exactly how old that cluster of stars was. But, unfortunately...it's just not that good. You understand the hot, blue stars because they're easy; you can't do it for the old, red ones quite so well.

AI: Well, given the reality that the technology to test cosmological models

didn't exist until very recently, is it a fair statement to say, which others have said, that only lately has cosmology emerged from the realm of philosophical debates into that of a, you know, really testable, empirical science?

PW: Yes. Yeah. Okay, I mean, the--Hubble's observations on the expansion of the universe was a beginning; they were nineteen-twenty...eight, let's say. Then, the next critical thing was the first microwave background experiment, which was 1964. Then, the things that have been done over the last ten years had been very precise measurements, with concentrations in different elements. The technology, really, existed, but the people didn't know how to use it, if you like; they didn't know what to look for. Now, over the next 10 years, or so, from 1990 through to 2000, you've got COBE, you're going to have son-of-COBE, I can't remember what it's called, but it's another, it's going to give you another factor of ten accuracy. Hubble Telescope will nail down the Hubble constant, so it's no longer 87 plus or minus 20, it's going to be a real number.

AI: Hmph.

PW: And both of those things will be done well before the year 2000. So, it's__.

AI: Pretty exciting era.

PW: Oh, yes. Yeah.

AI: My last question is, on April 4, 1955, two weeks before his death, a historian of science had a two hour conversation with Einstein. And, during the interview, Einstein remarked that, at the start of the 20th century, only a small number of physicists were influenced by philosophy, or were philosophically minded, but that today, and he meant 1955, physicists are all but philosophers, yet he said, quote, "they apt to be bad philosophers." And what's your response to that...comment?

PW: I don't think it was true then; it certainly isn't true now. I think, that in fact, very few...physicists know much philosophy. You're, you're looking at a--I mean...yes, Einstein was; yes Einstein's friends at Princeton were. John Bell was. You can look at a number of....It's easy to pick out the names of the people who really have...contributed in this way. But, the vast majority of working physicists that--are technicians. I mean, they're people who build things, they're people who do calculations.

AI: Okay. So, then, a vast majority of physicists aren't philosophically minded, as he, as he--.

PW: Yes.

AI: --was saying.

PW: Certainly not in my experience.

AI: So, is the Big Bang model, then...based on the most recent observations, healthy and strong?

PW: Yeah, and what's nice about it is, is that it's absolutely on the edge. I mean, for a long time it--because it was philosophy, no one was thinking about testing it.

AI: Right.

PW: But, now it's a theory that, you know, as I've said, was the, these measurements prove it to be: Hubble constant, and the age of the oldest stars, those are just on the edge. If either of them is--if they carry on getting better at the current rate, then, either cosmology, I mean, between the preferential for the Big Bang cosmology, either it's dead, or it's right.

AI: Well, those were the main issues I wanted to deal with. And, thanks for taking the time.

PW: Okay.

AI: My first question is on the Special Theory. When Einstein formulated the concept that natural laws were identical for all observers, and that the speed of light was a constant in the universe, he gave rise to a number of astonishing predictions. For example, that moving objects were shorter along the axis of motion than when at rest; that time as measured by a clock in relative motion measured time at a slower rate than an identical clock at rest; that the mass of an object was linked to its relative velocity, so that an object moving close to the speed of light has a greater mass than when at rest. The question is, what do these results *really* mean in terms of everyday human experience? What is *really* happening, in a physical sense, to objects moving close to the velocity of light?

PW: Part of it is this - I guess it's a 20th century idea: you're not allowed to ask the question what *really* happens. The question you're allowed to ask is: what can you observe. And so, what you observe is that the mass of the particle is increasing, and they have a high velocity with respect to you. It's then natural to ask, what *REALLY* happens to the mass, and it's not an answerable question. It really does depend on the frame of reference: you can measure the mass in this frame, you can measure it in another frame.

AI: Okay. So, there is no absolute answer to this question?

PW: No.

AI: Okay. Now, in the Special Theory of Relativity, Einstein dealt with a very limited form of motion: that is, objects moving at a constant velocity, hence the term "special" in the title of the theory. But Einstein was compelled to show that relativistic effects applied to non-uniform motion as well, thus, giving rise to the General Theory of Relativity. And, I was wondering if you could explain the essence of the theory and what it predicts.

PW: The General theory.... The essence is that, if you have(*coughs*). Okay, let me start over. There's a principle of equivalence which says that, in a sense, acceleration and gravitational fields are identical. And so, one of the things he was trying to understand was why all objects appeared to accelerate in a gravitational field at exactly the same rate. And this is observationally true, and it's checked to an enormously high accuracy. So, what he built into the General Theory of Relativity was essentially that as input, rather than that as output. And the...usual way of describing it is that, a massive body will "warp" space-time in its vicinity; it will give it a curvature. And that when you see, for example, a ball traveling in a parabola, it's actually traveling in a straight line, but in a warped space, a curved space.

AI: Okay. That leads nicely into the third question. Now, the concept that mass "warps" or "curves" the fabric of space-time is used to explain the force we call gravity. Indeed, the most common analogy is to represent space-time as a 2-dimensional plastic grid surface: the depression in that plastic surface, caused by the presence of a large object, represents the force of gravity. But in actuality, what is *really* going on at the physical level? What does it mean when physicists talk about space-time as having some form of tangibility? And how does the general public conceptualize explanations by physicists like Stephen Hawking, when he argues, "the mass of the sun curves space-time in such a way that although the Earth follows a straight path in 4-dimensional space-time, it appears to us to move along a circular orbit in 3-dimensional space."

PW: The best analogy I know to this is living on the surface of the globe as we do. What we mean by a straight line on the surface of the globe is...somewhat peculiar. For example, if you take a Mercator projection of the Earth, and you simply draw a straight line from New York to Paris, the chances are that is not the shortest distance as measured along the globe. So - and the shortest distance, which by definition is the straight line, is some line which actually deviates from the straight line of the Mercator projection. So...what you have to do first is to accept the idea that the straight line is the shortest distance: actually, because straight...has a whole lot of emotional baggage that goes with it, it's safer to use the word geodesic -

AI: Right.

PW: - which really means the shortest distance. So, that an apparently straight line in one frame of reference, is actually curved in another frame of reference, and isn't the shortest distance.

AI: Right. Okay. According to historical records, it was a Belgian priest by the name of Abbe Lemaitre who first purposed that the universe had begun as a "primordial" atom. But according to Hawking and others, it was George Gamow who first articulated the modern version of the Big Bang theory. Would this be a fair assessment?

PW: I think so. Yes. Lemaitre, if I remember right, had.... Actually, when you mentioned that to me, I wasn't aware it was him. I thought it was...the other guy....

AI: Friedman?

PW: Yeah. Yeah. But you're probably right; Lemaitre was probably the first. Lemaitre and Friedman both had, essentially...metrics in the Theory of General Relativity, which made, if you like, predictions that the universe had expanded from a "primordial" atom. George Gamow was the first guy to think through the other logical consequences of this. For example, if the universe started as a highly compact object, it must have been extremely hot, and therefore, there must be consequences flowing from that...thermodynamics, not just from Relativity.

AI: I guess, Einstein chided himself for trying to input a cosmological constant to prevent -

PW: Yeah.

AI: Which later turned out to be false, 'cause they found - well, Hubble found empirical evidence to show that the universe was expanding.

PW: Yeah. Einstein was desperately trying to fudge the theory so it didn't automatically expand; and that's what the cosmological constant did. Then of course, it does expand.

AI: A few days ago, I handed to you an article which argues that one does not need the Big Bang to explain the genesis of the universe. What is your critique of that article?

PW: Actually, there are tremendous number of models that do that; you don't even need to go outside General Relativity; you can write down a model that's completely consistent with classical General Relativity which has no Big Bang. The things you're allowed to play with in General Relativity are: number 1, the density of the universe; number 2, the curvature parameter, k ; and number three, the cosmological constant. Now, there's a standard assumption

for these: you assume the density is somewhere less than critical; you assume the cosmological constant is zero; and you assume the curvature factor is plus 1. But - you can fiddle with these assumptions, and in that, you can produce several universes that don't have a Big Bang beginning. For example, one that contracts from an infinite size to a minimum size, and then starts re-expanding. So...you can then ask the question, well, is this theory somehow aesthetically better than General Relativity. Now, you can argue that the Big Bang is...an unaesthetic thing. But on the other hand, the evidence we have is that there was a Big Bang. That's....What he does there is to add an extra term, essentially, which is a bit like adding the cosmological constant, except that in his case, it's an anti-symmetric tensor. So in a way, it's sort of fudged in, in the beginning. Now, sure, you get rid of the Big Bang, but it's not clear to me that the...what comes along with that isn't considerably worse, in that you have this rather ugly looking extra tensor sitting around in General Relativity; it has no real business being there.

The second point about this is that, it's similar to Grands-Dicke theory. Grands-Dicke theory says that General Relativity is incomplete: there's an extra term in it which is a scalar field as opposed to a tensor field. And then, Dicke did a number of very careful experiments to try and search for this extra term. And he ended up by finding that the strength of this extra term must be less than 1% - I think it was - of the standard form. So, you can't...so, although you can...nominally add this, you then find that if you do, it would turn out to be so weak that it wouldn't be important. It makes it kind of ugly; firstly, you add something that's unnecessary, and then you say, well, it's hardly there anyway. Now my guess is, and he doesn't address this point in that paper - and I've forgotten the guy's name anyway - my guess is you find similar things there; the anti-symmetric tensor would necessarily have a rather weak...coupling, so, it would not be all that important.

AI: Okay.

PW: So, I think that the executive summary is that, yes, that's a model without a Big Bang, but, there are quite a few models that don't give a Big Bang, and...that this are...in - at the cost of getting rid of the Big Bang, introduces something that I think most people would regard as, sort of, extra baggage.

AI: Okay.

PW: If you want a much prettier model though - the Big Bang by the way - there's the idea that Andre Linde, and he put it forward: he's at Caltech, I think. And his universe is what's called continuous inflation, and it's...it consists of many universes, so, let's call it a multiverse, in a word, some of which at any given time are growing from something that looks like a Big Bang, but actually there never was an actual Big Bang in any of these universes; they simply expand, and they're expanding from something small, not infinitesimal.

AI: Okay.

PW: So, that's a nice model; it gets rid of most of the objections, but it also keeps the observational data that we seem to have had a Big Bang.

AI: But doesn't he argue, among others who are anti-Big Bang, that the Big Bang theory doesn't account for the...somewhat...inhomogeneity of the universe in terms of the distribution of matter?

PW: It...it's not...it depends when you think that inhomogeneity formed; if you think that inhomogeneity formed in the first milliseconds, then the Big Bang is in serious - the standard Big Bang model - is in serious trouble. Most people I think, now, would argue that the inhomogeneity developed at about a million years afterwards, and had grown since.

AI: Okay. So the theory is, despite critics assumptions, it basically...the basic test is that it stands up to empirical observation.

PW: Yeah. Yeah. And it can still be wrong.

AI: Okay. I guess the - one question...going back to the notion of gravity, I guess...nobody knows what gravity is in the sense, you can't take it apart and look at it and analyze why it works the way it does, can you?

PW: That's sort of correct. I mean...one way of saying that is you can write down...other field theories...which work perfectly well...and describe things like gravity but are a bit different.

AI: Weren't Feynman and Hawking trying to come up with a quantum theory of gravity?

PW: Yes.

AI: And it hasn't been -?

PW: It's extremely difficult. You can do a quantum theory of gravity as long as gravity is weak. That's not particularly interesting. What you'd like is a quantum theory of gravity when gravity is strong, and no one has managed to make that work.

AI: Okay.

PW: It may suggest that there is no theory. And...for example, Penrose...suggests that in his-what's the book called ?-Emperor's New Clothes.

AI: Okay. And...the final question is, when we talk about...General Relativity, Einstein seemed to have struggled with the mathematics of it for a good couple of years, and he had to ask his friends who were pure mathematicians to help him. And the term tensor calculus continues to rise. What would be the proper definition of that term?

PW: Tensor calculus is something that - a technique for dealing with...multi-dimensional objects. I mean, for example, a vector in 3-dimensional space; three numbers to describe a direction.

AI: Right.

PW: That's a kind of tensor. Now Einstein found he needed...6-dimensional tensors to describe General Relativity, and...he - and Feynman actually comments on this in his book. The most staggering thing about this is the step that goes - to go from the very simple tensors that were

around at this time, to realizing that you needed something much more complicated to describe General Relativity. It's really bizarre. I don't think they had a particular reason to have made it.

AI: Okay.

PW: Presumably, Einstein tried a whole lot of other things...and they didn't work, but he didn't bother...writing these down.

AI: Okay. So, I guess, for now...it's possible that, say, a hundred years from now, the Big Bang theory could be...quite modified from what it is today?

PW: I would say 10 years; I don't think you need to wait a 100 years.

AI: That soon?

PW: Oh, yeah. Yeah. I think you'll know by...certainly within the next 10 years. Well, wait a minute two separate things - I'm sorry. The standard Big Bang theory could be wrong virtually tomorrow.

AI: Okay.

PW: That might imply that General Relativity is wrong. But there are more ingredients to standard Big Bang than General Relativity.

AI: Okay. And the standard Big Bang theory would be the one we've been...discussing.

PW: Yeah.

AI: Okay.

PW: And you've got to assume...no cosmological constant; you've got to assume this and that.

AI: So, I guess that's all the questions I wanted to ask you. Thank-you very much.

PW: Okay.

Appendix B: The Journals. The Survey.

The tables below represent the population of journals compiled for this thesis. The periodicals were divided up into three categories of journals: prestigious, semi-prestigious, and non-prestigious. In this case, prestige was a function of citation rates; a journal's respective citation index was obtained using the 1993 Journal Citation Reports (JCR).

Prestigious Journals

<u>Journal Name</u>	<u>Citation Rate 1993 JCR</u>
1. Nature	226,827
2. Science	170,514
3. Physical Review Letters	103,790
4. The Astrophysical Journal	57,088
5. Nuclear Physics-B	25,819
6. Astronomy & Astrophysics	18,404
7. Reviews of Modern Physics	8,850
8. Astronomical Journal	8,093

Semi-Prestigious Journals

<u>Journal Name</u>	<u>Citation Rate 1993 JCR</u>
1. Annals of Physics	6,410
2. Scientific American	4,194
3. Astronomy & Astrophysics Supplement Series	3,161
4. Annual Review of Astronomy & Astrophysics	2,549
5. Reports on Progress in Physics	2,545
6. American Journal of Physics	1,784
7. IEEE Transactions in Plasma Science	1,124
8. Physics Today	1,109

Non-Prestigious Journals

Journal Name	Citation Rate 1993 JCR
1. Aerospace America	41
2. Journal of the Royal Astronomical Society of Canada	87
3. British Journal for the Philosophy of Science	204
4. Contemporary Physics	406
5. Progress in Particle and Nuclear Physics	478
6. Theoretical and Mathematical Physics	931
7. Annual Review of Nuclear and Particle Science	1,080
8. New Scientist	1,086

After the journals were divided up into their respective categories, three of the highest cited journals in the prestigious and semi-prestigious categories, and three of the most poorly cited journals in the non-prestigious category, were surveyed; the survey, commencing in 1989 and terminating in 1994. Three journals in each category were surveyed, and only three, due to temporal constraints.

The above journals were selected because they published articles in theoretical cosmology, and because Carleton University's library possessed editions of the periodicals which covered the 1989-1994 survey period.

Since 24 journals were compiled for this survey, they were arbitrarily divided up into groups of eight for the sake of convenience.

It should be noted, that this population of 24 periodicals, has a cumulative citation total of 644,372. Approximately 78% of that figure can be accounted for by the three highest rated journals in the prestigious category.

The Survey.

In light of unforeseen circumstances, I was forced to conduct a random sample of two journals, specifically, Physical Review Letters and Annals of Physics; time limitations did not permit a complete survey as with the other periodicals. The sample designs for the two periodicals, are discussed below.

Physical Review publishes a large number of articles each week, and these articles are subsequently bound into individual volumes and placed on the shelves for inspection at Carleton University's library. For the year 1989, Physical Review had 12 volumes of research articles. For the survey, I gave each tome a number ranging from 1 to 12. Then, using the random number generator in the text Understanding Data, I selected 7 random numbers corresponding to 7 volumes of Physical Review. Starting off at the "cell" of numbers located in the first column and the first row of the random numbers table, and reading from left to right, the following 7 numbers were generated 1,10,5,6,3,7,12.

The year 1990 had 9 volumes; 6 of the volumes were randomly sampled. Starting at column 2, row 1 of the random numbers table, the following numbers were obtained: 8,9,7,2,6,3.

The year 1991 had 10 volumes; 6 of the volumes were surveyed. Commencing at the "cell" located in column 3, row 1, the following numbers were obtained: 4,2,6,8,10,3.

The year 1992 had 9 volumes; 6 were surveyed. Commencing at the "cell" found in column 4, row 1, the numbers generated were: 5,1,3,7,4,9.

The year 1993 had 10 volumes; 5 were surveyed. Starting at the "cell" in column 3, row 5, the numbers obtained were: 10,4,3,5,8 .

For 1994, there were 8 volumes; 4 were surveyed. Commencing at the "cell" in column 4, row 7, the numbers obtained were: 7,6,8,2.

The publications of the journal Annals of Physics, are bound into exactly 8 volumes each for each of the years, 1989-1994, at Carleton's library. A random sample of 4 journals was selected for each of the five years encompassing the survey. The columns (C), and the rows (R) of the "cells" in the text Understanding Data, used to generate the random numbers for this survey, and the random numbers produced for the years 1989 to 1994, were as follows: for 1989, C1R1: 1,5,6,3; 1990, C2R1: 8,7,2,6; 1991, C3R1: 4,2,6,8; 1992, C4R1: 5,1,3,7; 1993, C5R1: 7,3,8,1; and for 1994, C3R8: 8,6,5,1.

In order to demonstrate how the various estimates of the number of articles published in the previously mentioned journals, were computed, the analysis performed on Annals of Physics will be used as an example.

Firstly, 48 volumes of the Annals of Physics were randomly sampled; each volume contained two months worth of articles, or two half months worth of articles. For example, one volume of the journal would contain articles for the months designated January 1, and February 1; or, articles for the "months" designated November 1, and November 15. Thus, from 1989 to 1994, Annals of Physics published 96 "months" worth of articles. Of this population of 96 "months", 48 were randomly obtained. The average number of articles ($\bar{x}$) published each "month" for this sample came to: 6.895833333. In order to estimate the total number of articles published by Annals of Physics from 1989 to 1994, the estimated average number of articles published each "month", 6.89583..., was multiplied by 96. This gave a total article count of 662.

In order to calculate the error on this estimate, the following formula was used: $\Delta \bar{y} = Ns/(n)^{1/2} \times (1-t)^{1/2}$ *, where $t = n/N$; N , being the population size, n , the sample size, and s , being the sample standard

* I am indebted to Dr. Ikuko Webster for showing me this formula.

deviation. Using this formula, an error rate of 17.53173413, was obtained. But, since the sampling design did not employ replacement, this error term had to be modified by what is known as the population correction factor (eg. $[(N-n)/(N-1)]^{1/2}$ (Harnett, 1982:277-278). This resulting computation gave the final error rate as: 12.46188364. Thus, the estimated total number of articles published from 1989 to 1994 came to: 662 ± 12 .

The above mathematical methodology was used to calculate the values for the remaining categories in tables 10A and 10B (eg. total number of articles on the Big Bang, No. Pro, and No. Inconclusive).

Examples of Pro, Anti, and Inconclusive

Big Bang Journal Abstracts

Pro Big Bang Abstract

"The relativistic hot Big Bang model for the expanding Universe has yielded a set of interpretations and successful predictions that substantially outnumber the elements used in devising the theory, with no well-established empirical contradictions. It is reasonable to conclude that this standard cosmology has developed into a mature and believable physical model"(Peebles et. al,1991:769).

Anti-Big Bang Abstract

"In contrast to standard ECSK theory with the Brans-Dicke scalar field (ϕ) nonminimally coupled to the curvature scalar, an additional new pseudo scalar term $\chi^N E^{\alpha\beta\mu\nu} R_{\alpha\beta\mu\nu}$ (contraction between Levi-Civita pseudo tensor and curvature tensor) has been included in the Lagrangian. The new term is non-zero due to the non-symmetric nature of the connection and vanishes identically in the general theory of relativity. We show that there exists a nonsingular cosmological solution for a spatially flat ($k = 0$) Robertson-Walker line element in the radiation era; therefore our model has no big bang"(Jha,1994:1067).

Inconclusive Big Bang Abstracts

"Galaxies, mapped in two or three dimensions, are not distributed randomly but are clustered on small scales ($< 5 h^{-1} \text{ Mpc}$, where $h \approx 0.5-1$ is Hubble's constant in units of $100 \text{ km s}^{-1} \text{ Mpc}^{-1}$), for reasons conventionally ascribed to the effects of gravity. Whether galaxies remain correlated on very large scales ($\sim 50-100 h^{-1} \text{ Mpc}$) is of particular interest, because such structures are unexpected in most cosmological theories. We have combined data from four distinct surveys at the north and south Galactic poles to produce a well sampled distribution of galaxies by redshift on a linear scale extending to $2,000 h^{-1} \text{ Mpc}$. Here we report our finding of an excess correlation and an apparent regularity in the galaxy distribution with a characteristic scale of $128 h^{-1} \text{ Mpc}$. This structure is revealed only after the completion of recent surveys extending to redshift $z > 0.2$. Similarly deep surveys with greater angular spread are needed to verify our results and to determine the implications for cosmology"(Broadhurst et. al,1990:726).

"The Milky way is traveling through the universe in concert with a swarm of other galaxies. The source of the impetus may be a remote concentration of mass on a scale that challenges current theory,"(Dressler,1987:46).

Appendix C: Survey of Physics Abstracts

The population of Physics Abstracts was arbitrarily restricted to the years spanning from 1970 to 1994. Each year was given an index number from 01 to 25. Then, using the random numbers in appendix c of the text Understanding Data, ten random numbers were drawn, each number representing a specific year. The ten numbers were generated by starting at the "cell" of numbers in column 3, row 1 of the random numbers table, and reading the digits from left to right. The following ten numbers were produced: 20,22,4,2,16,18,25,6,12,19. These numbers corresponded to the years, 1989,1991,1973,1971,1985,1987,1994,1975,1981, and 1988.

The mathematics involved in estimating the total number of articles written by our small group of cosmologists, is identical to that shown in Appendix B.

Lastly, the number of books written by the cosmologists was also obtained in order to compliment the above statistical analysis. Now, the word, book, was operationalized in the following fashion by Books in Print:

"The database includes scholarly, popular, adult, juvenile, reprint, and all other types of books covering all subjects, provided they are published or exclusively distributed in the United States and are available to the trade or to the general public for single or multiple copy purchase. All editions and bindings are included: hardcover, paperbound, library binding, perfect binding, boards, spiral binding, text editions, teachers' editions, and workbooks"(Books in Print,1995:vii).

The British equivalent of Books in Print, operationalized books in the following way:

"Whitaker's Books in Print lists titles if they are published in the United Kingdom and are freely available to the general public through the book trade. English language titles published in continental Europe are also recorded. Additionally, titles published elsewhere overseas may be included provided they have English language text and are available to the trade through a sole stockholding agent based in the United Kingdom. As a general rule, books carrying a retail price of under £0.15 are not included, although some may

be listed for the convenience of book trade reference if they are deemed to be of sufficient general interest"(Whitaker's Books in Print,1995:4-5).

The Sample of Cosmologists

In addition to my own research efforts in compiling a list of prominent cosmologists, I consulted Dr. Watson on this matter. With his advice, I constructed a small sample of ten of the most prestigious cosmologists working today. While this sample is not representative of all elite cosmologists, it does include those researchers Dr. Watson considers to be among the top physicists presently conducting research within cosmology. These notable scientists are as follows: (1) Stephen W. Hawking; (2) P.J.E Peebles; (3) Joseph Silk; (4) Steven Weinberg; (5) Andre Linde; (6) Edwin L. Turner; (7) David Schramm; (8) John Ellis; (9) Keith Olive; (10) Richard G. Kron.

Since time was a critical factor, I selected from this sample the first four cosmologists listed above, researchers who are, in many ways, the most famous, the most respected physicists still practicing their craft today, scholars who have made pioneering contributions to the relativistic hot Big Bang model.

Appendix D:
The Special and General Theories of Relativity

The Special Theory of Relativity

If you had lived in the tiny, English village of Woolsthorpe in 1666, you might have encountered a frail, sickly, bad-tempered youth rushing home from Cambridge University, where an outbreak of plague had forced the cancellation of classes, and the closure of the distinguished academic institution(Clark,1972:102; Sagan,1980:68,199). He was a lad of only twenty-three, but his teachers had long ago recognized the fiery intellect that rested within his inquisitive soul. In time, he would be looked upon by his scholarly descendents as the father of modern physics, the most astounding scientific genius who had ever lived. His name was Isaac Newton, and his powers of observation forever changed the world(Clark,1972:102; Sagan,1980:68,199).

For a restless intellect such as Newton, the temporary closure of Cambridge University was a nuisance, and as time passed, the disheartening news arrived that the fabled institution would not be re-opened for at least a year(Sagan,1980:68). As he waited within the protective confines of his Lincolnshire home for the medical crisis to end, Newton occupied himself by developing the differential and integral calculus, conducting research on the nature of light, and formulating the theory of universal gravitation, perhaps his most astonishing accomplishment(Clark,1972:102; Sagan,1980:68-69).

Newton demonstrated, mathematically, that the fall of the proverbial apple, and the motion of the Moon in its orbit about the Earth, were governed by the same, intangible force(Clark,1972:102; Sagan,1980:69). This mysterious entity Newton christened gravity, and believed that it was the fundamental force wrought by nature, a force that constrained the movements of the stars and planets, humans and animals, and even the smallest particles composing the fabric of matter(Clark,1972:103).

Newton's law of gravitation argues that, two bodies of a given mass, attract each other with a force that is directly proportional to the product of their masses, and inversely proportional to the square of the distance between them(Kaufmann,1988:66). Thus, the gravitational force experienced by two bodies would be three times as strong if one of the bodies had its mass tripled. And, if one of the bodies had its mass doubled, and the other had its mass quadrupled, then the force of gravity experienced by the two objects would be eight times as strong(Hawking,1988:16).

Furthermore, Newton's law predicts that if two objects are moved away from one another, the gravitational force experienced will be smaller, so long as the mass of the objects remains constant. In terms of the mathematics, the force diminishes inversely as the square of the distance. Thus, the gravitational force exerted by a star on a planet is exactly one-sixteenth that of a similar planet at one-fourth the distance(Hawking,1988:17; Sagan,1980:69).

It was a measure of Newton's reclusiveness, and his fiercely competitive nature, that he waited twenty-one years, after that miraculous summer of 1666, before revealing his incredible discoveries to the world. But at long last, in 1687, Newton published his pioneering work in his now legendary Philosophiae Naturalis Principia Mathematica. Within the pages of the Principia, Newton purposed the most detailed and technical accounting of the forces comprising the physical world than any one before in the history of science.

One of the implications of Newton's model of the universe, is that the concept of standard rest was eliminated. That is, motion could be perceived as a relative phenomenon. For example, if you were on a train, looking at the landscape flashing past your eyes, you could argue that

the train was at rest, and that the landscape was moving past you at a constant velocity with respect to the train; or that the landscape was at rest and the train was in motion. In effect, since the forces of nature are identical on the moving train as they are off the train, there is no experimental method one could use to prove whether it is the train or the landscape that is moving(Hawking,1988:17).

Since the notion of an absolute standard of rest was effectively eliminated by Newton's mathematical models, this implied that an observer could not determine whether two events that took place at different points in time occurred in the same position in space(Hawking,1988:17). The best way to conceptualize this statement is to visualize yourself on a moving platform; whether that platform is a train, a bus or a plane, makes no difference. Now, suppose you and a friend are playing Ping-Pong while the train is speeding along at ninety-miles per hour. The game is proceeding smoothly until a poor swing of the paddle causes the ball to bounce straight up and down, striking the Ping-Pong table twice on the exact same spot one second apart. For someone watching the game from outside the train, the two bounces would appear to have taken place one-hundred and thirty-two feet apart, since in one second the train would have travelled that distance between the bounces. In effect, the position of the ball between the two bounces and the distance between them would be described differently by you, and the observer on the track. Thus, by dethroning the notion of absolute rest, Newton, in essence, formulated the following universal commandment: Thou shalt not give an event an absolute position in space(Hawking,1988:18).

Yet, Newton was quite concerned with this lack of absolute space, even though it was a logical consequence of his mathematical framework(Hawking,1988:18). However, while he brooded over his intellectual hammer blows to the concept of absolute position, he found comfort in the fact that the notion of absolute time had been untouched by his research. For Newton, time was an entity that existed independent of space. Thus, within the Newtonian model, two observers could measure the interval of time between two events, and that this time would be identical for both observers(Hawking,1988:18). As Newton wrote in his famous text:

"Absolute, true, and mathematical time, of itself and from its own nature, flows equably, without relation to anything external, and by another name is called duration"(Newton,1960:6).

Newton's argument that time is an absolute force, is an argument most people would readily accept; it does, after all, make perfect sense. However, while commonsense notions of time have a pragmatic quality in a world of planes, trains, and falling apples - objects that travel relatively slowly - they become obsolete when dealing with things moving at, or close to, the speed of light(Hawking,1988:18).

The physical nature of light remained a mystery until 1865 when the British physicist James Clerk Maxwell, succeeded in constructing a solid, mathematical theory of light. By combining the partial theories employed by researchers in the late nineteenth-century to describe the twin forces of electricity and magnetism, Maxwell argued that light consisted of oscillating electric and magnetic fields that propagated through space at a specific fixed velocity(Hawking,1988:19; Kaufmann,1988:80). But to state that light travelled at a constant speed made little sense since Newton had eliminated the notion of absolute rest in the late

seventeenth-century. So, if light was to travel at a constant rate, one would have to specify what that constant rate was to be measured relative to (Hawking, 1988:19; Lindley, 1993:55). Thus, in order to resolve this dilemma, scientists conceived of an entity called the "luminiferous aether", or simply the "ether", an intangible substance that supposedly permeated "empty" space. It was postulated that light propagated through the ether much as sound waves propagated through air, and its speed should be, could be, measured relative to the ether (Hawking, 1988:19; Lindley, 1993:43,55). Two observers, moving relative to the ether, would see light approaching them at various speeds, but - and this is the important point - light's speed relative to the ether would remain constant. In effect, since the Earth was travelling through the ether as it orbited the Sun, the velocity of light measured in the direction of the Earth's voyage through the ether (when the Earth is moving toward the source of the light, which in this case is the Sun) should be higher than the speed of light at right angles to that voyage (when the Earth is not moving toward the Sun) (Hawking, 1988:20).

In 1887, two American physicists, Albert Michelson and Edward Morley, carried out an ingenious experiment to determine how fast the Earth was moving through the ether, at the Case School of Applied Science in Cleveland (Hawking, 1988:20; Pool, 1990:1207).

The Michelson-Morley experiment, as it came to be called, used a complex system of mirrors to split a beam of light into two parts travelling perpendicular to one another, and then to recombine the two beams so they would produce an interference pattern (Pool, 1990:1207). The two scientists reasoned that the Earth's motion through the ether should alter the measured speeds of the light beams in various ways, and thus, affect how they interfered with one another. In essence, they compared

the velocity of light in the direction of the Earth's motion with that at right angles to the Earth's motion. If the ether did indeed exist, then the interference patterns produced by the interaction of the two beams of light would change, and from measuring this differential, the Earth's speed through the ether could be calculated(Hawking,1988:20; Pool,1990:1207).

But to the surprise of the scientists, the interference pattern remained constant; the expected change did not materialize. This experiment implied - quite forcefully - that the speed of light was identical in every direction, and cast a dark shadow over the concept of the ether(Hawking,1988:20; Pool,1990:1207).

Thus, the world of theoretical physics had been thrown into a conceptual quagmire by the results of the Michelson-Morely experiment. For nearly two decades after the experiment, theorists tried to reconcile their cherished model of the ether with the disheartening outcome of the Michelson-Morley experiment, an experiment that, in essence, proclaimed the ether an abstract fantasy.

Then, in the summer of 1905, a young, hitherto unknown clerk in the Swiss patent office, submitted a most extraordinary paper to the prestigious German periodical Annalen der Physik. The paper was simply entitled "On the Electrodynamics of Moving Bodies", a paper that would revolutionize the way physicists - and in good time, ordinary citizens - viewed the twin concepts of space and time(Clark,1972:101; Hawking,1988:20). The theoretical model purposed within this nine thousand word thesis would come to be known by specialists and non-specialists alike, as Albert Einstein's special theory of relativity(Clark,1972:101).

The idea for the special theory had come to Einstein as a young lad

of sixteen. After reading Bernstein's People's Book of Science, a text that described in great detail the speed of light through the vacuum of space, Einstein began to wonder what the physical world would look like if one could follow a beam of light at the speed of light. Thus, Einstein posed the question: What would be seen by any observer who could move as swiftly as the oscillating electromagnetic radiation known as light(Clark,1972:113-114; Sagan,1980:199)? According to Einstein, one would see "a spatially oscillatory electromagnetic field at rest"(Schilpp,1949:53).

The implications of this logic were astounding. For one thing, it would mean that the laws of electromagnetism as perceived by observers at rest, and those travelling at the speed of light, would be different(Clark,1972:114). Another consequence of this logic was that different observers, in various states of relative motion, would obtain different measures for the speed of light. But according to the field equations of Maxwell's electromagnetic theory, the speed of light was a fundamental constant, its velocity invariably(Clark,1972:116-117).

In order to solve this conceptual dilemma, Einstein was forced to abandon the notion of not only absolute space, but absolute time as well, an act that filled him with a certain amount of regret for it meant challenging the Newtonian model, and the father of modern physics(Kaufmann,1988:70). Nevertheless, Einstein approached this physical problem much as the great fictional detective Sherlock Holmes approached many of his baffling cases: stick to the facts, and when all the probable explanations have been discarded, whatever remains, however improbable, must be the truth(Lindley,1993:56).

In essence, the basic postulate of Einstein's special theory was that the laws of physics should be identical for all observers,

regardless of their motion. Thus, in the case of Maxwell's theory concerning the velocity of light, all observers should measure the same speed of light, no matter how fast they are travelling(Hawking,1988:20). This reasoning has some incredible consequences. For example, imagine that you are on a space station, while a friend is travelling at 98 percent of the speed of light relative to you, holding a one foot long ruler parallel to the direction of motion. According to your (stationary) measuring device, you conclude that the ruler is approximately 2.39 inches in length; your friend would conclude that the ruler is only 12 inches in length(Kaufmann,1988:470). Similarly, a one kilogram brick travelling 98 percent the speed of light would appear to a stationary observer to behave as though it possessed a mass of approximately 5.03 kilograms(Kaufman,1988:471). Yet, perhaps the most stunning prediction of the special theory is that even the passage of time is influenced by relative motion.

For example, suppose you were standing in the depths of space, watching a friend hurtles towards you in a ship travelling at 98 percent of the speed of light. Now, imagine that a large light fixture falls from the ceiling of the ship to the floor. Your friend measures the fall as having taken 2.9 seconds; but, according to your watch, the fall took 14.57 seconds! This remarkable phenomenon is called time dilation; time flows at a slower pace as you near the speed of light(Kaufmann,1988:470).

It should be noted that this effect is not an optical illusion; it has nothing to do with the physical composition of the clock or timing device; it is not a mechanical or engineering phenomenon(Clark,1972:121). Indeed, in the words of Ronald W. Clark, time dilation "...was a property of the way in which God had made the world"(Clark,1972:121).

The same comment can be made regarding the other logical consequences of travelling close to the speed of light; these consequences are as "real" as those that occur at non-relativistic velocities. When people ask the questions: When you say that a one kilogram brick moving close to the speed of light has a mass of five kilograms, what are you really saying? And is this change in mass real? The fact is that in relativity the word "real" has no meaning. What is "real" depends on your frame of reference. As Clark states, "Just as beauty lies in the eye of the beholder, so does each man (sic) carry with him his (sic) own time"(Clark,1972:121).

For non-scientists, the predictions of the special theory are hard to swallow. But as the 90th anniversary of the special theory dawned and passed away, it should comfort the general public to know that every prediction outlined by Einstein's theory has been verified to countless decimal places(Pool,1990:1207).

Indeed, in 1971, the U.S. Navy attempted to test the phenomenon known as time dilation. Four clocks were placed aboard a fighter jet and flown around the world. Since the velocity of the jets were substantially slower than the speed of light, atomic clocks had to be used to detect the time-dilation effect, clocks that were accurate to within one nanosecond, or one-billionth of a second. The time measured by these clocks was compared with the time recorded by similar, stationary clocks at the U.S. Naval Observatory. However, due to the complexity of the experiment, and the infinitesimally small effect they were trying to measure, numerous variables had to be controlled for; for example, the acceleration and deceleration of the planes relative to the Earth, variations in direction of travel, and the attenuated gravitational field experienced by the clocks in flight. However, in the end, the phenomenon of time dilation

was confirmed to within experimental error (Giancoli, 1985:620; Serway, 1986:908). As the original researchers of this experiment concluded:

"Relative to the atomic scale of the U.S. Naval Observatory, the flying clocks lost 59 ± 10 ns during the eastward trip and gained 273 ± 7 ns during the westward trip.... These results provide an unambiguous empirical resolution of the famous clock paradox with macroscopic clocks" (Serway, 1986:908).

In 1985, physicists at the University of Aarhus in Denmark and Colorado State University, put time dilation on a unique experimental footing with the aid of an accelerated beam of neon atoms. When excited by a laser, neon atoms emit light at a specific frequency, thus, enabling them to be used as remarkably accurate time pieces. By analyzing the variance in the velocity of these atomic "clocks" as the Earth moves through space, the scientists measured the time dilation phenomenon to an uncanny accuracy of 40 parts per million (Pool, 1990:1208).

In 1905 Einstein rebelled against the elitists notions of absolute time and space, thus forcing a conceptual revolution within the realm of theoretical physics, and forced human kind to observe the physical world in a different shade of light. One of the most elegant remarks on relativity, and of Einstein, comes to us from planetary astrophysicist, Carl Sagan:

"Europeans around the turn of the century generally believed in privileged frames of reference: that German, or French, or British culture and political organization were better than those of other countries... The young Einstein rebelled against the notion of privileged frames of reference in physics as much as he did in politics. In a universe filled with stars rushing helter-skelter in all directions, there was no place that was "at rest," no framework from which to view the universe that was superior to any other framework. This is what the word relativity means. The idea is very simple, despite its magical trappings: in viewing the universe, every place is as good as every other place" (Sagan, 1980:200).

The General Theory of Relativity

In the special theory of relativity Einstein had argued that the concepts of absolute space and time had no place in nature's domain. Motion was a relative phenomenon, whether it was the motion of a passenger walking on train, or of the galaxies speeding through the cosmos. Yet, the special theory dealt with a very limited form of motion known as linear motion, motion in a straight line at a constant velocity, hence the presence of the word "special" in the title of the theory(Clark,1972:151). In the mundane, pragmatic world, this was exemplified by the plane travelling along at constant speed, from which no experiment could prove the existence of motion; the only way a passenger could conclude that he or she was moving, was to look out the window and relate the plane to another frame of reference(Clark,1972:151).

But a sudden change in velocity would render this ignorance of motion null and void. If the plane were to suddenly accelerate, the passenger sitting comfortably in a chair would be thrust backwards; similarly, deceleration would throw the humble traveller forward. In addition to the unpleasant experience of being tossed around, the passenger would be at further risk of being drenched by a glass of water or hit by other inanimate objects aboard the plane, objects whose sudden burst of animation would provide the voyager with yet another clue that the plane was in flight(Clark,1972:151).

This incongruity between the relativistic logic of uniform motion, and the non-relativity of non-uniform motion, between the fact that in the first instance, motion could not be discerned unless it was compared to something else, while in the second instance, motion could be deduced by the passenger within the individual's own frame of reference,

filled Einstein with great concern(Clark,1972:151). He wrote, "Because of this, we feel compelled at the present juncture to grant a kind of absolute physical reality to nonuniform motion"(Einstein,1924:62).

The thought experiment involving the passenger aboard a rapidly accelerating or decelerating plane, sensitized Einstein to the fact that his special theory was inconsistent with another great theory of the physical world, that theory being Newton's model of gravity. According to the Newtonian framework, objects attracted one another with a force that was inversely proportional to the square of the distance between them. Thus, if you moved the objects in question apart, the gravitational field between them would change instantaneously; this implied that gravity was a force that could travel with infinite speed, a proposition that violated the special theory of relativity. Thus, for nearly seven years, Einstein attempted to resolve this dilemma, trying to develop a relativistic theory of gravity(Hawking,1988:29; Lindley,1993:78-79). Then, at long last, in the fall of 1915 there appeared a most remarkable article in Volume 49 of the Annalen der Physik, an article entitled "The Foundation of the General Theory of Relativity"(Clark,1972:252; Hawking,1988:29; Lindley,1993:79).

Within this now legendary paper, Einstein rejected the Newtonian model which argued that gravity was a force that acted instantaneously over infinite distances(Clark,1972:253; Hawking,1988:29). Instead, Einstein made the imaginative suggestion that gravity was, in effect, caused by the curvature of space itself; and since space and time in Einstein's framework are inextricably interwoven, we say that matter "warps" the fabric of this integrated entity known as space-time, causing the force we refer to as gravity(Boslough,1989:564; Hawking,1988:29; Lindley,1993:80). While this conceptualization of gravity seems somewhat

paradoxical, it makes perfect sense in the abstract realm of pure mathematics. However, for the non-specialist, one way to visualize Einstein's theory is to represent space-time as a two dimensional rubber sheet etched with horizontal and vertical lines like one would find on graph paper(Boslough,1989:563). Now, heavy objects - a ball bearing, a brick, a baseball - would depress the sheet when placed on it, analogous to the way matter "curves" or "warps" space-time(Boslough,1989:564).

The beauty of this model is that it eliminates the need to view gravity as a force. For example, if you were to place a basketball on the rubber sheet, a large area of depression would form around the ball. If you then rolled a ball bearing along the sheet toward the depression at a high velocity, it would dip toward the depression and roll away at a different angle. If the ball's velocity is weak - but not too weak - it will orbit the dimple indefinitely, if friction is controlled for(Boslough,1989:564).

Thus, the Earth is not forced to orbit the Sun because of an entity called gravity; instead, it follows the path of least resistance in a curved space, a path referred to as a geodesic(Boslough,1989:564; Hawking,1988:29). As Hawking explains:

"The mass of the sun curves space-time in such a way that although the earth follows a straight path in four-dimensional space-time, it appears to us to move along a circular orbit in three-dimensional space. In fact, the orbits of the planets predicted by general relativity are almost exactly the same as those predicted by the Newtonian theory of gravity"(Hawking,1988:30).

Yet, in the case of Mercury, a planet so close to the Sun that the curvature of space has a significant effect upon it, the equations of Newtonian physics falls short in terms of predicting the planet's orbit. In actuality, as Mercury orbits the sun, the orbit itself rotates, tracing out a rosette figure about the Sun. This excess rotation, the

differential between that observed, and that predicted by Newtonian mechanics, amounts to a mere 43 arc seconds per century(Kaufmann,1988:70-71). In other words, the perihelion of Mercury - the point in its orbit when the distance between Mercury and the Sun is at a minimum - advances by an infinitesimally small amount each year, a value that cannot be explained with Newtonian mechanics(Hawking,1988:30-31; Kaufman,1988:70-71). Yet, Einstein's general theory predicted that Mercury's orbit should be a precessing ellipse, and even predicted the amount of this precession, a prediction that was wholly substantiated by empirical observations(Clark,1972:259; Hawking,1988:30-31; Kaufmann,1988:70-71).

With the general theory, Einstein predicted a host of new phenomena never imagined before in the realm of physics. For example, he hypothesized that light rays passing near the Sun should be deflected, on account of the fact that the Sun's mass is so great that it significantly curves the fabric of space-time. Thus, light from a distant star whose trajectory brings it close to the Sun, would be deflected through a small angle, perhaps at most, an angle of approximately 1.75 arc seconds(Hawking,1988:31; Kaufmann,1988:72).

This imaginative prediction was first tested in 1919 during a total solar eclipse. During the brief period of time when the Moon shielded the Sun's blinding solar disk, astronomers obtained a series of photographs depicting the distribution of stars around the Sun. Careful analysis of the photographs revealed that the background stars were indeed shifted from their usual positions, deflected by an amount predicted by the general theory of relativity(Hawking,1988:32; Kaufmann,1988:72).

Another prediction of the theory is that the passage of time is affected in the presence of a strong gravitational field; thus, as in the

special theory, time is perceived as a variable entity and not as a constant(Hawking,1988:32; Kaufmann,1988:72). The logic at the heart of this prediction is as follows: in nature there is a correlation between the energy of light and its frequency, the number of waves of light passing a given point in one second; the greater the energy, the higher the frequency(Hawking,1988:32; Kaufmann,1988:81). For example, Einstein argued that an atom radiating light in a weak gravitational field would vibrate (oscillate) more quickly than in a strong gravitational field. But, as stated earlier, since the energy and frequency of light are related, an atom located in a weak gravitational field would be vibrating at a higher rate than one in a strong gravitational field, hence the frequency of light emitted would be higher than its counterpart located in a region where gravity was strong(Clark,1972:260; Hawking,1988:32). Thus, to someone living high above the surface of the Earth, it would seem that events transpiring down below were taking longer to happen(Hawking,1988:32).

This remarkable prediction was tested in the late 1960's at Harvard University. A beam of light was projected from the third floor of the Physics Building to the basement. According to theory, light passing near a region where gravity is relatively strong, would lose energy, its frequency attenuated. In terms of the electromagnetic spectrum, light possessing a high frequency would appear somewhat violet, whereas light of a lower frequency level would appear blue or red. In the Harvard experiment, the light radiating in the basement of the Physics Building did appear somewhat bluer than it did on the third floor. Since the Earth's gravitational field is pretty weak this shift in frequency was incredibly small, one part in 10 trillion(Clark,1972:261).

In another experiment, using atomic clocks, it was shown that a clock

mounted on the top of a building ran faster than an identical clock located at the bottom, a result that further solidified the general theory of relativity(Hawking,1988:32; Kaufmann,1988:72).

The general theory was inspired by a conceptual dilemma; it was an attempt to fashion a truly general theory of motion. Einstein realized that a passenger - like our hypothetical plane traveller - would realize that he or she was in motion if the plane's speed were to change drastically in a short period of time. Einstein's problem was how to resolve the discrepancy between the relativity of uniform motion and the nonrelativity of non-linear motion(Clark,1972:151). His solution was, not surprisingly, ingenious, a solution that lies at the heart of general relativity.

To the mind of Isaac Newton, an apple falls to the ground because it is pulled down by the force of gravity. However, Einstein argued that the apple would behave in the same fashion, in the depths of space, far from any gravitational field, if the ground were to accelerate upward(Boslough,1989,564; Kaufmann,1988:471). In other words, in this example, one could state that the apple didn't fall to the ground, but that the ground "rose" to meet the apple(Kaufmann,1988:471).

This apparent equality between gravity and acceleration, is known as the principle of equivalence, and demonstrates that motion can be perceived as relative even in an accelerated frame of reference(Kaufmann,1988:471).

One way to visualize this argument is to imagine Newton standing in a closed box upon the Earth, while Einstein is in a similar box floating in empty space, far from any gravitational field. Now suppose an apple falls from the ceiling of Newton's compartment to the floor. The apple behaves exactly as it would outside the box. Now, imagine that Einstein's

box suddenly accelerates upward at a constant rate - an acceleration rate that duplicates Earth's gravitational field. Now, an apple dropped from the ceiling of this box will behave exactly as it does on the Earth. Thus, the two men "...in their closed compartments...have no way of telling who is at rest on the Earth and who is in the elevator moving upward at a constantly increasing speed"(Kaufmann,1988:471).

The principle of equivalence enabled Einstein to revolutionize our conceptualization of gravity, and the very structure of the cosmos(Kaufmann,1988:471). To this day, nearly eighty-one years after its birth, the general theory of relativity is considered one of the most elegant mathematical models ever devised of the physical world, a model that has withstood every attempt to break it, a model born of the imagination of one rebellious physicist(Lindley,1993:90).

Indeed, it was within the abstract logic of general relativity that the idea of a dynamic, expanding universe was first conceived, a universe wrought at a finite point in time(Hawking,1988:33; Kaufmann,1988:563). Thus, in many ways, Einstein is considered the founding father of modern cosmology, the creator of the paradigm known as the big bang.

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