Chapter 19: A Perspective on Existence

Man is not born to solve the problems of the universe, but to find out where the problems begin, and then to take his stand within the limits of the intelligible.
J.W. von Goethe

What are the limits of the intelligible? Go to the library. Find a book on astronomy printed a century ago and skim the chapter on cosmology, if you can find one. By contrast, consider the scope of our current world-view. Whether closed or open, the history of the Universe up to the present time seems fairly well defined (except for the imponderable questions of beginning – cosmogony). If we recognize the transient nature of the early phases of the Universe up through the epoch of decoupling of matter from radiation, the remaining vast scenario of evolution has a compelling simplicity based on a single theme: gravitation. In Chapter 16, we already mentioned the role of the gravitational instability in amplifying subtle structure present in that relatively homogeneous gas of primordial elements during the epoch of decoupling. The importance of gravity in determining the present, highly inhomogeneous condition of the Universe has, however, not been fully stated. Gravitational instability implies that mass associations on various scales from clusters of galaxies down to stars and planets are continually being urged to assume a more compact form by the mutual gravitational attraction of their parts.

Clusters of galaxies, galaxies, star clusters and planetary systems are able to maintain their form only because of a highly successful hedge against further relaxation: orbital motion. But even orbits gradually shrink. For instance, the central regions of galaxies may be plagued by frequent stellar collisions during some phase of their evolution, which leads to a central condensation of matter. Such subtle kinds of friction will ultimately cause this class of systems to “run down” and eventually collapse.

Individual stars are a completely different matter. The response of a great cloud of interstellar gas to the influence of gravity is to contract and consequently to heat up. The temperature increase in the interior of such a proto-stellar cloud slows gravitational contraction because of the internal gas pressure that increases in proportion to the temperature. However, the proto-star continues to contract because the heat generated by contraction is continually being radiated away at its surface. Eventually, this process of contraction and heating leads to interior temperatures of over 10 million degrees. For the first time since the early period of the Big Bang, conditions for nuclear reactions are possible. In the fusion of hydrogen nuclei (protons) to form helium nuclei, an extremely efficient means of heating the interior of that slowly collapsing proto-star is realized. In this way a star is born.

For stars, nuclear reactions are only a temporarily successful hedge against further contraction. A pressure balance is achieved between the compressing forces of gravity and outward forces of gas pressure in the super-hot stellar interior. Of course, this balance cannot be maintained indefinitely, because nuclear fuel (hydrogen) must be continually consumed by conversion to helium in the core of the star in order to counteract the monumental loss of heat from the star at its surface. For our own star we call that loss “sunshine”. Despite this difficulty, our sun can maintain this kind of equilibrium for around 10 billion years. More massive stars squander their nuclear energy reserves in a shorter time; less massive stars can survive still longer.

For all stars, nuclear fuel eventually runs out and further collapse is inevitable. In massive stars when further contraction heats the interior to still higher temperatures, the “ashes” of the previous reaction (the helium which was produced from hydrogen) may “ignite” by entering into a new reaction that converts helium to carbon. When helium is depleted, the carbon nuclei are fused to form still heavier nuclei. A sequence of such nuclear “burning” stages eventually builds nuclei up through iron as the interior temperature climbs to over a billion degrees.

At still higher temperatures, further reactions cool rather than heat the interior of the star. The result is catastrophic. Pressure balance is destroyed and the star collapses. Under the right conditions, the rich horde of nuclear material that builds up in the evolving cores of such stars, is scattered back into the interstellar medium with the incredible violence of a supernova explosion. Such vast clouds of debris, whose element composition has been enriched far beyond the meager primordial fare of hydrogen, helium, and traces of other light elements, now begin to contract to form a new generation of stars and perhaps some of that material will form much smaller, associated condensations that we call “planets”. This is a path that leads to mankind. . .and surely beyond.

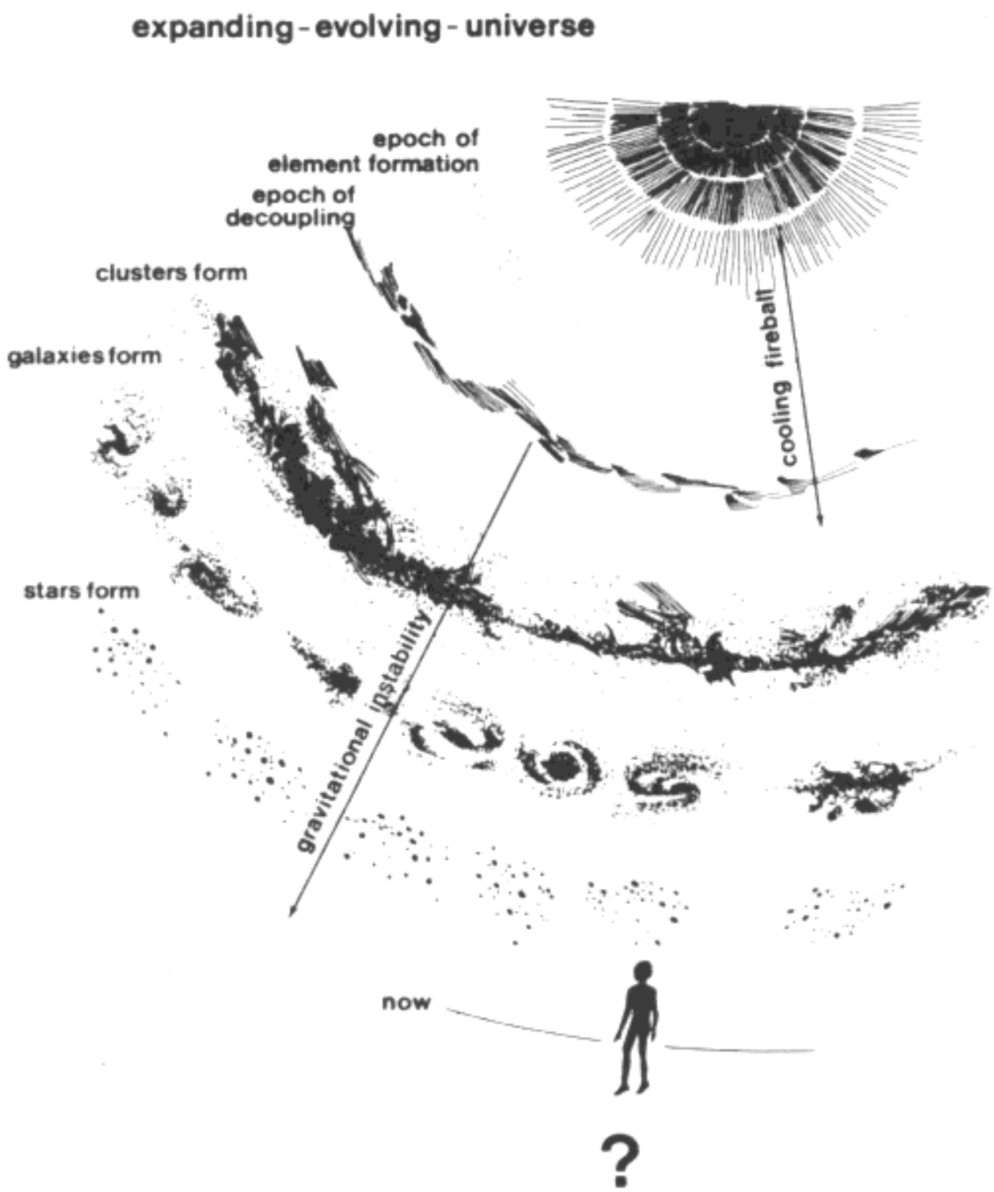

Fig. 19a

The point to be stressed is that gravity is responsible for the diversity of form and substance we see in the Universe today. That once featureless, primeval gas of hydrogen and helium has been structured into the hierarchy of mass associations from clusters of galaxies to planets, and at the same time has been transformed into roughly a hundred different chemical elements, including a substantial proportion of carbon, oxygen, and nitrogen, the building blocks of life. Nucleosynthesis in stars is a response to the crushing bonds of gravity just as the formation of galaxies is a response on a larger scale. Gravity organizes and animates our world in a profoundly fundamental manner.

In this grand scenario, our present, pleasant existence may be seen as only a temporary byproduct of a headlong plunge toward total gravitational collapse. Galaxies, stars, planets, are only battles in a grim war for total domination by gravity. Figure 19 expresses this dilemma. Here the Universe is organized in terms of size (in units of solar radii) and mass (in units of solar mass). Large things are to the right in the diagram, massive things toward the top. Thus, low-density objects are found toward the lower right-hand corner and high-density objects toward the upper left. Since the quantity of matter is generally constant during the formation and evolution of astrophysical objects, gravitational instability in the early Universe causes material to enter the diagram along the right hand margin and move horizontally to the left. In a more anthropomorphic description, gravity "herds" the contents of the Universe toward the precipice: that diagonal boundary labeled "gravitational radius". Gravity is continually, and patiently, pressing for that ultimate victory.

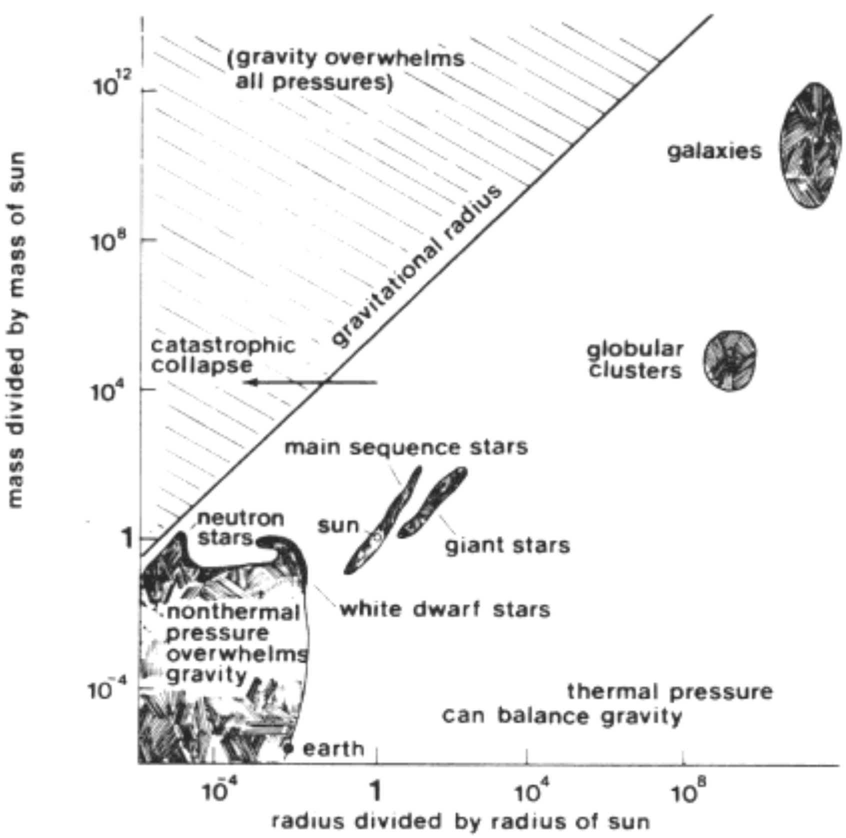

Fig. 19b

The next time you survey the starry sky on a dark, moonless night, try to see of it as Copernicus would have – staring into a quiet, motionless eternity. We have lost our innocence, the sky can never seem so serene, timeless and passive again. On a time scale beyond our direct comprehension, the sky is full of activity, building, tearing down, reorganizing, and reprocessing – all the things that characterize life, including mortality. We ourselves are a product of that activity. We, and our potential companions throughout countless galaxies, are extensions of that Universe evolved to self-awareness – a modern reply to the Copernican dilemma. What man loses in the face of the Cosmological Principle, he gains in self-respect as a special, if not unique, aspect of creation.

In the spirit of this discussion, gravitation is the fundamental theme of evolution in the Universe. Gravity seems responsible for every aspect of our existence from the sunlight that sustains us to the chemicals that compose us. Our previous discussions of mass, geometry and gravity have, however, been ambiguous about which of these three is "truly fundamental". Mass gives rise to gravity, but gravity might seem an equivalent definition of mass, especially in view of Mach's principle. Can both be expressed in terms of the geometry of spacetime? John Wheeler, who more than any other person carried forth the work of Einstein in the latter portion of the 20th century, showed (with Charles Misner) that the seed of Einstein's dream of finding a Unified Field Theory (a unified description of at least electromagnetism and gravity in terms of the geometry of spacetime) was actually implicit in Einstein's original work.

This is not a complete theory since it does not provide a quantum mechanically consistent unification of electromagnetism with gravity, and was abandoned by Wheeler in the 1970s. It nonetheless suggests an elegantly simple picture of the physical World that is reminiscent of pre-Socratic attempts to reduce the world to fundamental substance or principle. In the scheme of Wheeler and Misner, the basic stuff comprising the World is rather more sophisticated – the geometry of spacetime. First, as we have seen, gravity is locally equivalent to an accelerated frame of reference, or more generally to a manifestation of the geometry of spacetime. In this sense, we arrive at a concept of gravity without gravity. Furthermore, because of the equivalence of mass and energy – a topic that we have carefully avoided – it is possible to form a Black Hole with no substantial particles at all, but with light alone. If the energy density of radiation can locally be made sufficiently extreme, an event horizon will be produced. Such a Black Hole is indistinguishable from one formed by matter in the collapse of a massive star (that is, one made from "real" mass). In this sense we have mass without mass. This already-unified-field theory of Misner and Wheeler (geometrodynamics) also showed how light (electromagnetic waves) can be considered equivalent to an appropriate rippling of spacetime, thereby yielding light without light. Similarly, spacetime can be "knotted up" in a way that such knots behave as particles subscribing to Newton's laws, yielding particles without particles. If all these fundamental phenomena can be replaced by an equivalent geometrical description, then asked Wheeler: "Is spacetime the arena in which mass and radiation act out physical reality, or is spacetime both the arena and the very substance of our being?"

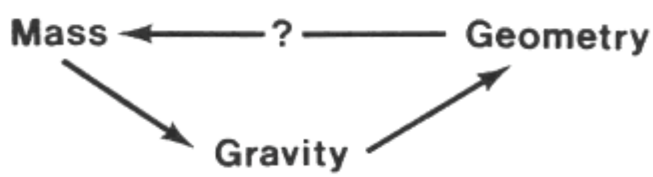

Fig. 19c

Think back across the span of historical efforts to make sense of the human experience of the natural world. Wheeler's vision resonates with that of Pythagoras , but also claims kinship with Plato, Aristotle and the geometers of the Athenian Academy – their search was for a correspondence between geometry and the physical Universe as well. Curiously, there is a trace of another great historical theme which we traced from Hellenism through the Renaissance and see it still as a persistent current in what might have been thought a century beyond the claim of the magi. The volume celebrating Wheeler's festschrift was titled: Magic Without Magic.

Wheeler recognized a crucial failing that this theory shared with all others, revealing a serious disjuncture in the structure of ideas that strive to express a comprehensive understanding of the natural World. He is fond of pointing out that such flaws in our physics, point to a crisis that may lead to new, richer and still more fundamental theories. The crisis here is gravitational collapse – the complete breakdown of presently understood physical laws as the density of matter mounts higher and higher. We cannot understand neither the details nor the meaning of a gravitational singularity, of matter being reduced to zero volume (if that really happens). It may be time for a new world-view, based on some still more fundamental concept. Wheeler has suggested we look for *pre-geometry*.

In the context of cosmology, this problem of ultimate collapse is translated into one of *beginnings*, of cosmogony. How do we explain the initial singularity from which the Universe appears to have burst forth? What fundamental principles allow us to understand (at least phenomenologically) how it is that the Universe comes into being at some point in time, and what lies before that time? Perhaps the failure lies in our thinking about the nature of time? In the Renaissance we struggled with the ideas of a Universe either infinite or finite in spatial extent. Both alternatives seemed equally incomprehensible; we had no principles to bring to bear on that choice, and little confidence in being able to approach the problem on strictly rational grounds. Many great minds of that time felt that questions of finitude or infinitude were either meaningless, or at least not "scientific" questions. Yet this crisis eventually brought about the revolutionary description of a relativistic aspect of the physical world formulated by Einstein.

This problem of cosmogony thrust upon us by the Big Bang Theory and its observational support has many parallels with the older questions of spatial infinity. In our era, it is limited extension in the 4th dimension, time, that is incomprehensible. There are many now who say that such questions of origin are meaningless; others allow such questions, but not within the domain of physical science. Still others, who might even admit physical significance, would simply brand them as premature. Current intrusions of dogma seem subtler to us now than they will in retrospect. How will future historians comment on the Bondi, Gold, and Hoyle *Steady State Theory* of 1948? Perhaps it will be noted as the first attempt in post medieval times to cast off the dogmatic sanctions against cosmogonic theories.

Let's meet the obvious concern head-on. Cosmogony is no more and no less a religious matter than entomology, pharmacology, or solid-state physics, if we allow questions of origin to be considered as questions about the physical world. If we walk into the countryside and encounter a tree it does not seem such a profound (or non-physical) line of inquiry to ask where it came from, how it grew, what came before? There was a seed, and before that another, previous tree. We do not understand all the details of procreation, but the tree definitely does not suddenly appear in a mysterious puff of smoke. In the familiar scientific view, there is a natural process, a natural order of events that lies within our comprehension. We look around and see many trees, and in all stages of life: some seedlings, some mature, others fallen. We do not need to patiently observe the life cycle, the evolutionary experience of a single tree, to piece together a rational, descriptive scenario.

We have, however, only one Universe – only a single sample from which judgments must be made. This demands we be untiringly resourceful in our observations, and implies that questions will be difficult to formulate. Even so, for the physical scientist, it seems natural to ask how and from what former state the Universe has evolved, where "former" can be pressed as far back as we desire. This is no more than we asked of the tree, and both the Universe and the tree are physical entities. The Universe, as we know it, was not always here – what came before? Such inquiry has no more, no less, spiritual implication than any other question about the physical world, and need not raise ultimate questions about existence. The historical bond between science and theology as *intellectual* pursuits was formally severed in the 17th century, largely as a legacy of Rene Descartes and Isaac Newton, except for an enduring shared sense of mystery. We know that such *formal* arrangements soon broke down, and that in a world that includes the full scope of human experience, not one neatly partitioned to enable an ill-fated *quest for certainty*, we find for some that science and religion are still at war in the 21st century. This is a fascinating, distinctly human struggle far beyond the scope of this discussion in complexity, but with subtexts that cannot be ignored in contemplating the roots of modern science.

A key element in the comparison of our present confrontation with cosmogony and the Renaissance struggle with cosmological infinities is the matter of *motivation.* Look back even as far as Pythagoras, the concept of the mystical is preeminent. More important forces than a thirst for scientific facts drove Ptolemy. Copernicus, Kepler, Newton were all seeking to probe the mind of the Creator, to reveal the Grand Design. The mystical influence on Renaissance scientific thought may be largely understood in terms of the Hermetic tradition, the occult concept of Hermes Trismegistus, that alleged Egyptian contemporary of Moses, whose lost writings set down the wisdom of the ancients, the mystical secrets of nature and the means of acquiring knowledge through gnosis. It all sounds rather like Ptolemy, and we know now that the Corpus Hermeticum was certainly written in that era, not at the time of Moses. But mysticism appeals to the human mind in all ages. That Hermetic tradition which was so boldly exemplified by the life and works of Giordano Bruno is still found today in astrology, secret societies, and lingering impressions of magic and alchemy. And what about the dream that in long forgotten times man had access to the secrets of nature, the wisdom of the ancients?

It was within the context of Hermeticism that Lord Keynes labeled Newton "…. the last of the magicians". In science today one may not easily or directly identify the Hermetic influence, but something more basic remains. Over the centuries, the science of each age has been motivated, not directly by some objective rationale, but tangentially by the possibilities implicit in the unknown. Not the promise of just a more comprehensive understanding of the basic organization and underlying principles of the physical world, but the mystical appeal of profound, unimaginable insights.

Think back to Kepler's work and the epilogue of the Harmonice Mundi:

> *I write my book to be read, either by present day or by future readers—what does it matter? It may wait a hundred years for its readers, since God himself has been waiting 6,000 years for one who penetrated his work.*

A modern historian and philosopher of science, Pannekoek, comments on Kepler's assessment of his own work:

> *We read this proud pronouncement with a smile of admiration, knowing that later science has accepted and preserved from the entire work on "The Harmony" only that one page containing the third law. Must we say, then, that all other work done by Kepler in this book was a waste of time? To perform great things, man has to set himself even greater aims. The lasting fruit can grow only in a larger organic structure, first living, afterwards withering to dry straw. The strong impulses to work and struggle which man receives from his world are transformed in him into objectives and tasks largely determined by the world concept of his time. Through his lifework then there runs, as the fulfillment of the ideas absorbed in his youth, a unity of purpose which makes it a harmonious entity. But later generations—different persons with different aims in a changed world—take from it only what may serve them, discarding the framework. Thus what inspired and proved the triumph of the earlier precursor often appears to those who follow to be superfluous or a false direction. In later centuries, when scientific research took on more the character of the routine work along fixed tracks, this may be less visible. In this time of renovation, discovery and transition, Kepler's work shows better than any other the relation between general and personal elements in the growth of science.*

And what will the future write about us? The questions may change from age to age, but not the reasons for asking. Man is caught by his own imagination, motivated by the fantasies he projects into the unknown and is never thoroughly rational. This has always made for interesting times.

> *The highest wisdom has but one science—the science of the whole—the science of explaining the whole of creation and man's place in it.* Leo Tolstoy – War and Peace