Chapter 15: A Cosmic Perspective

This book describes the progress of human thought about the physical universe from ancient to modern times. In this chapter we will consider the progress of science as well as its limitations in our attempt to answer profound questions about our existence.

Humanity's Place in the Universe

What science has gained for humanity is nothing short of astonishing: a coherent story of the evolution of the cosmos from an extremely simple and exotic state to the current complex universe with countless galaxies, stars, and planets. We know that we live on one of those planets, a modest-sized terrestrial sphere orbiting a modest-sized star, which itself moves in a circle of radius 8.3 kiloparsecs about a 4-million-solar-mass black hole at the center of the Milky Way Galaxy. The Milky Way belongs to the Local Group of tens of galaxies, which is a member of the Virgo supercluster of galaxies.

Humanity has discovered its physical "roots." Although each of our personal lives started with the fertilization of an egg inside our mother's womb, our heritage extends much farther back in time — nearly 14 billion years ago when the early universe contained only an extraordinarily hot and dense "sea" of fundamental particles. A few minutes later, electrons and the nuclei of hydrogen and helium atoms composed most of the normal matter, and when the universe was about 400,000 years old the electrons combined with the nuclei to form complete atoms. Within about half a billion years, stars and galaxies started to form out of gas clouds. The stars transformed some of the simple nuclei into heavier elements, and upon dying released the enriched material back into space so that later generations of stars and planets contained all (about 90) natural elements and hundreds of isotopes. On at least one planet — the Earth about 4 billion years ago — complex carbon-based molecules that could reproduce themselves were synthesized. On that planet, this led to life and eventually to intelligent life. Now we humans, the outcome of almost 14 billion years of cosmic evolution, can observe and contemplate the cosmos.

Since we are so intimately connected with the universe, we should feel compelled to consider our place in the vast cosmos. From one viewpoint, we are less significant than a grain of sand on an ocean beach. However, as we will discuss below, there is a line of thought that suggests that humans might have an important — and not necessarily positive — impact on our cosmic neighborhood.

Better Descriptions through Science

When we review the progression of scientific ideas, as outlined in this book, we notice that there have been three great scientific eras: ancient Greece, the European Renaissance, and the modern era, which started with the age of Enlightenment in Europe. This last period has now lasted about 400 years and shows no sign of decline. During these times of scientific achievement, superstition and myth has been replaced by an evolving structure of theoretical models supported by observational and experimental data. The ability of these models to predict — in many cases quantitatively — the observed behavior of nature has become more accurate with time. Through the scientific method of observations, hypotheses, predictions, and tests, the description of physical phenomena has been continually refined.

Does this mean that science has revealed the *truth* about the universe? As is discussed in Chapter 1, truth is an elusive concept that has an obvious everyday meaning but not so obvious philosophical interpretation. What we can say about our scientific theories is that they are human-based descriptions of the world that are consistent with the data that we have collected. We have seen that some of these descriptions have changed qualitatively even while the quantitative predictions have remained quite

accurate. An example is the explanation of how the force of gravity is transmitted. Newton's view (Ch. 4) was action at a distance, Einstein's (Ch. 9) was a geometrical effect on space-time, and in the quantum theory (Ch. 8) there is an exchange of virtual particles. Hence, our picture of the natural world is not the "ultimate truth" in a philosophical sense. On the other hand, the ability to predict phenomena accurately provides a strong connection between scientific theories and reality. The statement "The Earth goes around the Sun in an elliptical orbit with a period of 365.24 days" provides such a vivid description of what we observe that we can say it is true. Still, the Earth's motion relative to the cosmic microwave background (CMB) radiation is in fact much more complex than this, since the Sun orbits the center of the Milky Way galaxy and the Milky Way is moving relative to the CMB.

Questions not yet Answered by Science

Since science is a human endeavor, it is constrained to describe the universe within the limits of the human mind. It is also restricted to address questions about phenomena that have measurable effects in the physical world. Because of this, there are a number of intellectual questions that science may never be able to answer. Among the issues discussed in this book that science may be unable to resolve are whether we possess true free will, the ultimate nature of reality, how the universe came into existence, whether there are other universes, and why there is any existence at all instead of nothingness. Since the age of Enlightenment, the academic disciplines such as theology, philosophy, and science have followed separate paths, each studying its own well-defined realm of knowledge with minimal overlap. However, proper consideration of these and other compelling questions benefit from the perspective of disciplines other than the natural sciences.

One major uncertainty is whether we will ever be able to answer with confidence questions such as how the universe came to exist. To do so would require that the answer be put into the form of a hypothesis with predictions that can be tested by observations of our universe. But it is unclear whether the development of such hypotheses about so profound a question is possible.

There are other major unanswered questions about the universe that science should eventually be able to resolve. Some of these are: Why does the universe expand? Why is the expansion accelerating (*i.e.*, what is dark energy)? What is dark matter? Is the universe infinitely large? How are all the types of fundamental particles and fields related? Is there life elsewhere? Are there civilizations that we can communicate with? While it may take decades, centuries, or longer to find the answers, these questions are all amenable to the scientific method.

Possible Futures of Humanity

Generally speaking, it seems that there are three possible futures for humankind. One is to discontinue our population growth and to live in harmony with our environment on the surface of the Earth until the Sun becomes a red giant in about 5 billion years. (It is possible — perhaps even likely — that we will figure out how to manipulate our genes to halt the aging process and therefore become at least potentially immortal.) This might imply a future of stagnation, for humans have thrived on crossing technological, intellectual, and personal boundaries over the past several centuries, consuming ever more resources in the process. On the other hand, perhaps we can learn to be creative in our enterprises without continued consumption of our world. Of course, it is possible that humans will evolve naturally, but it seems that, once we can manipulate our genes, we will more likely alter ourselves to suit our needs.

Another possible future is for human-caused changes in the environment to cause a runaway process that renders the Earth inhospitable to human life. For example, the continued increase in atmospheric carbon dioxide caused by modern technology and destruction of forests could cause a runaway greenhouse effect, as apparently occurred on Venus because of its proximity to the Sun. Humans would then become extinct,

along with many other species. The Earth, on the other hand, will of course survive and its atmosphere and surface might, over a long period of time, return to the conditions under which life thrives today.

Some futuristic thinkers champion the prospect of human expansion into space. The argument is that civilized humans are inherently explorers and expansionists, so we should accommodate these tendencies rather than fight them. For example, the asteroids could be mined for technologically crucial metals once we exhaust the supply in the crust of the Earth. One can imagine large solar arrays in space to generate power, space stations in orbit around the Earth and the Moon, and bases on the Moon and Mars. To go one step further, perhaps the Earth will become so crowded that colonies of people will live on spaceships in the solar system. Once the solar system becomes crowded (or even before), some adventuresome colonies might set out for other star systems. A large wheel-shaped (rotating to simulate gravity with centripetal force) structure could hold millions of people, so the idea is not as confining as it might seem at first. The technology to do this is not terribly far from what is possible at the present time. (Relativistic space travel, which would be more exciting, perhaps, is more difficult because most of the weight of the spaceship would need to be fuel at the beginning of the trip in order to accelerate to a speed close to that of light. See Ch. 9.) People, if they are not immortal by then, would be born, live full lives, and die in their space colonies. A rough calculation indicates that, in fact, humans could populate the entire Milky Way galaxy in about 50 million years, a brief period on cosmic time scales. An interesting argument against this vision is the likelihood that other older, technologically more advanced, civilizations from other planets would presumably have already done this. If so, why don't we see them in the solar system?

Our Place in the Universe: Another Perspective

Figure 15-1. The cosmic calendar, as envisioned by late astronomer Carl Sagan. The entire history of the universe is imagined to take place over one "cosmic year." [Source: discovery.com]

As outlined in the introduction to this chapter, each human is the product of nearly 14 billion years of natural processes. Indeed, all the hydrogen atoms in the molecules in our bodies come directly from the Big Bang and the heavier elements were synthesized in stars that have since died. However, the human species has existed only over a very brief fraction of cosmic time. This can be illustrated by creating a "cosmic calendar" (Fig. 15-1) in which the entire life of the universe is scaled down to one Earth-year. On this scale, the first stars and galaxies formed in late January. The Sun formed in late August and the Earth on about September 1. Primitive life appeared in late September. Free oxygen became prevalent at the

beginning of December and the first creatures appeared on land on about December 20. Dinosaurs were in their prime from December 24 to 29. The first humans appeared about 2.6 hours before midnight on December 31, and our species, homo sapiens, about 6 minutes before midnight. So, humans are mere infants in the cosmic timeline.

Humans are small creatures on a relatively small planet that orbits a mediocre star, one of about 200 billion stars in the spiral Milky Way galaxy. We now know that planetary systems are common around stars. The Milky Way is larger than the average galaxy, but only one of countless other galaxies in what is perhaps an infinitely large universe. Our planet is therefore just a "speck of dust" in the cosmos.

The Earth is a relatively serene planet that is quite hospitable to humans, natural disasters such as earthquakes, volcanoes, and extreme weather conditions notwithstanding. Most of the universe, however, is hostile to intelligent life: cold and nearly empty, with the denser regions often subject to violent phenomena and lethal "rains" of energetic radiation and high-energy particles. In fact, we can depend on occasional collisions of asteroids and comets with the Earth to wreak havoc, exterminating many species of living creatures in the aftermath. This creates ecological space for new species to develop and thrive.

Yes, individually we are totally and utterly insignificant members of the universe, subject to the hostile forces of nature that can terminate our existence in the blink of an eye. However, consider the third scenario for the future of humanity discussed above. Even if we use up the Earth's resources, we can colonize space, expanding first to nearby star systems and then the entire galaxy, exhausting the resources of one world after another in the process. We could then expand into the neighboring galaxies. Indeed, humans could become cosmic polluters, a blight on a beautiful, diverse collection of worlds around billions of stars. Of course, we could become more benign as we occupy other star systems, although we have shown few signs of restraint as a species thus far. Besides, living organisms by their nature consume resources from their environments and leave waste products behind.

The main point here is not, however, to promote cynicism, but rather to assert that humans are potentially very important on a cosmic scale, at least in our Galaxy. Since we will likely develop the technology to become so significant, we have an obligation to become good citizens, first of the Earth — it's not too late! — and then of the cosmos. This will require long-term planning rather than a focus on quick solutions to short-term problems. For if we continue to plan only in the short-term, we will probably find that human existence will become only short-term as well. Humans are now at a critical point in their history, the stage at which their collective activity affects the physical conditions of the surface and atmosphere of the Earth. The actions of the next generation, including readers of this textbook, is crucial to the destiny of humanity. Long-term sustainability should be the primary goal of human civilization.

Questions for Discussion

A. What roles do you think theology, philosophy, and science should play in our contemplations about why the universe exists?

B. Do you think that humans should eventually mine resources from other bodies in the solar system for use in technology?

C. Do you think that the destiny of humanity lies in the colonization of space and other worlds?

D. If we assume that humans will, eventually, colonize space and other worlds, how should we go about doing this? What are our responsibilities?

E. What fundamental questions about the universe do you think we can never answer definitively?