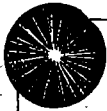


From "Cosmos" by Carl Sagan



CHAPTER I

THE SHORES OF THE COSMIC OCEAN

The first men to be created and formed were called the Sorcerer of Fatal Laughter, the Sorcerer of Night, Unkempt, and the Black Sorcerer... They were endowed with intelligence, they succeeded in knowing all that there is in the world. When they looked, instantly they saw all that is around them, and they contemplated in turn the arc of heaven and the round face of the earth... [Then the Creator said]: "They know all... what shall we do with them now? Let their sight reach only to that which is near; let them see only a little of the face of the earth!... Are they not by nature simple creatures of our making? Must they also be gods?"

—The Popol Vuh of the Quiché Maya

The known is finite, the unknown infinite; intellectually we stand on an islet in the midst of an illimitable ocean of inexplicability. Our business in every generation is to reclaim a little more land.

—T. H. Huxley, 1887

The Cosmos is all that is or ever will be. Our feeblest contemplations of the Cosmos stir us—there is a tingling in the spine, a catch in the voice, a faint sensation, as if a distant memory, of falling from a height. We know we are approaching the greatest of mysteries.

The size and age of the Cosmos are beyond ordinary human understanding. Lost somewhere between immensity and eternity is our tiny planetary home. In a cosmic perspective, most human concerns seem insignificant, even petty. And yet our species is young and curious and brave and shows much promise. In the last few millennia we have made the most astonishing and unexpected discoveries about the Cosmos and our place within it, explorations that are exhilarating to consider. They remind us that humans have evolved to wonder, that understanding is a joy, that knowledge is prerequisite to survival. I believe our future depends on how well

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we know this Cosmos in which we float like a mote of dust in the morning sky.

Those explorations required skepticism and imagination both. Imagination will often carry us to worlds that never were. But without it, we go nowhere. Skepticism enables us to distinguish fancy from fact, to test our speculations. The Cosmos is rich beyond measure—in elegant facts, in exquisite interrelationships, in the subtle machinery of awe.

The surface of the Earth is the shore of the cosmic ocean. From it we have learned most of what we know. Recently, we have waded a little out to sea, enough to dampen our toes or, at most, wet our ankles. The water seems inviting. The ocean calls. Some part of our being knows this is from where we came. We long to return. These aspirations are not, I think, irreverent, although they may trouble whatever gods may be.

The dimensions of the Cosmos are so large that using familiar units of distance, such as meters or miles, chosen for their utility on Earth, would make little sense. Instead, we measure distance with the speed of light. In one second a beam of light travels 186,000 miles, nearly 300,000 kilometers or seven times around the Earth. In eight minutes it will travel from the Sun to the Earth. We can say the Sun is eight light-minutes away. In a year, it crosses nearly ten trillion kilometers, about six trillion miles, of intervening space. That unit of length, the distance light goes in a year, is called a light-year. It measures not time but distances—enormous distances.

The Earth is a place. It is by no means the only place. It is not even a typical place. No planet or star or galaxy can be typical, because the Cosmos is mostly empty. The only typical place is within the vast, cold, universal vacuum, the everlasting night of intergalactic space, a place so strange and desolate that, by comparison, planets and stars and galaxies seem achingly rare and lovely. If we were randomly inserted into the Cosmos, the chance that we would find ourselves on or near a planet would be less than one in a billion trillion trillion* (10^{24}), a one followed by 33 zeroes). In everyday life such odds are called compelling. Worlds are precious.

From an intergalactic vantage point we would see, strewn like sea froth on the waves of space, innumerable faint, wispy tendrils of light. These are the galaxies. Some are solitary wanderers; most inhabit communal clusters, huddling together, drifting endlessly in the great cosmic dark. Before us is the Cosmos on the grandest

*We use the American scientific convention for large numbers: one billion = 1,000,000,000 = 10^9 ; one trillion = 1,000,000,000,000 = 10^{12} , etc. The exponent counts the number of zeroes after the one.

scale we know. We are in the realm of the nebulae, eight billion light-years from Earth, halfway to the edge of the known universe.

A galaxy is composed of gas and dust and stars—billions upon billions of stars. Every star may be a sun to someone. Within a galaxy are stars and worlds and, it may be, a proliferation of living things and intelligent beings and spacefaring civilizations. But from afar, a galaxy reminds me more of a collection of lovely found objects—seashells, perhaps, or corals, the productions of Nature laboring for aeons in the cosmic ocean.

There are some hundred billion (10^{11}) galaxies, each with, on the average, a hundred billion stars. In all the galaxies, there are perhaps as many planets as stars, $10^{11} \times 10^{11} = 10^{22}$, ten billion trillion. In the face of such overpowering numbers, what is the likelihood that only one ordinary star, the Sun, is accompanied by an inhabited planet? Why should we, tucked away in some forgotten corner of the Cosmos, be so fortunate? To me, it seems far more likely that the universe is brimming over with life. But we humans do not yet know. We are just beginning our explorations. From eight billion light-years away we are hard pressed to find even the cluster in which our Milky Way Galaxy is embedded, much less the Sun or the Earth. The only planet we are sure is inhabited is a tiny speck of rock and metal, shining feebly by reflected sunlight, and at this distance utterly lost.

But presently our journey takes us to what astronomers on Earth like to call the Local Group of galaxies. Several million light-years across, it is composed of some twenty constituent galaxies. It is a sparse and obscure and unpretentious cluster. One of these galaxies is M31, seen from the Earth in the constellation Andromeda. Like other spiral galaxies, it is a huge pinwheel of stars, gas and dust. M31 has two small satellites, dwarf elliptical galaxies bound to it by gravity, by the identical law of physics that tends to keep me in my chair. The laws of nature are the same throughout the Cosmos. We are now two million light-years from home.

Beyond M31 is another, very similar galaxy, our own, its spiral arms turning slowly, once every quarter billion years. Now, forty thousand light-years from home, we find ourselves falling toward the massive center of the Milky Way. But if we wish to find the Earth, we must redirect our course to the remote outskirts of the Galaxy, to an obscure locale near the edge of a distant spiral arm.

Our overwhelming impression, even between the spiral arms, is of stars streaming by us—a vast array of exquisitely self-luminous stars, some as flimsy as a soap bubble and so large that they could contain ten thousand Suns or a trillion Earths; others the size of a small town and a hundred trillion times denser than lead. Some stars are solitary, like the Sun. Most have companions.

Systems are commonly double, two stars orbiting one another. But there is a continuous gradation from triple systems through loose clusters of a few dozen stars to the great globular clusters, resplendent with a million suns. Some double stars are so close that they touch, and starstuff flows between them. Most are as separated as Jupiter is from the Sun. Some stars, the supernovae, are as bright as the entire galaxy that contains them; others, the black holes, are invisible from a few kilometers away. Some shine with a constant brightness; others flicker uncertainly or blink with an unflinching rhythm. Some rotate in stately elegance; others spin so feverishly that they distort themselves to oblateness. Most shine mainly in visible and infrared light; others are also brilliant sources of X-rays or radio waves. Blue stars are hot and young; yellow stars, conventional and middle-aged; red stars, often elderly and dying; and small white or black stars are in the final throes of death. The Milky Way contains some 400 billion stars of all sorts moving with a complex and orderly grace. Of all the stars, the inhabitants of Earth know close-up, so far, but one.

Each star system is an island in space, quarantined from its neighbors by the light-years. I can imagine creatures evolving into glimmerings of knowledge on innumerable worlds, every one of them assuming at first their puny planet and paltry few suns to be all that is. We grow up in isolation. Only slowly do we teach ourselves the Cosmos.

Some stars may be surrounded by millions of lifeless and rocky worldlets, planetary systems frozen at some early stage in their evolution. Perhaps many stars have planetary systems rather like our own: at the periphery, great gaseous ringed planets and icy moons, and nearer to the center, small, warm, blue-white, cloud-covered worlds. On some, intelligent life may have evolved, reworking the planetary surface in some massive engineering enterprise. These are our brothers and sisters in the Cosmos. Are they very different from us? What is their form, biochemistry, neurobiology, history, politics, science, technology, art, music, religion, philosophy? Perhaps some day we will know them.

We have now reached our own backyard, a light-year from Earth. Surrounding our Sun is a spherical swarm of giant snowballs composed of ice and rock and organic molecules: the cometary nuclei. Every now and then a passing star gives a tiny gravitational tug, and one of them obligingly careens into the inner solar system. There the Sun heats it, the ice is vaporized, and a lovely cometary tail develops.

We approach the planets of our system, largish worlds, captives of the Sun, gravitationally constrained to follow nearly circular orbits, heated mainly by sunlight. Pluto, covered with methane ice and accompanied by its solitary giant moon Charon, is illuminated by a distant Sun, which appears as no more than a bright point of light in a pitch-black sky. The giant gas worlds, Neptune, Uranus, Saturn—the jewel of the solar system—and Jupiter all have an entourage of icy moons. Interior to the region of gassy planets and orbiting icebergs are the warm, rocky provinces of the inner solar system. There is, for example, the red planet Mars, with soaring volcanoes, great rift valleys, enormous planet-wide sandstorms, and, just possibly, some simple forms of life. All the planets orbit the Sun, the nearest star, an infirmo of hydrogen and helium gas engaged in thermonuclear reactions, flooding the solar system with light.