The Whole Shebang: Preface
Excerpt 2 : The Cosmological Model

Cosmology, once the province of mythology, is now a science. It differs from other sciences, however, in one important way. Other sciences thrive by comparing things—quarks with leptons, gas planets with rocky planets, chalk with granite. But cosmologists have only one universe to study. So it must be compared, not with anything concrete, but with theories and computer models of what other universes might be like, or how the real universe might have turned out differently. Therefore it may be very difficult to determine which aspects of our universe could not have been otherwise and which resulted from chance. The task poses a marvelous challenge to the imagination of the cosmologists, whose charter to envision alternative universes is enlivened by the possibility that other universes may actually exist.

The standard (or "big bang") cosmological model is broad and pliant. It comprises an arena within which many narrower theories and experimental programs thrive and compete. It is incomplete: Scientists don't yet know exactly how old the universe is, how big it is, how rapidly it expands, or how much matter is in it. (As the English astronomer royal, Martin Rees, remarks, "It's embarrassing that ninety per cent of the universe is unaccounted for.")[6] Nor is it clear how the matter we *do* see organized itself into stars and galaxies. There are a great many things we do not know. But it is quite possible that all these issues will be resolved, one way or another, without leaving the basic precepts of the standard model behind.

So we begin with the basic precepts of the standard model. They include these:

Physical laws adduced on Earth pertain throughout the observable universe. And a good thing, too. It would be a lot harder to do physics if, say, each galaxy had its own physics. Fortunately, scientists find that stars millions of light-years away from Earth are made of atoms identical with those here at home—although, of course, one encounters, in plasma jets, black holes, and other such exotic objects, much more extreme ramifications of physics than can be reproduced here at home.

The universe is expanding. Einstein's general relativity theory predicted that cosmic space should be either expanding or contracting. Evidence that it is expanding was then found, in the *redshift* of light coming from galaxies. The only available and wholly consistent explanation for this phenomenon is that it is a Doppler shift—that is, one due to the recession of galaxies from our galaxy and from one another. The rate of expansion is not yet known exactly, but the correct value probably will turn out to be somewhere within 20 percent of contemporary estimates. What the expansion rate means in terms of the age of the universe depends on the geometrical model of the universe one adopts, but to a first approximation the expansion rate suggests an age for the universe of roughly 15 billion years. This fits well with what the astrophysicists estimate to be the ages of the oldest existing stars, about 14 billion years. There are, however, some recent observations that yield a smaller age for the universe. If these data hold up, cosmologists will face a chronological crisis.

The universe is isotropic and homogeneous. Isotropic means that it looks much the same in every direction. If you are swimming far out to sea, your view is isotropic: The sea looks the same in every direction, so you can't tell from the view which way you're looking.

Observationally the universe appears to be isotropic, with galaxies and clusters and superclusters of galaxies found in equal numbers in all parts of the sky except where clouds of dust and gas in our own galaxy obscure our view of space beyond. By *homogeneous,* astronomers mean that, while matter is collected locally into planets, stars, and galaxies, and while the galaxies in turn are clustered, on very large scales their distribution is smooth. If you scooped up a random piece of space the size of a star or a galaxy you'd get inhomogeneous results, sometimes netting stars or planets or nebulae, more often coming up with only space. But if you used a big enough scoop—one measuring, say, a billion light-years on a side—you'd get the same mix of galaxies and space no matter where you took your sample.

General relativity accurately describes the behavior of gravitation in the universe today. Einstein's theory describes gravitation as a warping of space in the presence of matter. Using the theory, it is therefore possible to model the overall shape of cosmic space if one knows the cosmic matter density: the more matter, the more acutely space is curved. For convenience, cosmologists describe the matter density by a single quantity, omega. If omega is greater than one, meaning that the universe is relatively dense, the cumulative gravitational force of all the galaxies will eventually halt cosmic expansion and the universe is destined to collapse. A universe with this kind of curvature is called *closed* and is analogous to a sphere. If omega is less than one, the universe is *open,* and will continue expanding forever. If omega equals one—a state known as *critical density*—the universe will continue expanding, but at an ever-slowing rate that will forever approach but never quite achieve stasis. Such a universe is called *flat.*

Another premise of the standard model is that *the early universe was in a state of high density and high energy.*

The big bang theory holds that the universe began in a *singularity* —a state of infinite curvature of spacetime. In a singularity, all places and times are the same. Hence the big bang did not take place in a preexisting space; all space was embroiled *in* the big bang. Nor did the big bang happen in a remote location: It happened right where you are, and everywhere else. All places that exist today were originally the same place. Nor was it an explosion, as we usually think of explosions, since things did not fly out into space but remained where they were, while the surrounding space expanded.

Since physicists understand thermonuclear reactions rather well, they can with some confidence work out what happened in the early universe. Their calculations predict, among other things, that photons released as the primordial material thinned and cleared should be detectable today as the cosmic microwave background. This prediction has been confirmed observationally.

The universe is evolving. Another important prediction yielded by nuclear physics is that the light elements hydrogen, helium, and lithium were made in the early universe, whereas the heavier elements were made later, in stars. This means, as one observer put it, that the periodic table is a *phylogeny*—a record of evolutionary development. If, as many theorists suspect, the constants of nature were decided by random "phase transitions" that took place during the first moment of time, then the laws of nature, too, are evidence of historical events. Evolution is creative: In an evolving universe, all events could not be predicted even if we knew the precise state of the early universe. Cosmology is an ongoing *story.*

Ferris, Timothy. *The Whole Shebang: A State-of-the-Universe(s) Report.* New York, NY: Simon & Schuster, 1997. Print.