Chapter 1

A Brief History of Cosmological Ideas

The cornerstone of modern cosmology is the belief that the place that we occupy in the Universe is in no way special. This is known as the **cosmological principle**, and it is an idea which is both powerful and simple. It is intriguing, then, that for the bulk of the history of civilization it was believed that we occupy a very special location, usually the centre, in the scheme of things.

The ancient Greeks, in a model further developed by the Alexandrian Ptolemy, believed that the Earth must lie at the centre of the cosmos. It would be circled by the Moon, the Sun and the planets, and then the 'fixed' stars would be yet further away. A complex combination of circular motions, Ptolemy's Epicycles, was devised in order to explain the motions of the planets, especially the phenomenon of retrograde motion where planets appear to temporarily reverse their direction of motion. It was not until the early 1500s that Copernicus stated forcefully the view, initiated nearly two thousand years before by Aristarchus, that one should regard the Earth, and the other planets, as going around the Sun. By ensuring that the planets moved at different speeds, retrograde motion could easily be explained by this theory. However, although Copernicus is credited with removing the anthropocentric view of the Universe, which placed the Earth at its centre, he in fact believed that the Sun was at the centre.

Newton's theory of gravity put what had been an empirical science (Kepler's discovery that the planets moved on elliptical orbits) on a solid footing, and it appears that Newton believed that the stars were also suns pretty much like our own, distributed evenly throughout infinite space, in a static configuration. However it seems that Newton was aware that such a static configuration is unstable.

Over the next two hundred years, it became increasingly understood that the nearby stars are not evenly distributed, but rather are located in a disk-shaped assembly which we now know as the Milky Way galaxy. The Herschels were able to identify the disk structure in the late 1700s, but their observations were not perfect and they wrongly concluded that the Solar System lay at its centre. Only in the early 1900s was this convincingly overturned,

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by Shapley, who realized that we are some two-thirds of the radius away from the centre of the Galaxy. Even then, he apparently still believed our galaxy to be at the centre of the Universe. Only in 1952 was it finally demonstrated, by Baade, that the Milky Way is a fairly typical galaxy, leading to the modern view, known as the **cosmological principle** (or sometimes the Copernican principle), that the Universe looks the same whoever and wherever you are.

It is important to stress that the cosmological principle isn't exact. For example, no one thinks that sitting in a lecture theatre is exactly the same as sitting in a bar, and the interior of the Sun is a very different environment from the interstellar regions. Rather, it is an approximation that we believe holds better and better the larger the length scales we consider. Even on the scale of individual galaxies it is not very good, but once we take very large regions (though still much smaller than the Universe itself), containing say a million galaxies, we expect every such region to look more or less like every other one. The cosmological principle is therefore a property of the global Universe, breaking down if one looks at local phenomena.

The cosmological principle is the basis of the Big Bang Cosmology. The Big Bang is the best description we have of our Universe, and the aim of this book is to explain why. The Big Bang is a picture of our Universe as an evolving entity, which was very different in the past as compared to the present. Originally, it was forced to compete with a rival idea, the Steady State Universe, which holds that the Universe does not evolve but rather has looked the same forever, with new material being created to fill the gaps as the Universe expands. However, the observations I will describe now support the Big Bang so strongly that the Steady State theory is almost never considered.