On the Shores of the Unknown

A Short History of the Universe

In this fascinating book, astronomer Joseph Silk explores the universe from its beginnings to its ultimate fate. He shows how cosmologists study cosmic fossils and relics from the distant past to construct theories of the birth, evolution, and future of the universe. Stars, galaxies, dark matter, and dark energy are described, as successive chapters detail the evolution of the universe from a fraction of a microsecond after the Big Bang. Silk describes how physicists apply theories of subatomic particles to recreate the first moments of the Big Bang, and how astronomers chart the vast depths of space to glimpse how the most distant galaxies formed. He describes the search for dark matter and the dark energy that will determine the ultimate fate of the universe. This highly readable account will appeal to all those with an interest in the story of the universe.

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Prologue

The universe began in a violent explosion that occurred about 15 billion years ago: this is the modern hypothesis that has replaced the myths of classical Greece and Rome, of ancient China and India. We feel certain that our theories have more truth than the beliefs of our ancestors, yet are we so much smarter than they were? Perhaps a thousand years in the future, the Big Bang theory will itself be regarded as a twentieth-century myth.

I am an optimist, however, who finds our current paradigm so compelling that I can only imagine it will eventually be subsumed into a greater theory, without losing its essential features. This conviction provides justification enough to describe the archaeology of the universe. By probing fossil fluctuations in the distribution of matter and fully formed galaxies, the oldest stars and the largest structures, one can reconstruct almost the entire history of cosmic evolution.

The story has been told before, but there are two good reasons for a fresh approach. The study of the cosmos has been revitalised with the discovery of seed fluctuations from which structures later emerged. This was the crucial missing link needed to reconcile the Big Bang theory with the large-scale distribution of matter around us, and it injected a note of reality into the science of cosmology. From a cosmic perspective, one might say that galactic raw material was discovered that is yielding intimate clues about an origin in the remote past. This is a timely moment to describe our view of cosmic evolution.

An equally compelling reason is that there exists no truly accessible and modern description of the Big Bang theory, with its many ramifications arising from the domains of astronomy and of the physics of elementary particles. One of the perennial fascinations of

the science of cosmology is that people, both lay cosmologists as well as the professionals, view it as having the potential to answer the 'ultimate questions' about our place in the universe, the creation and existence of the universe, and indeed of God. It is by no means coincidental that the Big Bang epic has excited the attention of theologians and philosophers as well as of astronomers, mathematicians, and physicists.

Some have viewed the theory as providing confirmation of religious views of creation. The science historian and mathematical physicist E. T. Whitaker declared in 1942 that 'when by purely scientific methods we trace the development of the material universe backwards in time, we arrive ultimately at a critical state of affairs beyond which the laws of nature, as we know them, cannot have operated: a Creation in fact. Physics and astronomy can lead us through the paths to the beginning of things, and show that there must have been a Creation.'

In 1951, Pope Pius XII, under the influence of Whitaker, went the additional step. He averred in an address to the Pontifical Academy of Sciences that 'thus with concreteness which is characteristic of physical proofs, it [science] has confirmed . . . the well-founded deduction as to the epoch [some five billion years ago] when the cosmos came forth from the hands of the Creator. Hence, creation took place in time. Therefore, there is a Creator. Therefore, God exists!'

On hearing these words, one can well imagine that the President of the Pontifical Academy, eminent cosmologist and cofounder of the Big Bang theory, Abbé Georges Lemaître, must have stirred uneasily. To compare the primeval explosion from which the universe emerged to the miracle of creation must have seemed to leave him, a proponent of the Primeval Atom phase that preceded the Big Bang, on somewhat uncertain and heretical ground. Lemaître insisted that physics would suffice to describe the beginning of the universe: 'Cosmogony is atomic physics on a large scale.'

The Big Bang was not an easy pill to swallow, for scientists and

theologians alike. Eminent astrophysicist and science populariser Arthur Eddington was 'unwilling to accept the implied discontinuity in the divine nature.' Others went further. The pioneering cosmologist E. A. Milne concluded in his magnum opus *Relativity, Gravitation and World Structure*, published in 1935, that 'the system to which we have likened the universe is an intelligible system. It contains no irrationalities save the one supreme irrationality of creation – an irrationality indeed to physics, but not necessarily to metaphysics . . . Theoretical cosmology is but the starting point for deeper philosophical enquiries.'

Some scientists conceded the battle for understanding how the universe began to the theologians, who after all had been wrestling with it for many centuries. Astronomer Robert Jastrow described the cosmologists' dilemma thus, in a quote beloved by theologians: 'It seems as though science will never be able to raise the curtain on the mystery of creation. For the scientist who has lived by his faith in the power of reason, the story ends like a bad dream. He has scaled the mountains of ignorance; he is about to conquer the highest peak; as he pulls himself over the final rock, he is greeted by a band of theologians who have been sitting there for centuries.'

In contrast, some eminent scientists have no recourse to any deity in constructing a suitable cosmology. One convenient way out is the assertion that time itself was created at the moment of the Big Bang. This is not a very radical idea, for St Augustine wrote in the fifth century, 'The world and time had both one beginning. The world was made, not in time, but simultaneously with time.' This was a remarkably prescient notion: to physicist Steven Weinberg, 'it is at least logically possible that there was a beginning, and that time itself has no meaning before that moment.'

However, as the mathematical physicist Stephen Hawking points out, a proper formulation of this concept of the beginning of time, as well as that of space, must await a quantum theory of gravity, should it be forthcoming. In this case, 'there would be no boundary to space-time and so there would be no need to specify the behaviour at

the boundary. There would be no singularity at which the laws of science broke down and no edge of space-time at which one would have to appeal to God or some new law to set the boundary conditions for space-time. One could say: "The boundary condition of the universe is that it has no boundary." The universe would be completely self-contained and not affected by anything outside itself. It would neither be created or destroyed. It would just be.' In other words, the universe is the way it is because the universe was the way it was.

The most eloquent expression of this cosmic agnosticism was prophetically penned in 1920 by, again, Arthur Eddington: 'We have found that where science has progressed the furthest, the mind has but regained from nature that which the mind has put into nature. We have found a strange footprint on the shores of the unknown. We have devised profound theories, one after another, to account for its origin. At last, we have succeeded in reconstructing the creature that made the footprint. And Lo! it is our own.'

Discoveries and breakthroughs in cosmology proceed at a breathtaking pace. It is increasingly difficult for the theologians to keep up. At the same time, cosmologists have not been deterred from dabbling in occasional theological metaphors. The shower of images reached a crescendo in 1992 with the epochal discovery of ripples in the cosmic microwave background. Newspapers around the world, less discriminating perhaps than the scientists anticipated, jumped on the cosmic connection. The most notorious examples, 40 years after Pius XII's endorsement of the new cosmology, compared the long-sought fluctuations to various attributes of God. These vary from 'His face', 'His handwriting', and 'His mind', to mere relics such as the 'Holy Grail'.

To properly appreciate the significance of such statements, it would be helpful to have laid out for one the workings of modern cosmology at an accessible level. This book is devoted to such a goal. I hope that the following chapters will be sufficiently transparent to the many lay cosmologists among us that such connections can be more fully appreciated, although I hasten to add, not necessarily justified.