Introduction

Most scientists think that the work they do is very important. Well, they would wouldn't they? It is a human trait, an aspect of vanity, to consider that what one does is more significant than it really is. You might think that scientists would be objective and self-critical and, to be fair, many of them are, but mostly they are prone to all the weaknesses of humanity at large. Nevertheless, if you were to ask a group of scientists which they thought was the most important, the most fundamental, of all scientific problems, the majority would probably reply that it is to understand the origin of the Universe. But, I hear you say, surely that it is a solved problem and in one sense it is. The big-bang theory starts with an event that occurs at an instant when there is no matter, no space and no time. A colossal release of energy at that 'beginning of everything' spreads out creating matter, space and time. There is some supporting evidence for this model. When we look at distant galaxies we find that they are receding from us at a speed proportional to their distance. If all motions were reversed then in 15 billion (thousand million) years they would all converge at the point where the big bang began — which can be regarded as anywhere since everywhere diverged from the same point at the beginning of time. Before 15 billion years ago there was no time — nothing existed of any kind.

I hope that you understand all that because I certainly do not. It is not that I do not *believe* in the big-bang theory — it is just that I do not really *understand* it. The mathematical model of the big-bang is plain enough and many physicists and astronomers, including myself, can deal with that but I doubt that there are many people on this Earth that really *understand* it. My own test of whether or not I understand something is whether or not I can explain it to others. Sometimes in my teaching career, when I have been preparing a new course, I have suddenly realised that I could not provide a clear explanation for something — the reason being that the topic I *assumed* I understood I did not really understand at all. Fortunately, in the teaching context, by reading and a bit of thought I have been able to deal with my own shortcomings. Nevertheless, I can promise you that I shall not be writing a book on the origin of the Universe.

So, if we now exclude the origin of the Universe and take it as an observational fact that we have matter, space and time, what would most scientists think of as the next most important problem? That surely must be to explain the origin of life. By what process can inanimate matter be transformed even into the most primitive life forms? Is it actually a spontaneous process? We are straying close to religious issues here so I shall go no further in that direction. But, once life exists, even in a primitive form, we do have a theory that *can* readily be understood, Darwin's theory of evolution, which leads us to the higher forms of life, including ourselves. Random genetic mutations occasionally create an individual that has advantages over others in its environment. The principle of 'survival of the fittest' ensures that its newly modified genes flourish and eventually become dominant and by small changes over long periods of time a new species can evolve. There is also some evidence for the occasional rather more rapid creation of new species. Something that Darwin's ideas do not deal with directly is the existence of consciousness, the knowledge of one's own identity and relationship to the outside world. That too is one of the difficult problems of science, although there are those who attempt to explain it in terms of computer technology by asserting that human beings resemble rather complex computers.

The topic of this book is not as important as those mentioned above and in many ways it is much more mundane. The Solar System is a collection of objects — the Sun, planets, satellites etc. — made of ordinary matter — iron, silicates, ices and gases, the properties of which we well understand. The Universe is full of such material so all we have to do is to find a way of transforming it from one state to another. Having said that, although it is not an important problem in a fundamental sense, it is nevertheless quite an interesting one because it turns out to be very difficult. For more than two hundred years scientists have been struggling to find ways of just producing the Sun, planets and satellites, let alone all the other bodies of the Solar System. Part of the problem has been that scientists have tended to concentrate on parts of the system rather than looking at it as a whole. It is as though one was trying to understand the structure and workings of a car by studying just the wheels, the transmission system or the seats. It is only by looking at the whole car that one can understand the relationships of one part to another, how it works and how it was made. The same is true for the Solar System. It is not a collection of disconnected objects bearing little relationship to one another. It is a *system* and it will only be understood by examining it as a system.

The story that I tell goes back a long way — perhaps almost to the beginning of sentient mankind. Starting from the observations that a few points of light wandered around against the background of the stars, a picture emerged of a collection of bodies, connected to the Earth, Moon and Sun, that formed a separate family. Gradually the picture improved until, about three hundred years ago, we not only knew how all the bodies moved relative to each other but also understood the nature of the forces that made them move as they do.

Large telescopes, operating over a range of wavelengths from X-rays to radio waves, together with spacecraft, have given us detailed knowledge of virtually all the members of the solar-system family even to the extent of knowing something about the materials of which they consist. In addition, from Earth-bound observations we have even been able to detect planets around other stars — many of them — so we know that the Solar System is not a unique example of its kind. New knowledge has provided guidance for theoreticians attempting to explain the origin of the Solar System — but it also gives new constraints that their theories need to satisfy.

I began my study in this area, generally known as cosmogony, in 1962, intrigued by the fact that, while there had been many theories put forward, not one had survived close scientific scrutiny. While some of them were superficially attractive they all failed because they contravened some important scientific principle; it is a basic requirement of any theory that *every* aspect of it must be consistent with the science that we know. If a theory explains many things in the Solar System but is in conflict with scientific principles then it is wrong. You can no more have a nearly plausible theory than you can have a nearly pregnant woman. Armed with the knowledge that, since the Solar System exists, there must be some viable theory for its origin I started on what turned out to be a long hard road. There were many dead ends and new beginnings. Ideas arose, seemed promising, failed critical tests and then were abandoned. However, one early basic idea that was the core of what came to be called the Capture Theory survived and evolved. What it evolved into is very different from the starting form but the essential idea is still there. Gradually a picture emerged that seemed to make sense — a good sign — and instead of problems piling up as had been the original experience, it was solutions to problems that seemed to proliferate.

I have already confessed to my lack of deep understanding of the big-bang theory but I *do* understand the nature of planets and related bodies and hence I am prepared to write about the formation of the Solar System. However, in writing a book an author has to consider first the readership for whom it is intended and that was a problem with which I wrestled for some time. A complete deep scientific treatment of all aspects of the various theories would be unintelligible to most non-specialist readers and would just be a reproduction of what is already available in the scientific literature. An alternative approach, in which only verbal descriptions were given throughout, would be more readable but would lack credibility — many theories sound plausible enough when described in hand-waving fashion but wilt under close scientific scrutiny. So, to maximize the readership while maintaining scientific integrity, I have decided on a middle course. Fortunately the level of science needed to deal with most aspects of cosmogony can be understood by anyone with a fairly basic scientific background. The approach that has been adopted is to introduce equations here and there to provide scientific substance together with narrative to explain what they mean. In addition, for those who wish to delve more deeply into the subject, reference will be given to a small selection of books and papers in scientific journals — but I stress, these are *not* essential reading! Hopefully, this text alone will provide an account in a form that should both be understood by the non-expert reader and also be of interest to those with wider knowledge of astronomy or general science.