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Origins

How the Planets, Stars, Galaxies, and the Universe Began

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Preface: An Observer's Manifesto

I have always thought that the title of the most popular astronomy book of all time was a bit of a fraud. Steven Hawking's famous book was mostly about a tiny sliver of time — the first 0.000 000 000 000 000 000 000 000 000 000 000 0001 seconds after the Big Bang. This is an important sliver that is believed to contain the answers to many fundamental questions. Can we construct a theory that will unify the two revolutionary theories, general relativity and quantum mechanics, which were two of the most important scientific discoveries of the twentieth century? Is there even a "theory of everything" that will unify all the forces of nature? However, according to the latest results from the WMAP satellite, the Big Bang occurred — and therefore *time* began — 13.7 billion years ago. Therefore, to write a book that excludes 99.9999 per cent (I will not bother with the remaining 37 digits) of the history of the Universe, including the important part in which planets, stars, galaxies — all the things that are important to us — formed, and then call it *A Brief History of Time* does seem, to say the very least, rather inaccurate.

This is a book about what happened next, especially the origins of the planets, stars, and galaxies. It is a good moment to write such a book because we have probably learned as much about these subjects in the last ten years as we have in all the time before, and much of this recent research has not yet diffused from the scientific journals into the public consciousness. There is also one huge advantage in writing about this later period in the history of the Universe. The earlier period is important because of the big unanswered questions, but it is so long ago that what is written about it is often highly speculative and uncertain. In contrast, we have a surprising amount of very definite and concrete information about most of the rest of the history of the Universe, especially from about 2 seconds after the Big Bang until the present day. For

a start, astronomers have the huge advantage over historians, archaeologists, and journalists in that they really can observe history as it is happening. The fact that the speed of light, though very large, is finite means that looking out into space is the equivalent of looking back in time; we can sit on the third planet of our average star and use our telescopes to look at events billions of years in the past. According to the latest results from WMAP, we can observe historical events all the way back to four hundred thousand years after the Big Bang. Before this time, we can not observe events directly because the Universe was ionized, which obscures our view in the same way that the center of the Sun, a ball of ionized gas, is hidden from our view. However, in the same way that we think we understand the processes in the center of the Sun because nobody has been able to think of any other way of explaining the Sun's exterior properties, we have fairly definite knowledge of events in the Universe at earlier times. In particular, the Universe must have had certain properties about two seconds after the Big Bang to explain the chemical elements we see around us today.

The final part of this book is about the biggest of the origin questions, the origin of the Universe itself. In the book's final chapter, I do travel back to this earlier time. My view of this period, though, is rather different. I am an observational astronomer rather than a theoretical physicist, so I am less interested in (and not an expert in) the theories about this period. I am more interested in gritty facts. What facts do we know about this period and what is speculation? What conclusions can we tease out of the few facts that we do know? Can we build telescopes that will allow us to look even further back toward the Big Bang? This chapter is short on the abstract beauty of theoretical physics, but it does try and give a hard-nosed observer's view of what we know and don't know about the first fraction of a second after the Big Bang.

This final origin question is, of course, different in kind from the other three. It is not even clear whether the question has any meaning. If the Universe is defined as consisting of everything there is, does it really make sense to ask how it began — a question that presupposes the existence of there being something *other* than the Universe. It is impossible to discuss this question without

moving far from the comfortable world of an observer — the world of telescopes, stars, and galaxies — into the strange worlds of philosophy and of the meaning of language. It is also a question that has been discussed in many other books. In keeping with the observational slant of this book, I have tried to sift through the speculations of physicists and philosophers for ideas that we might someday be able to test with our telescopes.

I have written this book for a reader without any prior knowledge of science, and I have tried hard not to slip into astronomer's jargon and to explain each technical term as I come to it. One of the challenges of writing any book, popular or otherwise, about research in these fields is the pace of change. This means that by the time this book is in print it will be out-of-date. I have taken out some basic insurance against obsolescence by providing a website to accompany this book, which contains new results obtained since this book was published about all of the origin questions (www.originquestions.com).

One common style of science writing, used in many otherwise excellent books, is to describe the present state of scientific knowledge without much explanation of how scientists arrived at this state. I am not a great fan of this ahistorical style for two reasons. First, it tends to give the impression of the present state of knowledge as something immutable — a finished and polished body of work. In reality, the present state of knowledge is always tentative, and some of the discoveries described in this book will undoubtedly vanish within a few years like the morning dew. Second, this writing style also tends to denude the science of all human personality and leave the impression that science is an activity carried out by disembodied intellects, whereas in reality it is a vigorous human activity. In this book, I have always tried to tell the human story of each discovery. The book is therefore a mixture of a description of our present state of knowledge and an explanation of how this state of knowledge came to be. Occasionally in the book I have also told stories from my own career as an astronomer. This is not because my career has any more significance than the careers of the rest of the several thousand professional astronomers around the world, but because I wanted to give the reader a feeling for what it has been like to *be* an astronomer during this exciting period in our subject's history.

I should immediately add that I do not make any great scholarly claims for the historical parts of this book. My account of the recent research into the origins questions is inevitably biased by my own personal geographical and intellectual trajectory over the last two decades; another scientist would undoubtedly emphasize a slightly different set of discoveries as being the important ones. The book is also biased because I have picked out discoveries that make good stories. The historical parts of this book are probably closer to journalism than real history, but I have at least tried to be a good journalist and get the story of each discovery as straight as possible. Because of the limited amount of written information about many of these discoveries, I have often had to rely on the memories of the participants. I am particularly grateful to David Jewitt for his comments about the discovery of the Edgeworth–Kuiper Belt, Derek Ward-Thompson for his account of the discovery of Class 0 protostars, Phil Mauskopf for his memories of the BOOMERANG project, and Simon Lilly for checking my memories of the *annus mirabilis* in our own research field.

The colleagues who have helped me during my own career as an astronomer are too numerous to mention, but I can at least have the pleasure of thanking the following colleagues for specific help with this book, which has ranged from casual conversations over coffee to reading and making comments on individual chapters: Anthony Aguirre, Elizabeth Auden, Mike Edmunds, Rhodri Evans, Walter Gear, Dave Green, Haley Gomez, Simon Goodwin, Dave Jewitt, Simon Lilly, Malcolm Longair, Phil Mauskopf, Dimitris Stamatellos, Derek Ward-Thompson, and Anthony Whitworth.

I am particularly grateful to Gwyneth Lewis, who was the "idiot reader," as she describes it. Without any scientific background, she read the entire manuscript to check that I was explaining things as clearly as I thought (I often was not). As a professional writer and the official national poet of Wales, Gwyneth also made many invaluable comments about style, language, and the art of writing. Also in the world of writers and publishing, I am grateful to Simon Mitton for his original encouragement to write a book, John Watson for taking a flier on an unknown author, and Harry Blom, Christopher Coughlin, and Louise Farkas at Springer.

I thank my children, Nicholas, Juliet, and Oliver, for a reason that will become clear. Above all, I thank my wife Keirsten. Without her love and support over the last two decades, I would not be an astronomer and would never have written this book. I dedicate it to her.

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