Preface

ARE FASHION, FAITH, OR FANTASY RELEVANT TO FUNDAMENTAL SCIENCE?

This book has been developed from an account of three lectures I gave at Princeton University in October 2003 at the invitation of Princeton University Press. The title I had proposed to the Press for these lectures – Fashion, Faith, and Fantasy in the New Physics of the Universe – and which remains as the title of this book may well have been a somewhat rash suggestion on my part. Yet it genuinely expressed a certain unease I felt about some of the trends that were part of the thinking of the time concerning the physical laws governing the universe in which we live. Well over a decade has passed since then, but the topics, and much of what I had to say about them, appear to be, for the most part, at least as relevant today as they were then. I gave those talks with some apprehension, I might add, as I was trying to express some points of view that I worried might resonate not too favourably with many of the resident distinguished experts.

Each of the eponymous words "fashion", "faith", and "fantasy" suggests a quality that would seem to be very much at odds with the procedures normally considered appropriate when applied to a search for the deep principles that underlie the behaviour of our universe at its most basic levels. Indeed, ideally, it would be very reasonable to assert that such influences as fashion, or faith, or fantasy ought to be totally absent from the attitude of mind of those seriously dedicated to searching for the foundational underpinnings of our universe. Nature herself, after all, surely has no serious interest in the ephemeral whims of human fashion. Nor should science be thought of as a faith, the dogmas of science being under continual scrutiny and subject to the rigours of experimental examination, to be abandoned the moment that a convincing conflict arises with what we find to be the actuality of nature. And fantasy is surely the province of certain areas of fiction and entertainment, where it is not deemed essential that significant regard be paid to the requirements of consistency with observation, or to strict logic, or even to good common sense. Indeed, if a proposed scientific theory can be revealed as being too much influenced by the enslavement of fashion, by the unquestioning following of an experimentally unsupported faith, or by the romantic temptations of fantasy, then it is our duty to point out such influences, and to steer away any who might, perhaps unwittingly, be subject to influences of this kind.

Nevertheless, I have no desire to be entirely negative with regard to these qualities. For it can be argued that there is something of distinctly positive value in each of these eponymous terms. A fashionable theory, after all, is unlikely to have such a status for purely sociological reasons. There must indeed be many positive qualities to hold multitudes of researchers to a highly fashionable area of study, and it is unlikely to be the mere desire to be part of a crowd that keeps such researchers so fascinated by what is likely to be an extremely difficult field of study – this very difficulty often having roots in the highly competitive nature of fashionable pursuits.

A further point needs to be made here, with regard to research in theoretical physics that may be fashionable, yet far from what is plausible as a description of the world – indeed, as we shall find, often being in fairly blatant contradiction with current observations. Whereas those who work in such areas might well have found huge gratification, had observational facts turned out to be more in accordance with their own pictures of the world, they often seem relatively undisturbed by facts that are found to be less obliging to them than they would have liked. This is not at all unreasonable; for, to a considerable degree, these researches are merely *exploratory*, the viewpoint being that expertise may well be gained from such work, and that this will eventually be useful in the discovery of better theories which agree more closely with the actual functioning of the universe we know.

When it comes to the extreme faith in some scientific dogmas that is often expressed by researchers, this also is likely to have a powerful rationale, even where the faith is in the applicability of such a dogma in circumstances that lie far beyond the original situations where strong observational support initially laid its foundations. The superb physical theories of the past can continue to be trusted to provide enormous precision even when, in certain circumstances, they have become superseded by better theories that extend their precision or the range of their applicability. This was certainly the case when Newton's magnificent gravitational theory was superseded by Einstein's, or when Maxwell's beautiful electromagnetic theory of light became superseded by its quantized version, wherein the particulate aspects of light (photons) could be understood. In each case the earlier theory would retain its trustworthiness, provided that its limitations are kept appropriately under firm consideration.

But what about fantasy? Surely this is the very opposite of what we should be striving for in science. Yet we shall be seeing that there are some key aspects to the nature of our actual universe that are so exceptionally odd (though not always fully recognized as such) that if we do not indulge in what may appear to be outrageous flights of fantasy, we shall have no chance at all of coming to terms with what may well be an extraordinary fantastical-seeming underlying truth.

In the first three chapters, I shall illustrate these three eponymous qualities with three very well-known theories, or families of theory. I have not chosen areas of relatively minor importance in physics, for I shall be concerned with what are big fish indeed in the ocean of current activity in theoretical physics. In chapter 1, I have chosen to address the still highly fashionable string theory (or superstring theory, or its generalizations such as M-theory, or the currently most fashionable aspect of this general line of work, namely the scheme of things referred to as the *ADS/CFT correspondence*). The faith that I shall address in chapter 2 is an even bigger fish, namely that dogma that the procedures of quantum mechanics must be slavishly followed, no matter how large or massive are the physical elements to which it is being applied. And, in some respects, the topic of chapter 3 is the biggest fish of all, for we shall be concerned with the very origin of the universe that we know, where we shall catch a glimpse of some proposals of seeming sheer fantasy that have been put forward in order to address certain of the genuinely disturbing peculiarities that well-established observations of the very early stages of our entire universe have revealed.

Finally, in chapter 4, I bring forward some particular views of my own, in order to point out that there are alternative routes that could well be taken. We shall find, however, that the following of my own suggested paths would appear to involve certain aspects of irony. There is, indeed, an irony of fashion in my own preferred path to the understanding of basic physics – a path that I shall briefly introduce to the reader in §4.1. This is the path staked out by twistor theory, which I have myself been seminally involved with, and which for some forty years had attracted scant attention from the physics community. But we find that twistor theory has itself now begun to acquire some small measure of string-related fashion.

As to an overriding unshakable faith in quantum mechanics, as appears to be held by the considerable majority of the physics community, this has been further endorsed by remarkable experiments, such as those of Serge Haroche and David Wineland, which received well-deserved recognition by the award of the 2012 Nobel Prize in physics. Moreover, the award of the 2013 Nobel Physics Prize to Peter Higgs and François Englert for their part in the prediction of what has come to be known as the *Higgs boson* is a striking confirmation not only of the particular ideas that they (and some others, most particularly Tom Kibble, Gerald Guralnik, Carl Hagen, and Robert Brout) had put forward in relation to the origin of particle masses, but also of many of the foundational aspects of quantum (field) theory itself. Yet, as I point out in §4.2, all such highly refined experiments performed so far still fall considerably short of the level of displacement of mass (as proposed in §2.13) that will be needed before one might seriously anticipate our quantum faith to be significantly challenged. There are other experiments at present under development, however, that are aimed at such a level of mass displacement, which I argue could well help to resolve some profound conflicts between current quantum mechanics and certain other accepted physical principles, namely those of Einstein's general relativity. In §4.2, I point out a serious conflict between current quantum mechanics and Einstein's foundational principle of equivalence between gravitational fields and accelerations. Perhaps the results of such experiments may indeed undermine the unquestioning quantum-mechanical faith that seems to be so commonly held. On the other hand, one may ask why should one have more faith in Einstein's equivalence principle than in the immensely more broadly tested foundational procedures of quantum mechanics? A good question indeed – and it could well be argued that there is at least as much faith involved in accepting Einstein's principle as in accepting those of quantum mechanics. This is an issue that could well be resolved by experiment in the not-too-distant future.

As to the levels of fantasy that current cosmology has been led into, I suggest in §4.3 (as a final irony) that there is a scheme of things that I put forward myself in 2005 – conformal cyclic cosmology, or CCC – that is, in certain respects, even more fantastical than those extraordinary proposals we shall encounter in chapter 3, some of which have now become part of almost all contemporary discussions of the very early stages of the universe. Yet CCC appears to be beginning to reveal itself, in current observational analyses, as having some basis in actual physical fact. It is certainly to be hoped that clear-cut observational evidence will soon be able to convert what may or may not seem to be sheer fantasy, of one kind or another, into a convincing picture of the factual nature of our actual universe. It may be remarked, indeed, that unlike the fashions of string theory, or most theoretical schemes aimed at undermining our total faith in the principles of quantum mechanics, those fantastical proposals that are being put forward for describing the very origin of our universe are already being confronted by detailed observational tests, such as in the comprehensive information provided by space satellites COBE, WMAP, and the Planck space platform, or by the results of the BICEP2 South Pole observations released in March 2014. At the time of writing, there are serious issues of interpretation concerning the latter, but these ought to be resolvable before too long. Perhaps there will soon be much clearer evidence, enabling definitive choices to be made between rival fantastical theories, or some theory not yet thought of.

In attempting to address all these issues in a satisfactory (but not too technical) way, I have had to face up to one particular fundamental hurdle. This is the issue of mathematics and its central role in any physical theory that can seriously purport to describe nature at any real depth. The critical arguments that I shall be making in this book, aimed at establishing that fashion, faith, and fantasy are indeed inappropriately influencing the progress of fundamental science, have to be based, to some meaningful extent, on genuine technical objections, rather than on mere emotional preferences, and this will require us to get involved in a certain amount of significant mathematics. Yet this account is not intended to be a technical discourse, accessible only to experts in mathematics or physics, for it is certainly my intention that it can be read with profit by non-experts. Accordingly, I shall try to keep the technical content to a reasonable minimum. There are, however, some mathematical notions that would be greatly helpful for the full appreciation of various critical issues that I wish to address. I have therefore included eleven rather basic mathematical sections in an appendix, these providing accounts that are not very technical, but which could, where necessary, help non-experts to gain some greater appreciation of many of the main issues.

The first two of these sections (§§A.1 and A.2) involve only very simple ideas, albeit somewhat unfamiliar ones, with no difficult notation. However, they play a special role for many arguments in this book, most particularly with regard to the fashionable proposals discussed in chapter 1. Any reader wishing to understand the central critical issue discussed there should, at some stage, take note of the material of §§A.1 and A.2, which contain the key to my argument against additional spatial dimensions being actually present in our physical universe. Such supra-dimensionality is a central contention of almost all of modern string theory and its major variants. My critical arguments are aimed at the current string-motivated belief that the dimensionality of physical space must be greater than the three that we directly experience. The key issue I raise here is that of functional freedom, and in §A.8 I outline a somewhat fuller argument to clarify the basic point. The mathematical notion under consideration has its roots in the work of the great French mathematician Élie Cartan, basically dating back to the turn of the twentieth century, but seeming to be little appreciated by theoretical physicists of today, although having great relevance to the plausibility of current supra-dimensional physical ideas.

String theory and its modern variants have moved forward in many ways in the years following these Princeton lectures, and have developed considerably in technical detail. I certainly make no claim to any kind of mastery of such developments, although I have looked at a fair amount of this material. My essential issue of concern lies not in any such detail but in whether this work really moves us forward very much towards an understanding of the actual physical world in which we live. Most particularly, I see little (if any) attempt to address the question of excessive functional freedom arising from the assumed spatial supra-dimensionality. Indeed, no work of string theory that I have seen makes any mention of this problem. I find this to be somewhat surprising, not just because this issue was central to the first of my decade-old three Princeton lectures. It had previously featured in a talk I gave at a conference honouring Stephen Hawking's 60th birthday at Cambridge University, in January 2002, to an audience containing several leading string theorists, and written accounts were subsequently provided.

I need to make an important point here. The issue of functional freedom is often rejected by quantum physicists as applying only to classical physics, and the difficulties it presents for supra-dimensional theories tend to be summarily dismissed with an argument aimed at demonstrating the irrelevance of these matters in quantum-mechanical situations. In §1.10 I present my main case against this basic argument, which I particularly encourage the proponents of spatial supra-dimensionality to read. It is my hope that by repeating such arguments here, and by developing them in certain further physical contexts (§§1.10, 1.11, 2.11, and A.11), I might encourage these arguments to be adequately taken into consideration in future work.

The remaining sections of the appendix briefly introduce vector spaces, manifolds, bundles, harmonic analysis, complex numbers, and their geometry. These topics would certainly be well familiar to the experts, but non-experts may find such self-contained background material helpful for fully understanding the more technical parts of this book. In all my descriptions, I have stopped short of providing any significant introduction of the ideas of differential (or integral) calculus, my viewpoint being that while a proper understanding of calculus would be of benefit to readers, those who do not already have this advantage would gain little from a hurried section on this topic. Even so, in §A.11, I have found it helpful just to touch upon the issue of differential operators and differential equations, in order to help explain some matters that have relevance, in various ways, to the thread of the argument throughout the book.