Preface

Confronted with the choice between paradise and knowledge, man, according to the Bible, chose knowledge. Were these really alternatives? It came to be that the gaining of knowledge and the wider horizon outside the garden of Eden brought to many as much pleasure and satisfaction as any paradise they could imagine.

Humans have always wanted to explore the world they live in, and they have always wanted to know what lies beyond the horizons that limit their view. The search for richer pastures, better climates, easier communication—all these certainly played a part in this, but behind it all there was an inherent human sense of curiosity. This curiosity triggered a journey starting some 200,000 years ago in a remote corner of Africa and has driven us to navigate all the oceans, to conquer the entire Earth, to probe the heavens and to penetrate ever more deeply into interstellar space, to study ever more distant galaxies. At the other end of the scale, high-energy particle accelerators allow us to resolve the structure of matter to an ever higher degree, to look for its ultimate constituents and study how they interact with each other to form our world. Are there limits, is there an end to this drive, at the large scale as well as at the small?

In the last hundred years, modern physics and cosmology have shown that there exist regions forever beyond our reach, hidden from us by truly ultimate horizons. These regions we can access in our imagination only; we can speculate what they are like and whether perhaps some sign of their existence, some indication of their nature can ever reach our world.

Such hidden regions exist in those remote parts of the universe where, from our point of view, space expands faster than the speed of light. Closer to us, they are found in black holes, where gravity is strong enough to retain even light within its horizon of ultimate attraction. And in the realm of the very small, quarks remain forever confined to their colorful world of extreme density; they can never be removed from it. But given the Big Bang origin of the universe, our world in its very early stages was immensely hot and dense; and given the spectrum of all the particles created in high-energy collisions, we can try to reconstruct ever earlier stages. The evolution of the universe, with cooling and expansion, then defines horizons in time, thresholds through which the universe had to pass to reach its present state. What were the earlier stages like?

Although it is not possible to transmit information across the "event horizons" that form the borders of these forbidden regions, still sometimes strange signals may appear, providing us with hints of the existence of those other worlds. Such striking phenomena can become possible through quantum effects; "Hawking–Unruh" radiation provides one example expected to arise in a variety of cases, whenever there exists an event horizon. And looking at the multitude of "elementary" particles produced in high-energy accelerators, we can speculate that they originally came from a simpler, more symmetric world, which in the course of the evolution experienced transitions, like the freezing of water or the magnetization of metals, to form the many-faceted and less symmetric world we see today.

The aim of this book is to tell the story of how the different horizons, on Earth and in the heavens, on large and on small scales, now and in the past, were discovered and used to define our view of the world. It is a story of the evolution of this view, which started before "science," and which is much more than just "something for scientists." It started with philosophers wondering what matter was made of, and how; with sailors daring to find out if the world ends somewhere; with astronomers trying to determine our position among the stars, to estimate the size of the Earth by looking at the Sun and using the newly developed geometry. With Edgar Allan Poe, the Big Bang appeared in literature before it was commonplace in physics and cosmology; and aspects of both black holes and wormholes were part of the stories of Lewis Carroll before they became significantly appreciated in science. Many of the ideas, even today's, have come up here and there in the course of time. The ways of treating them, and the tools used for that were different, of course, and changed over the centuries. But what remained was that desire to see what lies beyond, and to find out whether there is a limit to what we can reach and understand.

We begin by looking at the various horizons partitioning our world and then show how different forbidden regions arise in the universe, and when and how they can emit signatures as testimony to their presence and their nature. The mysterious light emerging from an event horizon, or the equally mysterious clusters in a new and strange ether, they may well remain all that we can ever see of what is hidden beyond the ultimate horizons.

This book is not meant to give a systematic presentation of the recent developments in physics or cosmology. Its aim is to tell a story that began a long time ago and that will certainly not come to an end very soon. And it covers developments that sometimes, as in the age of Vasco da Gama and Columbus, or in the time of Einstein, Planck, Bohr and Heisenberg, revolutionize the world in two or three decades. At other times, between Ptolemy and Copernicus, it takes a millennium to add a couple of epicycles to the accepted scheme of things. The problem is, in the words of the renowned Austrian theorist Walter Thirring, that "to do something really new, you have to have a new idea," and that does not happen so very often. It does not suffice to play on the keyboard of the available theoretical formalisms; this just leads to many melodies and not to any convincing and lasting new harmony.

I have tried to present things in a way not needing any mathematics. That is, as I indicate in the section on Notation, a two-sided issue. Even Einstein sometimes presented the special theory of relativity in terms of people on a train versus people on the ground. It can be done, and it is indeed helpful to convey the basic ideas. For a full understanding of the ultimate conclusions, however, mathematics becomes essential. To travel a middle road, I have at times added inserts, in which some aspects of the basic mathematical formulation are indicated. But I hope that the presentation remains understandable even if you skip these.

One unavoidable aspect appears if one tries to present things in as readable a way as possible: some points and concepts are mentioned more than once. Although strictly speaking logical, the reminder "as already discussed in the previous Chapter" is in fact often not what the reader wants; it seems better to just briefly recall the idea again. So I offer my apologies for a number of repetitions. And another apology is probably also needed. When forced to choose between scientific rigor and simplifying an idea enough to make it understandable, I generally took the latter path. I thought it better to try to have readers follow my train of thought, even if they will later need corrections, than to lose them in technical details they cannot follow. My inspiration here were the words of the great Danish physicist Niels Bohr, who noted that *Wahrheit* (truth) and *Klarheit* (clarity) are complementary: the more precisely you enforce one, the less precise the other becomes.

Finally, it is my pleasure to express sincere thanks to all who have helped me with this endeavor. Obvious support came from my colleagues here in Bielefeld, in Brookhaven, at CERN, in Dubna and elsewhere. They have been of crucial importance in forming my view of things. And last, but far from least, profound thanks go to my wife, who has patiently borne with me during all these years.

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