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Roberto Mangabeira Unger and Lee Smolin
Frontmatter
More information

The Singular Universe and the Reality of Time

A Proposal in Natural Philosophy

Cosmology is in crisis. The more we discover, the more puzzling the universe appears to be. How and why are the laws of nature what they are?

A philosopher and a physicist, world-renowned for their radical ideas in their fields, argue for a revolution. To keep cosmology scientific, we must replace the old view in which the universe is governed by immutable laws by a new one in which laws evolve. Then we can hope to explain them.

The revolution that Roberto Mangabeira Unger and Lee Smolin propose relies on three central ideas. There is only one universe at a time. Time is real: everything in the structure and regularities of nature changes sooner or later. Mathematics, which has trouble with time, is not the oracle of nature and the prophet of science; it is simply a tool with great power and immense limitations. The argument is readily accessible to non-scientists as well as to the physicists and cosmologists whom it challenges.

ROBERTO MANGABEIRA UNGER is a philosopher, social and legal theorist, and politician. His engagement with cosmology and natural philosophy in this book deepens and generalizes ideas that he has developed in *False Necessity*, *The Self Awakened*, and *The Religion of the Future*, among other writings.

LEE SMOLIN is a theoretical physicist who has made important contributions to quantum gravity. Born in New York City, he was educated at Hampshire College and Harvard University. He is a founding member of the Perimeter Institute for Theoretical Physics. His earlier books explore philosophical issues raised by contemporary physics and cosmology: *Life of the Cosmos*, *Three Roads to Quantum Gravity*, *The Trouble with Physics*, and *Time Reborn*.

Unger and Smolin have been collaborating for eight years on the project that this work brings to fruition.

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A Proposal in Natural Philosophy

ROBERTO MANGABEIRA UNGER
AND
LEE SMOLIN

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Contents

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The nature and scope of this work

Roberto Mangabeira Unger and Lee Smolin

To think of the universe as a whole rather than of something within the universe is one of the two most ambitious tasks that thought can undertake. Nothing matches it in ambition other than our attempts to form a view of ourselves. In addressing this topic, we soon reach the limits of what we know and even of what we can ever hope to know. We press science to the point at which it passes into philosophy and philosophy to the point at which it easily deceives itself into claiming powers that it lacks.

Yet we cannot cast this topic aside. First, we cannot avoid it because we are driven to understand whatever we can about our place in the world, even if what we do know, or might discover, represents only a small and superficial part of the enigmas of nature. Second, we should not seek to escape it because no one can develop and defend ideas about parts of natural reality without making assumptions, even if they remain inexplicit, about nature as a whole. Third, we need not turn away from it because among the greatest and most startling discoveries of science in recent times are discoveries about the universe and its history. The most important such discovery is that the universe has a history. Part of the task is to distinguish what science has actually found out about the world from the metaphysical commitments for which the findings of science are often mistaken.

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In this book, we deal with this subject directly. Three ideas are central to our argument.

The first idea is the singular existence of the universe. (We use singular here in the sense of unique, not in the sense in which relativists use it to mean a singularity at which the curvature of spacetime and other quantities become infinite. In fact we later argue that the universe cannot be singular in that sense.) There is only one universe at a time, with the qualifications that we discuss. The most important thing about the natural world is that it is what it is and not something else. This idea contradicts the notion of a multiverse – of a plurality of simultaneously existing universes – which has sometimes been used to disguise certain explanatory failures of contemporary physics as explanatory successes.

The second idea is the inclusive reality of time. Time is real. Indeed, it is the most real feature of the world, by which we mean that it is the aspect of nature of which we have most reason to say that it does not emerge from any other aspect. Time does not emerge from space, although space may emerge from time.

That time is inclusive as well as real means that nothing in nature lasts forever. Everything changes sooner or later, including change itself. The laws of nature are not exempt from this impermanence. By implying the mutability of the laws of nature, the idea of the inclusive reality of time contradicts a dominant interpretation of what the physics and cosmology of the last hundred years teach us about the workings of nature.

Twentieth-century science overthrew the conception of an invariant background in space and time to the events and phenomena of nature. Einstein's greatest accomplishment in inventing general relativity was to replace Newton's absolute space and time with a conception of spacetime that is both relational and dynamical. When he did so, however, he reaffirmed the notion of an immutable framework of natural laws. We have ordinarily expected such timeless laws to supply warrants to our practice of causal explanation. If the laws of nature change, how can we hope to establish scientific inquiry on a secure basis? A major concern of this book is to propose answers to this question.

Now, however, we have grounds to overthrow the view that was reaffirmed when belief in an invariant background of space and time was abandoned. Unless we accomplish this second overturning we cannot do justice to the most important discovery made by the cosmology of the twentieth century: the discovery that the universe, and everything in it, has a history. The prevailing accounts tell that history against a background of immutable laws of nature. We argue that there is more reason to read that history as including the evolution of the laws themselves. History then subjects the laws as well as everything else to the effects of time.

If time is inclusively real in cosmology, which has the whole universe for its subject matter, it must be inclusively real in every department of science and in every piece of nature.

The third idea is the selective realism of mathematics. (We use realism here in the sense of relation to the one real natural world, in opposition to what is often described as mathematical Platonism: a belief in the real existence, apart from nature, of mathematical entities.) Now dominant conceptions of what the most basic natural science is and can become have been formed in the context of beliefs about mathematics and of its relation to both science and nature. The laws of nature, which it has been the supreme object of science to discern, are supposed to be written in the language of mathematics.

We cannot give an adequate account of the singular existence of the universe and of the inclusive reality of time without developing and vindicating a certain view of mathematics. Mathematics has two subject matters: nature (viewed in its most general aspects) and itself. It begins in an exploration of the most general relations in the world, abstracted from time and of phenomenal particularity, but it soon escapes the confines of our perceptual experience. It invents new concepts and new ways of connecting them, inspired by its previous ideas as well as by the riddles of natural science.

Our mathematical inventions offer us no shortcut to timeless truth either about nature or about some special realm of mathematical objects outside nature. They have no prophetic role, notwithstanding the vast power and prestige of mathematics. They may or may not be useful. They never replace the work of scientific discovery and of imagination. The effectiveness of mathematics in natural science is reasonable because it is limited and relative.

The singular existence of the universe, the inclusive reality of time, implying the mutability of the laws of nature, and the selective realism of mathematics all have justifications of their own. However, they are more than a collection of separate and loosely related propositions. The more deeply we understand them, and appreciate the reasons for holding them to be true, the more clearly do we come to recognize their many and intimate relations to one another. They represent three sides of the same comprehensive view. They support and refine one another. It is only when we appreciate their connections that we can grasp just how much they require us to break with certain ideas that continue to enjoy wide influence both within and outside science.

* * *

This work deals with foundational problems in basic science. It proposes a reinterpretation of some of the most important discoveries of twentieth-century cosmology and physics, the historical character of the universe first among them. The reinterpretation has consequences for the future agenda of these sciences. It seeks to distinguish what we in fact know – the hard empirical residue of scientific discovery – from the lens of assumptions through which we are accustomed to see the larger significance of these factual findings.

The history of physics and cosmology has been in large part the history of a marriage between two sources of inspiration. One source is our probing of the manifest world, through observation and experiment, conditioned by our success at inventing and deploying equipment that enables us to extend or exceed our powers of perception. The other source is a vision of reality at the center of which there often stands an ontological program: a view of the kinds of things that there ultimately are and of the ways in which they connect. Such were the ontological programs associated with the science of Aristotle, of Newton, and of Einstein.

It will sometimes happen that no fundamental progress can be achieved in science without dissolving this marriage between the empirical residue and the philosophical gloss. Once the marriage is dissolved, it becomes possible to see the discoveries of science with new eyes. It is never possible, however, to do so without changing some of our beliefs about how nature works.

Two large philosophical traditions inform the ideas of this book. They can be placed under two labels: the relational approach to nature and the priority of becoming over being. In this work, we make no attempt to justify them as philosophical conceptions outside the scientific contexts in which we make use of them. The case for them here lies in the insights that they together make possible.

The relational idea is that we should understand time and space as orderings of events or phenomena rather than as entities in themselves. More generally, it is the view that within a network of causal connections, extending outward to a causally connected universe, everything influences everything else through causal links. In understanding the operation of nature, this relational structure matters more than any of its parts. Its parts matter, and exert their effects, by virtue of the role that they perform within the relational network to which they belong.

In the history of physics and of natural philosophy the two chief statements of the relational view have been those formulated by Gottfried Leibniz in the late seventeenth century and by Ernst Mach in the late nineteenth century. A complication of our argument is that neither of these versions of the relational approach is wholly adequate to our purpose. We must therefore develop another version along the way.

A second philosophical inspiration of this book is less easy to associate with a single doctrine, a ready-made description, or a few names. It is the tradition of thought that affirms the primacy of becoming over being, of process over structure, and therefore as well of time over space. It insists on the impermanence of everything that exists. On this view, the rudimentary constituents of nature, described by particle physics, are impermanent. So, too, are the laws of nature, expressed in the language of mathematics, which it has been the chief ambition of modern science to establish.

The present quest for a grand theory of everything – of the fundamental forces and fields in nature – goes forward on the basis of viewing these law-like regularities and elementary constituents as if they were forever. As a result, we argue, it fails fully to appreciate the most important cosmological discovery: that the universe has a history. Cosmology must be a historical science if it is to be a science at all: a historical science first, a structural science only second, not the other way around.

In the history of Western philosophy, the line of thought that affirms the impermanence of structure has spoken in the voices of thinkers as different as Heraclitus, Hegel, Bergson, and Whitehead. Among the philosophical schools of other civilizations, notably of ancient India, it represented the hegemonic metaphysic.

Although it is not a view that has ever enjoyed commanding influence over the physics that Galileo and Newton inaugurated, it plays a major part in the life sciences as well as in the study of society and of human history. The structures investigated by the naturalist, the historian, or the social scientist may be enduring. No one, however, thinks of them as eternal. Moreover, insofar as there are regularities or laws that govern their workings, they evolve together with the phenomena that they govern.

The philosophical ideas that have guided and interpreted the program of modern physics have traditionally regarded this lack of eternal structures and laws in the life sciences and in the study of human affairs as a sign of the derivative or precarious character of those disciplines. The gold standard of scientific inquiry continues to be supplied, in the eyes of this tradition, by a way of thinking that treats impermanence, and thus time itself, as threats to the achievement of our most far-reaching explanatory endeavors.

One of our aims in this book is to show that the idea of the primacy of becoming over being deserves to hold in cosmology a place no less central than the one that it occupies in the supposedly less happy and less basic sciences. If it is entitled to this role in cosmology, which is the science of the whole universe and its history, it must merit it as well in physics, which studies pieces of the universe and moments of its history.

Among the implications of this philosophical conception, and of the idea of the inclusive reality of time, is the thesis that the new can emerge and does emerge during the evolution of the universe. The new is not simply a possible state of affairs, prefigured by eternal laws of nature. It is not simply waiting to fulfill the conditions that, according to such laws, allow it to move from possibility to actuality. The new represents a change in the workings of nature. Such change embraces the regularities – that is to say, the laws – as well as the states of affairs.

The emergence of the new is a repeated event in the history of the universe. It continues, under novel forms and constraints, in our own experience: the appearance of mind and the exercise of our human power to accelerate the production of novelty in the universe. Our science and our mathematics rank among the most notable instances of the exercise of this power.

The relational approach to space, time, and other physical properties and the primacy of becoming over being each solve a problem that the other leaves unsolved. Timeless versions of relational spacetime leave inexplicable basic features of nature such as the choice of laws and of initial conditions. Our best hope of explaining these enigmas is to put the laws of nature under the dominion of time: to hypothesize that they are mutable and that they have become what they are by evolving in real time. On the other hand, the priority of becoming over being has often been affirmed against the backdrop of an absolute rather than a relational view of time. The result may be to substitute a mystical notion for a scientific program by invoking an external force or entity that produces becoming in an otherwise passive universe. Only when we understand becoming from the perspective of relational time can we subject it to a dynamics that is internal to the universe. Only then can we lay it open to explanation by the methods of science.

The development of our three central ideas, in the spirit of these two traditions of thought, defines a position that can be labeled temporal naturalism. This position in turn informs an approach to the central problems and future agenda of cosmology.

* * *

The discourse in which we present our argument invokes, and seeks to reinvent, the vanished genre of natural philosophy.

This book is not an essay in popular science: the presentation of contemporary scientific developments to a broad readership. We hope that it will be accessible to readers who come to it from many different backgrounds, not just to cosmologists and physicists. Nowhere, however, have we deliberately compromised the formulation of the ideas to make them more accessible. The limitations of our arguments are those that are imposed by the limits of our understanding; they do not result from deliberate simplification.

In the absence of an established discourse of natural philosophy, scientists have often used the presentation of ideas to a general educated public as a device by which to address one another with regard to the foundational matters that they cannot readily explore in their technical writings. Here, however, we set our hands to natural philosophy directly, not under the mask of popularization.

The discourse of this book is also to be distinguished from the philosophy of science as that discipline is now ordinarily practiced. The work of the philosophy of science is to argue about the meaning, implications, and assumptions of present or past scientific ideas. It offers a view of part of science, from outside or above it, not an intervention within science that seeks to criticize and redirect it. It forswears revisionist intentions.

The proximate subject matter of the philosophy of science is science. The proximate subject matter of natural philosophy is nature. Unlike the philosophy of science, natural philosophy shares its subject matter with science.

A natural-philosophical argument about the universe and its history is not simply or chiefly an argument about cosmology. It is a cosmological argument. It intervenes, and takes a position, in the cosmological debates with which it deals. It does so on the basis of ideas and considerations both internal to contemporary science and external to it. It tries to describe and to explore a broader range of intellectual options than is represented in the contemporary practice of the fields that it addresses. Its goals are frankly revisionist: to propose and defend a redirection of cosmology that has implications for the path that physics can and should take.

In all these respects, the discourse of this book resembles nothing so much as what was known, up to the middle of the nineteenth century, as natural philosophy. The trouble is that, despite occasional and exceptional efforts by individual scientists and philosophers, natural philosophy has long ceased to exist as a recognized genre. (A major exception to its near-disappearance in the intervening period was the work of Ernst Mach at the turn of the twentieth century, together with the way in which Albert Einstein made use of Mach's ideas. Another exception was the natural-philosophical writing of Mach's contemporary, Henri Poincaré. To this day, biology has benefited from a long line of natural philosophers, many of them active scientists.) The duo of popular science and philosophy of science has usurped the place of natural philosophy.

Here we seek to breathe new life and form into this defunct way of thinking and writing. It is impossible to do justice to the intellectual difficulties and opportunities that we explore without defying the limits of the established technical discourse of cosmology and physics. Neither, however, can we advance the agenda that we set for ourselves without engaging these disciplines on their own terms as well as on terms that remain foreign to them.

The reasons to cross, in both directions, the frontier between science and philosophy, go beyond the practical need to find broader sources of inspiration when confronted with perplexities that established scientific ideas may be insufficient to overcome. These reasons have to do, as well, with an ideal of scientific inquiry and with a conception of the mind.

Science is corrupted when it abandons the discipline of empirical validation or disconfirmation. It is also weakened when it mistakes its assumptions for facts and its ready-made philosophy for the way things are. The dialectic between openness to the promptings of experience and openness to the surprises of the imagination is the vital requirement of its progress. When "normal science" begins to take on some of the characteristics of "revolutionary science" – the science of "paradigm change" – what results is a higher, more powerful practice of scientific work. Natural philosophy can be an ally of science in this effort to raise the sights and to enhance the powers of scientific thinking.

It is an effort that can succeed because the mind is what it is. We can always see and discover more than any set of methods and presuppositions, in any discipline, can prospectively. Vision exceeds method, and reshapes practice and discourse, according to its needs.

Natural philosophy, however, cannot be at the beginning of the twenty-first century what it was at the beginning of the nineteenth. It must turn into something else. Rather than providing a theory of this something else, we here offer an example of it.

* * *

Each of us presents separately the whole argument of this book, recording, each in his own way, the product of eight years of collaboration and discussion. One of us renders our joint argument as a systematic view in natural philosophy. The other expresses it in a version that, without ceasing to be natural philosophy, comes closer to the debates and theories of cosmology and physics today. He states it in the context of problems and ideas immediately familiar to contemporary cosmologists and physicists. He explores its implications for their present and future work.

The two of us agree about the overall direction and the central claims of the argument. We do not, however, agree about all the matters on which we touch. Some of the differences between us are minor. Others are substantial. Whether small or large, these differences serve as a salutary reminder that there are many ways to develop the same general view. We list and explore these disagreements in a note at the end of this book.

* * *

Our subject of study is the universe and its history. Our negative thesis is that the ways of thinking about the universe and its history that now enjoy the widest influence within cosmology fail adequately to convey the significance of what cosmology has found out about the world. They provide a flawed basis for its future development. Our affirmative thesis is that the intellectual instruments are already at hand to develop another and better way of thinking about these issues. This alternative is incompatible with commonly held views about the plurality of universes, the emergent or illusory nature of time, and the power of mathematics to serve science as its oracle and prophet.

The subject matter could not be more fundamental. Nothing can be properly compared to it other than our study of ourselves. Cosmology is not just one more specialized science. It is the study of the universe as a whole, beyond which, for science, there lies nothing.

All our ideas about parts of nature will be influenced, whether knowingly or not, by our assumptions about the whole universe. Contemporary physics and cosmology have repeatedly inverted this principle: they have tried to apply to the study of the universe and of its history procedures that are useful only when applied to the study of local phenomena. This inversion has led them into some of their gravest mistakes.

The science of cosmology, by which we mean the scientific study of the universe as a whole, cannot be just the physics of local or small phenomena, scaled up to the largest scales, as it usually has been. For reasons that we consider, physics has been the study of subsystems of the universe. This approach is incapable of providing answers to the central questions of cosmology, such as the nature of time and space and the origins or explanations of the laws and initial conditions of the universe. To answer these questions scientifically, with hypotheses open to empirical confirmation or falsification, requires a new approach, based on new principles and enlisting new methods. Our aim is to develop methods and principles adequate to a science of cosmology that is not simply a scaled-up version of contemporary physics. To develop them, we take as points of departure three conceptions: the singular existence of the universe, the inclusive reality of time, and the selective realism of mathematics.