

# Interrelationship between physics and philosophy: a dialogue of science and thought

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## Abstract

This paper examines the deep and enduring relationship between physics and philosophy, a connection that has shaped the trajectory of human inquiry from antiquity to the present. By tracing their shared historical roots, the paper emphasizes how early philosophical speculations laid the groundwork for scientific reasoning. Despite the modern institutional separation of these two disciplines, physics continues to grapple with questions that are fundamentally philosophical in nature, questions concerning the essence of time, space, causality, determinism, and the very nature of reality. The paper explores the epistemological structures that underpin scientific knowledge, such as the criteria for theory confirmation and falsifiability, and investigates the ontological assumptions embedded in classical and modern physics. Special attention is devoted to paradigm shifts in the history of science, including the contributions of figures such as Aristotle, Newton, Popper, and Kuhn, as well as the radical implications of quantum mechanics and general relativity. Through an analysis of contemporary debates, such as those surrounding interpretations of quantum mechanics, the multiverse, and the conceptual validity of string theory, the paper argues that philosophy remains indispensable for critically examining and contextualizing scientific thought. Far from being obsolete, philosophical reflection serves as a compass for navigating the conceptual challenges of physics. Ultimately, the dialogue between philosophy and physics is presented as a dynamic and reciprocal exchange, one that not only enriches both fields but is also necessary for advancing our understanding of the universe.

## 1. Introduction

From the earliest recorded attempts to understand the natural world, philosophy and physics have been deeply intertwined. In the ancient world, there was no firm distinction between theoretical reasoning about nature and what we now call empirical science. The pre-Socratic thinkers, such as Thales of Miletus, Anaximander, and Heraclitus, are often considered the first physicists, not because they conducted experiments in the modern sense, but because they sought rational, non-mythological explanations for natural phenomena.

Thales, for example, proposed that water was the fundamental substance (*archē*) of all matter, a claim that cannot be tested by experiment but is remarkable for its abstraction and logical coherence [1]. Heraclitus introduced the concept of *logos*, the rational principle underlying change. His famous statement that “everything flows” (*panta rhei*) signaled an early attempt to explain transformation and continuity in nature. These thinkers laid the foundation for natural philosophy, the intellectual precursor of physics, by applying reason.

Over time, this observational/theoretical inquiry evolved into a discipline that became increasingly mathematical, especially during the Scientific Revolution. The works of Galileo and Newton marked the transition to a new paradigm in which the language of mathematics became essential for expressing the laws of nature. By the 19th and 20th centuries, physics had developed into a highly formalized and empirically rigorous science, seemingly distancing itself significantly from its philosophical origins.

Nevertheless, fundamental questions about the nature of space and time, causal structure, and the ontological status of reality continue to occupy a central place in both physics and metaphysics. For example, Einstein’s theory of relativity did not merely revise Newtonian mechanics but challenged fundamental philosophical notions of simultaneity, reference frames, and the nature of time itself [2]. Similarly, quantum mechanics raises profound questions about determinism, observation, and the role of the observer, problems that remain unresolved within purely scientific frameworks and demand philosophical interpretation.

This paper seeks to explore and highlight the essential dialogue between physics and philosophy, arguing that their mutual influence is not only historical but continuous. Far from being relegated to the background, philosophy remains vital for clarifying and critiquing the assumptions, implications, and conceptual limitations of physical theories. To this end, the discussion is organized into four dimensions: (1) historical foundations, (2) epistemological questions, (3) ontological questions, and (4) the contemporary interface, including ongoing debates in quantum theory, cosmology, and the philosophy of science.

## 2. Historical Foundations: Philosophers as the First Physicists

In ancient Greece, the domains of science and philosophy were deeply intertwined, without a clear boundary separating empirical investigation from metaphysical speculation. Early thinkers, later called *physiologoi* or “natural philosophers,” sought to understand the cosmos through rational, often abstract reasoning rather than empirical experimentation.

Pythagoras (c. 570–495 BCE), for instance, believed that numbers were not merely tools for quantification but the fundamental essence of all things. According to his doctrine, “all is number,” a metaphysical claim that implied that the structure of reality was inherently mathematical [1]. His followers, the Pythagoreans, viewed mathematical relations as the foundation of harmony in nature, influencing both philosophy and the early development of acoustics and astronomy.

Plato (c. 428–348 BCE), a student of Socrates, expanded this idealistic framework by proposing a dualistic ontology in which the empirical world was a shadow of the eternal, unchanging realm of Forms or Ideas. In dialogues such as *The Republic* and *Timaeus*, Plato argued that knowledge derived from sensory experience was inferior to that gained through reason and contemplation of these perfect Forms. His cosmology in *Timaeus* presented a model of the universe based on geometric symmetry and eternal truths, a fusion of metaphysics and proto-science that significantly shaped Western epistemology and natural philosophy [3].

Aristotle (384–322 BCE), Plato’s most famous student, diverged from his teacher by emphasizing empirical observation and categorization. In his seminal treatise *Physics*, Aristotle laid the foundations for systematic investigation of nature. He proposed that all change involves the actualization of potentiality and categorized causality into four types: material, formal, efficient, and final causes. This teleological model framed natural phenomena as processes guided by purpose, a perspective that dominated scientific thought until the early modern period [4]. Aristotle also introduced fundamental concepts such as substance, motion, and the nature of time, many of which remain central to metaphysical debates today.

During the Middle Ages, philosophy and science were deeply embedded within theological frameworks, but the intellectual legacy of ancient Greece was preserved and synthesized, particularly within scholasticism. One of the most prominent figures of this period was Thomas Aquinas (1225–1274), a follower and interpreter of Aristotle’s achievements, who sought to reconcile Aristotelian cosmology with Christian doctrine. In his magnum opus *Summa Theologica*, Aquinas integrated Aristotle’s conception of motion, causality, and the structure of the cosmos with Christian metaphysics, presenting God as the unmoved mover and ultimate cause of all creation [5]. This synthesis provided a coherent worldview that dominated medieval thought and laid the intellectual foundations for the eventual rise of modern science.

The Renaissance and early modern period, however, introduced a paradigm shift. The authority of classical texts began to decline in favor of empirical observation and mathematical reasoning. Galileo Galilei (1564–1642) was a central figure in this transformation. Although celebrated for his telescopic discoveries and formulation of the law of inertia, Galileo also engaged deeply with philosophical questions. In works such as *Dialogue Concerning the Two Chief World Systems* and *The Assayer*, he emphasized the primacy of mathematics in describing nature, arguing that “the book of nature is written in the language of mathematics” [6]. He also advocated for the separation of physical inquiry from theological dogma, marking an important step toward the autonomy of science.

Isaac Newton (1643–1727) built upon this development and brought the Scientific Revolution to its peak with his groundbreaking work *Philosophiæ Naturalis Principia Mathematica* (1687). Newtonian physics offered a unified and mechanistic view of the universe in which all motion could be explained through a set of mathematical laws. Most importantly, Newton posited the existence of absolute space and absolute time, concepts not empirically derived but based on a philosophical framework of objectivity and universality [7]. While his mechanics dominated scientific thought for more than two centuries, Newton’s metaphysical assumptions were later challenged by Einstein’s theory of relativity, which replaced absolutes with relational and observer-dependent concepts.

The shift from scholasticism to empiricism, and from Aristotelian teleology to Newtonian mechanics, did not eliminate the philosophical foundations of science. On the contrary, it transformed them. These foundational thinkers illustrate how the philosophical and theological roots of early modern science were not discarded but reinterpreted through new methods and explanatory models.

### 3. Epistemology of Science: How Do We Know What We Know?

Philosophy remains indispensable in examining the foundations and limits of scientific knowledge. It provides conceptual tools for understanding what science is, how it progresses, and what it can legitimately claim to know. Central to this epistemological inquiry is the question of how scientific theories are confirmed.

In the 20th century, Karl Popper revolutionized the philosophy of science by introducing the criterion of falsifiability as the demarcation line between science and non-science. According to Popper, a theory can never be definitively verified; it can only be subjected to rigorous attempts at falsification. If a theory makes bold predictions that survive repeated empirical testing, it gains temporary acceptance but remains open to revision or rejection in light of new evidence [8]. This framework not only rejected the positivist idea of cumulative scientific progress but also emphasized the inherently provisional and self-correcting nature of science. In this way, Popper introduced a methodological shift in how science and scientific theories were approached, away from categorical acceptance of truth claims and toward a dialectical, relativized understanding of knowledge, dependent on the emergence of new discoveries.

Building on and challenging Popper's ideas, Thomas Kuhn offered a more nuanced and historically grounded perspective in his landmark work *The Structure of Scientific Revolutions*. Kuhn argued that science does not progress through the linear accumulation of facts, but rather through paradigm shifts, periods of revolutionary change in which one theoretical framework is replaced by another that is incommensurable with it. During periods of "normal science," researchers operate within a shared paradigm, solving puzzles and refining theories. However, the accumulation of anomalies eventually leads to crisis, followed by the adoption of a new paradigm that redefines the fundamental assumptions of the discipline [9].

This process reveals that science is not purely objective but also shaped by sociological and psychological influences, collective beliefs, and consensus. Kuhn's perspective broke the prevailing myth of science as a steady accumulation of truths, instead portraying it as a historically contingent enterprise full of detours and competing research traditions, not always driven by purely scientific reasons.

These epistemological frameworks were particularly challenged by the advent of quantum mechanics, which undermined many classical assumptions about the nature of reality and the process of measurement. In the quantum world, phenomena such as wavefunction collapse, Heisenberg's uncertainty principle, and quantum entanglement introduced inherent indeterminacy into the behavior of particles.

The wavefunction, a probabilistic description of a system, appears to "collapse" into a definite state only upon measurement, a process that remains philosophically controversial and experimentally elusive. The Copenhagen interpretation, defended by Niels Bohr and Werner Heisenberg, claimed that quantum mechanics does not describe objective reality itself but rather our knowledge of it. From this view, the observer is not a detached spectator but an integral part of reality [10]. This perspective challenged the classical ideal of the neutral, external observer and leaned toward epistemic instrumentalism.

In contrast, Hugh Everett's many-worlds interpretation offered a radically different perspective. Instead of collapse, Everett proposed that all possible outcomes of a quantum measurement actually occur, each in a separate, non-communicating branch of the universe. This theory preserves determinism at the cost of positing an infinite number of parallel worlds [11]. The implications are profoundly philosophical, raising questions about identity, causality, and the nature of existence itself.

These debates illustrate the necessity of philosophy in interpreting scientific theories that go beyond our intuitive grasp of reality. Without philosophical engagement, the fundamental questions raised by quantum physics would remain either unanswered or naively framed through outdated classical assumptions. In this case, philosophy serves as meta-reflection, a layer of critical examination above the strictly physical considerations of physics.

Quantum physics not only revolutionized physical theory but also posed deep epistemological and metaphysical challenges that remain unresolved today. At its core, quantum mechanics introduced a fundamental shift in how knowledge of nature is constructed and what can be known at all. One of the most controversial aspects is wavefunction collapse, the idea that a quantum system exists in a superposition of states until it is observed, at which point it "collapses" into a single definite outcome. This notion implies that measurement is not a passive act of observation but an active process that determines physical reality itself. Such a view undermines the classical ideal of objectivity, where systems are assumed to possess definite properties independent of observation.

Heisenberg's uncertainty principle further destabilized classical epistemology by imposing fundamental limits on what can be simultaneously known about a particle's position and momentum. Rather than attributing this to technical limitations in measurement, Heisenberg argued that uncertainty is an inherent feature of nature itself, implying that the act of measuring one quantity inevitably disturbs the other in a quantifiable way [10]. This principle has been interpreted not only as a statement about observational limits but also as a profound metaphysical claim about the indeterminacy built into the universe.

Perhaps even more philosophically puzzling is the phenomenon of quantum entanglement, in which particles that have interacted become correlated in such a way that the state of one instantly affects the state of the other, regardless of distance. Einstein famously referred to this as "spooky action at a distance," expressing skepticism about non-locality. Yet experimental confirmation of entanglement has forced a reconsideration of the classical notion of separability, the idea that distant objects should have independent existences.

These phenomena demand philosophical interpretation, as quantum mechanics itself does not offer a single, unambiguous picture of reality. The Copenhagen interpretation maintains that quantum mechanics is a theory of knowledge rather than reality itself, claiming that properties such as position or momentum do not meaningfully exist until they are observed. In contrast, Everett's many-worlds interpretation asserts that all possible outcomes are realized in a branching multiverse. While this interpretation preserves the mathematical formalism of quantum theory without invoking collapse, it raises unsettling ontological questions: What constitutes identity across different branches? Do these parallel worlds really exist, and if so, how can their reality be justified?

These interpretations demonstrate the extent to which modern physics requires metaphysical engagement. Quantum theory not only describes phenomena but compels scientists and philosophers alike to reconsider the very nature of existence, causality, and observation. Thus, philosophy is not an auxiliary discipline to quantum mechanics but an integral part of its interpretation and understanding.

#### **4. Ontology of Physics: What is Reality?**

Beyond questions of knowledge, physics must also grapple with what truly exists. Classical physics assumed a realist ontology, that objects possess properties independent of observation. Quantum mechanics, however, calls this into question. According to the Copenhagen interpretation, properties do not exist in definite states until they are measured [12]. Everett's interpretation, by contrast, proposes that all possible outcomes of quantum events are realized in separate branches of the multiverse [11].

Some physicists, such as David Bohm, have proposed hidden variable theories in an effort to restore determinism, although these come with their own philosophical challenges, particularly concerning non-locality. Such debates underscore the indispensability of philosophical engagement in making sense of scientific theories [10].

Broadly speaking, ontological problems in the philosophy of science concern the possibility and manner of existence of scientific objects. In this regard, physics offers the clearest example of an "empirical" science around which sharp divisions have emerged among philosophers of science—between realists and nominalists.

Realists argue that physical objects exist independently of whether they can be observed or known, while nominalists maintain that speaking of the existence of objects of empirical science is meaningful only in relation to the consciousness and activities of the subject attempting to know them. This divide remains alive today within the philosophy of science and can also be observed in fields beyond the empirical sciences, for example, in mathematics [13, 14].

#### **5. Contemporary Dialogue: Philosophy and Physics Today**

In today's scientific landscape, the relationship between physics and philosophy remains both contentious and vital. The renowned physicist Stephen Hawking famously declared that "philosophy is dead," arguing that it had failed to keep up with the advances of science, particularly in fields such as cosmology and fundamental physics [15]. This statement reflects a broader sentiment among some scientists who view philosophy as speculative or outdated compared to empirical data and mathematical formalism.

However, this perspective is far from unanimous. A growing number of physicists and philosophers emphasize the continuing importance of philosophical reflection in contemporary science. Carlo Rovelli, a leading researcher in quantum gravity, insists that science is deeply philosophical in its nature, especially when confronting fundamental questions such as the nature of time, the ontology of spacetime, and the limits of knowledge [16]. Similarly, Sean

Carroll argues that debates in cosmology, such as the interpretation of the Big Bang, the fine-tuning of universal constants, and the nature of the multiverse, are inherently reliant on philosophical reasoning [17].

Jim Baggott, a science writer and philosopher, criticizes theories that stray too far from empirical verification, such as certain versions of string theory, as “fairy-tale physics,” emphasizing the need for philosophical rigor in defining what qualifies as science [18].

New fields such as artificial intelligence, information theory, and quantum computing further demonstrate that philosophical inquiry is not optional but necessary. Questions about the nature of consciousness, the definition of intelligence, or the epistemological role of data interpretation in machine learning require a strong philosophical foundation.

Moreover, many speculative but mathematically consistent physical theories, such as string theory, loop quantum gravity, or holographic dualities, remain empirically inaccessible. In such contexts, philosophy plays a vital role in guiding theoretical development, assessing conceptual coherence, and distinguishing science from metaphysics.

## 6. Conclusion

The historical interaction between physics and philosophy is not merely a matter of academic curiosity but a lasting and evolving relationship that continues to shape our understanding of reality. As science advances into ever more abstract and complex domains, the need for philosophical reflection becomes increasingly acute. Philosophy helps to clarify fundamental concepts such as causality, existence, identity, and the nature of space and time—concepts that underpin physical models but often elude purely empirical investigation.

Conversely, physics provides philosophy with empirical grounding and methodological discipline. The empirical success of scientific theories imposes constraints on philosophical speculation, keeping it tied to the observable world. This synergy ensures that neither discipline functions in isolation: philosophy without science risks degenerating into detached idealism, while science without philosophy risks lapsing into uncritical instrumentalism.

Ultimately, both fields share a common goal—the pursuit of truth and the desire to comprehend the universe in its totality. Whether in interpreting quantum mechanics, exploring the origins of the cosmos, or probing the limits of knowledge, physics and philosophy remain complementary endeavors. Embracing this dialogue not only enriches both disciplines but also advances the

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