Modern Physics and Scientism: Changing Relations*

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Abstract

Successes of classical physics in the 19th century seemed to give decisive support to the positivist philosophy and its derivatives, e.g. in the form of «scientific» materialism or scientism. Deterministic character and causality implicit in the Newtonian mechanics, emphasis on matter and its transformations, together with the successful application of the reductionist method seemed to announce unlimited powers of reason, which would, applying the «scientific method», eliminate the need for and the possibility of any other approach to reality, and particularly all metaphysics.

However, modern science at the beginning of 20th century soon started shaking the basic assumptions of this ideological construction. Quantum mechanics and relativity questioned the idea of determinism, locality, local causality, role of the observer and even the realism of our theories. Matter seemed to lose its unchanging character, and the extension of reductionism from the method to the general ideology was shown to be dubious. Arrogant announcements of the final theory («Theory of Everything») suffered a mortal blow from Godel and his theorem, though it could have been anticipated even from the analysis of the character of scientific theories. Finally, extension of research from linear to nonlinear systems opened a whole new field of complex phenomena where emergent properties appear and characterize the behaviour of higher level system, thus making the reductionist programme impossible.

Many people today – including scientists - are still unaware of these results of modern physics, and thus possibly subject to certain philosophical and ideological prejudices.

Keywords: classical physics, determinism, scientism, fideism, quantum mechanics, relativity, causality, (non)locality, reductionism, complexity, realism

Introduction

Recent virulent and highly publicized scientistic attacks on religion and other aspects of spirituality (see e.g Dawkins 2006. It is interesting indeed to notice that religion is blamed as the cause of all possible crimes after the century in which more that one hundred million people were killed in the name of atheist ideologies!) coming from the biological circles remind one of another period in the history of science-religion turbulent relations, the one connected with the development of physical sciences. As Polkinghorne (1999) noted: "The contemporary biological scene is reminiscent of the state of physics in the post-Newtonian generation of the mid-eighteenth century. Both subjects scored notable initial successes (…). Both insights were of a mechanical nature … Both sets of adherents then went on to declare that their new discoveries supplied the basis for understanding practically everything (...). Physics has discovered that the world is more subtle and interesting than its eighteenth-century practitioners had supposed to be. It is difficult not to believe that biology will make a similar discovery in due time."

There are indeed significant analogies between the euphoria that dominated in physical sciences a century ago (though it still exists in some segments of the academic community)

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and the present situation in life sciences. In both cases impressive scientific results were – and are – extrapolated and used to justify certain philosophical theories – positivism, "scientific" materialism, etc. It should be added that this tendency gave similar "scientific justification" to the main totalitarian ideologies of the 20th century, communism and nazi-fascism.

Though the discussion is far from concluded, one could say that the results of modern science, its epistemological, philosophical and sociological analysis, as well as the simple insight into the real life and practice of a scientist indicate that Polkinghorne was right, at least in the realm of physical sciences. There the self-confidence of simplistic scientism was shaken by the revolutionary results of quantum mechanics and relativity theory, and more recently by the studies of complex non-linear systems. At least, the monotony of the positivist mantra was replaced by a more open discussion of the subtleties of the physical reality, allowing different views on these extremely complex issues.

In this paper I want to draw attention to some of the ideas that were used to support the scientistic or positivistic attitudes and to their evolution in recent times. One such group of concepts concerns *causality - (in)determinism – (non)locality*, and the other is related to *reductionism – emergence – complexity*, to which one could add the concept of (indestructible) *matter*. Also, critical discussion of the limitations of the *"scientific method"* and *scientific practice* should be included in this context. Though this analysis is neither original nor new nor complete, I believe that it could serve as a necessary reminder in view of all the misunderstandings and (pseudo)conflicts in the science-religion relations that we register every day. (A recent lively debate following an article (Davies, 2007) illustrates very well this statement.)

<u>Causality- (in)determinism – (non)locality</u>

Determinism and reductionism, as well as the unwavering belief in the "scientific method" were the key elements of the positivist approach to reality.

Determinism is commonly understood as a claim that the laws that govern the universe or its parts, together with the appropriate initial conditions, uniquely determine the behaviour of the universe (or its parts). This claim is based on the assumptions that these "laws" exist and are deterministic, that we can discover them, and finally that we can in practice apply them successfully.

Newton's classical mechanics with its deterministic equations gave strong support to such aspirations. As Laplace stated, if we knew the forces acting on material particles, their initial positions and velocities, we could in principle calculate their positions and velocities at any instant in the past and future, and thus model the evolution of the universe. Of course, there remain technical difficulties – knowing the initial conditions and performing the calculations, but the philosophical principle was here, leading to the belief in the infinite power of reason.

Indeterminism, as the negation of determinism, presented itself already in classical physics, where statistical mechanics had to give up complete description of individual particles in a many body system and to accept "statistical" indeterminism, though appearing only on the macroscopic level.

Quantum physics introduced much more basic source of uncertainty – not only related to the practical impossibility to determine the values e.g. of all initial conditions, but as a matter of principle. The analysis of measurements in the microscopic world showed (See e.g. (Bohr 1961), or (Heisenberg 1977). Standard text is (Jammer 1974).) that it is theoretically impossible to perform precise measurements of "incompatible" physical observables, as was formulated in the Heisenberg's uncertainty relations. This can be connected with the dual nature of matter, possessing both wave-like and particle-like properties, which in turn require the physical theory to become non-local. This non-locality was the main argument used by Einstein (in the form of the so-called EPR paradox) in his unsuccessful opposition to the quantum theory, not as a tool to produce useful results but as a valid description of physical reality. This reopened the old and eternal dispute about various aspects of realism in science.

All these developments created conceptual problems not only to physicists who in order to continue their research had to develop a new epistemology, new understanding of the relation between scientific theories and reality. (The classic texts are (Popper 1972), (Kuhn, Thomas S. 1962), (Lakatos 1962) and (Feyerabend 1975). A very interesting analysis that includes the experience of a practising scientist is presented in (Ziman 1974) and (Ziman 2000).) This process is still going on among some physicists, but also among some philosophers who realized that some of their basic assumptions were gradually dissolving.

The third source of indeterminism became more obvious recently, with the development of powerful computing facilities that could handle non-linear mathematical problems. (Classical physics, for obvious reasons, dealt mostly with linear systems, which are not only easier to solve, but also are more stable with respect to the initial conditions.) In this situation even deterministic laws of classical mechanics lead to "non-statistical uncertainties", in the form of the so-called deterministic chaos.

Another philosophers' pet concept, the idea of eternal and indestructible matter as the (only) basic and relevant substance also disappeared, together with the concepts of absolute time and space. The first shock came when Einstein noted that his special relativity implied that mass and energy were equivalent and could transform into each other. This had tremendous implications for physical sciences and (possibly even more) for their technological applications. Physicists gradually found a way to accept these new ideas, but for materialist philosophers it was more difficult to digest them, as well as further surprising developments: particle – wave duality, and more recently the complete departure of physical theories (or hypotheses?) from the common sense, e.g. in the basic ideas of the string theory. (For a relatively simple overview of the string theory see (Chalmers 2007:35).)

Types of reductionism

So-called strong reductionism presents the basis and justification of all scientistic programmes, including recent attacks on religion and all spirituality coming from some biologists, so it deserves special attention in this discussion..

Before analyzing various types of reductionism we should introduce the idea of a hierarchy or levels of complexity of systems. One possible ordering, but certainly not the only one, is e.g. related to their structure: quark, nucleus, atom, molecule, cell, organ, organism, and ecosystem. This hierarchy can also be mirrored in the hierarchy of scientific disciplines dealing with them, e.g. physics, chemistry, biology, psychology, sociology, etc.

It is essential to distinguish between different types of reductionism. The "weakest" form is the <u>methodological or constituent reductionism</u> where one divides a complex system into smaller subsystems in order to study and better understand the system. This type of reductionism was extremely successful in scientific research. However, it does not imply that the system is "nothing but" the collection of its constituent parts.

The second type is the <u>epistemological or conceptual reductionism</u>, which goes one step further and claims that the properties of higher level systems can be derived from the laws at the lower levels. This *constructivist* claim has recently been disputed, and it has been shown that in many cases new *emergent* phenomena appear at the higher levels which cannot be derived simply from the underlying laws.

The third and strongest type is the ontological or causal reductionism concerning the kinds of reality and of causality acting in the world. In a simplified way one could describe it as a claim that a higher-level entity is "nothing but" the collection of its parts, organized according to the same physical laws, and thus all the way to the smallest constituents, say, elementary particles. This implies that the reality is attributed ("ontologically reduced") only to the lowest level, contrary to the ideas of ontological *pluralism*, which attributes reality to each level of complexity.

As a method in scientific research, i.e. in its weakest form, reductionism contributed significantly to its successes. As a well known physicist and a Nobel prize winner P.W. Anderson put it in his seminal paper (Anderson 1972): "/The/ workings of all the animate and inanimate matter of which we have any detailed knowledge are … controlled by the same set of fundamental laws /of physics/… We must all start with reductionism which I fully accept."

Another Nobel laureate Steven Weinberg, who is a strong reductionist, has a more radical view: "All of the nature is the way it is … because of simple universal laws, … Every field of science operates by formulating … generalizations that are sometimes dignified by being called principles or laws. But there are no principles of … chemistry that simply stand on their own, without needing to be explained reductively from the properties of electrons and atomic nuclei, and … there are no principles of psychology that … do not need to be understood through the study of human brain, which in turn must ultimately be understood on the basis of physics and chemistry." (Weinberg 1995, quoted in Weinberg 2001) Or, in the words of another great scientist Albert Einstein who was quoted (in Gross 2005) as saying: " The supreme test of the physicist is to arrive at those universal laws of nature from which the cosmos can be built up by pure deduction."

From this one might conclude that reductionism in its strong version is still accepted among scientists, or at least among the leading physicists. But this would be far from true – Anderson (1972) in fact wrote his important paper entitled "More is different" (Anderson 1972) in order to refute such ideas. He strongly opposed the claim that "the ability to reduce everything to simple fundamental laws … implies the ability to start from those laws and reconstruct the universe… At each level of complexity new properties appear…Psychology is not applied biology, nor is biology applied chemistry… /T/he whole becomes … very different from the sum of its parts." In other words, Anderson refutes the *constructivist hypothesis*, i.e. "the ability to start from those laws and reconstruct the universe" and emphasizes what was soon to become an important issue, namely the emergence of new properties of the systems with higher level of complexity.

Reductionism, emergence and complexity

The idea of emergence and emergent properties is certainly not new nor restricted to physical sciences discussed here, but here I shall emphasize recent contributions by eminent physicists, arising not from philosophical considerations but from their own practical experience in scientific research. As Anderson commented: "Scientists are not particularly able philosophers, as the case of Bohr demonstrates, but at least they are in touch with reality at first hand, and their insights into the matter have profoundly changed our understanding of how we make discoveries."/11/

After Anderson's seminal paper in 1972 another very important contribution came from two eminent solid state theorists, Laughlin and Pines (LP) entitled "The Theory of Everything" Laughlin 2000) followed by a number of papers elaborating and extending their ideas. The paper deserves more careful consideration, but here I shall attempt to describe only the main ideas.

LP first refute the Theory of Everything as “the ultimate theory of the universe – a set of equations capable of describing all phenomena that have been observed, or that will ever be observed.” This would be nothing new – Theory of Everything (or equivalently “The End of Science “, as in (Horgan 1997)) has been announced, predicted and given up so many times before (see e.g. how another great physicist Stephen Hawking (2002) also changed his mind recently, probably after he realized the consequences of the Godel’s theorem for physics), but LP base their case on their detailed studies of many-body phenomena in physics, which can serve as a relevant model and testing ground for such meta-scientific theories. (Another useful and popular model are various computer games, e.g. the Game of Life (Abbott 2006).)

LP start from the “exact” (nonrelativistic) description of an N-body system with Coulomb interactions, their Theory of Everything at the lowest level (electrons and nuclei). This is already a very simplified model, which neglects all nuclear and subnuclear phenomena, but it contains many useful elements and can serve as a well-defined model of a many-body system. However, LP show how quickly, say, already for N greater that 10, (even) this description becomes (exact but) irrelevant, i.e. impossible to implement in the study of more complex systems, even small molecules. As a scientist progresses to higher levels, trying to explain e.g. electronic properties of solids or structural phase transitions etc., he needs “the schemes for approximating” which “are not first-principles deductions but are rather keyed to experiment…”. They analyze several experiments e.g. measuring fundamental physical constants, involving large number of electrons, and conclude that their interpretation, though true, “cannot be deduced by direct calculation from the Theory of Everything, for exact results cannot be predicted by approximate calculations. This point is still not understood by many professional physicists, who find it easier to believe that a deductive link exists and has only to be discovered than to face the truth that there is no link.” They continue – and this becomes a crucial step: “Experiments of this kind work because there are higher organizing principles in nature that make them work. The Josephson quantum is exact because of the principle of continuous symmetry breaking ( ). The quantum Hall effect is exact because of localization (…). Neither of these things can be deduced from microscopics, and both are transcendent, in that they would continue to be true even if the Theory of Everything were changed. Thus the existence of these effects is profoundly important, for it shows us that for at least some fundamental things in nature the Theory of Everything is irrelevant. P.W: Anderson's famous and apt description of this state of affairs is "more is different"".

LP call these states of matter whose properties are determined only by the higher organizing principle *quantum protectorates*, characterized by the emergent physical phenomena. They illustrate this concept on a number of examples from solid state physics – from the Landau liquid to superconductivity, ferromagnetism, quantum Hall states, etc., providing very convincing arguments for somebody who is familiar with the many body physics, though in places it becomes too technical for a general reader. (This is also an indication of scientific illiteracy in the contemporary academic community!)

LP extend their analysis to the higher energy phenomena which include the structure of the universe, where one observes qualitatively equivalent phenomena, but they also show that emergent behaviour, protection and self organization are not restricted to the quantum world, quoting examples of classical protectorates, like the phase transitions in classical systems. This they take as an indication that these ideas may be applied in biological systems.

LP conclude by dismissing the thesis of “The End of Science”, claiming instead that we have reached the End of Reductionism, because “in most respects the reductionist ideal has reached its limits as a guiding principle. Rather than a Theory of Everything we appear to face a hierarchy of Theories of Things, each emerging from its parent and evolving into its children as the energy scale is lowered. The end of reductionism is, however, not the end of science, or even the end of theoretical physics." Instead, they announce "a transition from the science of the past, so intimately linked to reductionism, to the study of complex adaptive matter, …"

I have quoted extensively from this seminal paper not only because it is closely linked to the field where I did most of my research. I find it very important because it reflects accurately the accumulated experience and opinions of several eminent practising scientists, many of whom are even atheists, and could be expected to support the scientistic attitudes. Unfortunately, this direct unbiased experience of practising scientists, as e.g analysed in (Ziman 1972) and Ziman 2000), is often ignored in the discussions about science. The fact that their thesis is somewhat "unorthodox" makes their contribution even more valuable, especially as it transforms the problem into a discussion of well-defined results of scientific research.

In conclusion, we see that modern physics has radically modified some of the key concepts underlying scientistic claims and thus invalidated their often-intolerant ideological extensions. One could expect that in life sciences a similar process of rethinking and consolidation will take place. However, as emphasized in the beginning, many prejudices about science and its message are still present, leading to ideological obfuscations and conflicts in the science-religion domain. One notices that non-scientists, particularly philosophers and theologians, tend to be unduly impressed by some pronouncements "in the name of science", even when they are not justified. Better understanding of the character and results (and limitations, as discussed in this paper!) of science and "scientific method", would certainly improve the chances for a fruitful interdisciplinary dialogue.

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