MODERN PHYSICS AND TRANSDISCIPLINARITY*

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Abstract

Great advances of classical physics in the 19th century, with its deterministic character, seemed to announce the triumph of the «scientific method», which promised to solve all important questions regarding nature and humanity, thus arrogantly claiming all other human achievements, including arts and humanities, and especially religion to be irrelevant. This gave support to materialist and positivist tendencies in philosophy, as well as to extreme scientism.

However, several surprising developments in the 20th century, including quantum physics and relativity, soon revolutionized physics. With their intrinsic nonlocality and indeterminism, they changed not only the preconceived ideas about the scientific research, but also modified its conceptual framework. Many of the previously accepted dogmas were reconsidered, like the (inductive) «scientific method», creation of hypotheses and their verification, subject-object interference, realism of physical theories, the use of ordinary language in science, reductionist programme had to be extended to include complexity and emergence, etc. Suddenly the arrogance of the 19th century science disappeared, the limitations of scientific research became obvious, and (some) physicists realized that other modes of acquiring knowledge were acceptable and even necessary, including humanities, philosophy, but also religious experience in many forms, and especially ethics in research and its technological applications.

I discuss these developments in modern physics that opened the way to transdisciplinarity, but also the problems in establishing this dialogue that arise from the present specialization and fragmentation of science.

I could borrow the motto of my talk from the deed of gift of the Dwight Harrington Terry Foundation Lectures on Religion in the Light of Science and Philosophy /1/: “The object of this foundation is not the promotion of scientific investigation and discovery, but rather the assimilation and interpretation of that which has been or shall be hereafter discovered, and its application to human welfare, especially by the building of the truths of science and philosophy into the structure of a broadened and purified religion.”

This agrees with my opinion, as a practising scientist, that many results of modern science – already obtained and confirmed – have been either neglected, or misinterpreted, or misused, or simply ignored in the discussion of more general topics, as is the one of science-religion relations. Many prejudices inherited from the 19^{th} century mechanistic age of science, as well as their philosophical extrapolations, remain, to the surprise of many scientists who do not follow closely the ongoing philosophical and ideological controversies. To this one can add the blind belief in the “scientific method”.

One of the reasons for this situation is the isolated position (i.e. ignorance) of science in the society, partly due to its enormous complexity. The other is the specialization and fragmentation of the scientific community itself, including the proverbial “two cultures” syndrome /2/, with the resulting lack of communication and understanding.

In this talk I want to contribute to the clarification of some of these misunderstandings related to the field of modern physics. This is important because the terms like determinism, causality, realism vs. idealism (and vs. critical realism), reductionism, holism, relativism, (non)locality, etc., often change their meaning and range of applicability on the way between physics on one side – where they supposedly acquire scientific approval and credibility, and philosophy and theology on the other, which might (and does) often lead to confusion.

Possible science – religion relations

Before discussing in more detail the science-religion relationship we should remember their possible positions, e.g. according to the classification suggested by Barbour /3/: *conflict – independence – dialogue – integration*, or by Haught /4/: *conflict – contrast – contact – confirmation*.

The first or *conflict* position, usually formulated in one of its extreme forms of scientism or fideism, obviously eliminates every possibility of a dialogue, claiming absolute truth and relevance either to the "scientific" or to the "revealed" approach to reality, and thus excluding everything else. The dominant "creed" in the 20th century was scientism, so I shall focus mainly on its defects, especially as it had disastrous philosophical and political extensions in the form of "scientific materialism" and as a justification for the totalitarian ideologies of nazism, communism and fascism. Furthermore, it still shows signs of virulent intolerance /5/. On the other side, fideism in its various forms was much less influential, though recently it reappeared in the (less radical) form of "intelligent design" theory /6/.

The second or *independence/contrast* position, formulated by Gould /7/ as NOMA ("Nonoverlapping magisteria"), tries to avoid the conflict between science and religion by separating completely their domains of relevance and validity. While it is indeed necessary to understand and appreciate the specific character of each of these human activities, the differences in their methodologies, their strengths and limitations, nevertheless any serious analysis would show that the complete separation is impossible. As pope John Paul II emphasized in his encyclical letter "Fides et ratio", faith and reason are inextricably connected and complementary, and one is impossible without the other, as every scientist feels when sincerely and honestly analysing the experiences in scientific research /8/.

However, it is also obvious that NOMA eliminates any constructive engagement between science and religion, so I shall adopt the third, *dialogue* or *contact* position (though they differ somewhat), which emphasizes compatibility and mutual complementarity of science and religion. (The fourth, *integration* or *confirmation* position is an ambitious extension of the third which would require a special discussion, and which also goes far beyond my scientific background.) In this process I shall not insist on the differences between various scientific disciplines, but restrict myself to physics as a representative of natural sciences.

In fact, the main message of this paper will be to show how the developments in physics in the 20th century weaken or completely destroy the conflict position which is most often formulated as scientism or scientific materialism, with the basic claim that science, by means of the exact "scientific method" can and will resolve all problems and answer all relevant questions. At the same time there are and can be no relevant or meaningful questions outside these. This position is based on several assumptions, which are accepted as dogmas, following e.g the determinism and reductionism of classical science (taken not only in the epistemological but also in the ontological sense!), and on the belief in the absolute power and "exactness" of the "scientific method". All of these assumptions were seriously questioned and modified by the developments in the 20th century.

Determinism

Classical physics achieved great progress with the mechanical deterministic (clockwork) model of the universe, based on the concept of absolute space and time, where the knowledge of initial or boundary conditions at some time would, in principle, enable us to determine the state of the universe at any time in the past or future. (Paradoxically, though this deterministic model is usually connected with Newton, he personally would have been horrified by its philosophical extrapolations!) Together with the successful use of reduction as a method and emphasis on (indestructible!) matter this led to the growing impression that science – starting with physics and chemistry and continuing with more complex systems as in biology – could and will solve all problems, answer all questions, using the "scientific method", reason, etc. As already mentioned, thus formulated scientism had various reflections in philosophy, even in politics and everyday life, from scientific materialism to political and ideological extremes like communism, fascism and nazism. Many of these convictions are still around, not always based on pure academic arguments, in spite of the fact that 20th century brought many developments in science which shattered this classical image of the world.

The loss of realism

Quantum physics revolutionized not only science but also equally our understanding of science, its results and limitations, relationship to reality, etc. Studies of the physical objects of microscopic dimensions showed that one cannot simultaneously determine values of pairs of so-called physical variables, e.g. position and momentum, as a matter of principle and not simply of experimental accuracy, as formulated by the Heisenberg uncertainty relations /9/. Initially this was attributed to the perturbing effect of the observer, but afterwards this methodological (or epistemological) indeterminacy was extended by some (Heisenberg) to ontological indeterminacy. (We should note that even this step was essentially an "act of faith" and had no empirical justification!)

The emotional reaction to this seeming loss of realism by some, including Einstein and Schrodinger, was soon to come, as well as interpretations of quantum mechanics alternative to the standard Bohr's "Copenhagen interpretation" /9/. (Einstein's opposition to quantum physics – to which he himself contributed so much – deserves additional analysis, and gives another illustration of the – partially - subjective character of scientific research!) E.g. in order to save realism in the theory Bohm introduced the concept of so-called hidden variables, or later Everett his "many-worlds" interpretation, which was a pretty high cost of restoring realism in physics.

Essentially, they introduced new assumptions that still lacked empirical support, and due to their character this will remain so. Namely, all these different interpretations in practice lead to the same empirical results, there is no way to prove or disprove any of them. Therefore acceptance of one of these (or some other) interpretations was based on non-scientific arguments, simply as a matter of taste. It turned out that most scientists (if they bother to think of it in their research) prefer the "Copenhagen interpretation", and one might attribute it to its relative simplicity, or conversely, to the convoluted ("unconvincing") nature of the others. I stress here the role of these non-scientific, i.e. non-empirical or subjective factors in scientific research – a topic that is usually not enough appreciated by non-scientists.

The analysis of the measurement process that introduced uncertainty in quantum mechanics produced also another revolution in modern science. When Einstein (and others) showed that the finite speed of light made impossible instantaneous measurements of the positions of the moving objects, the classical concepts of absolute time and space collapsed. It is interesting to note the important role of observer both in the macroscopic domains of classical physics (because special relativity is still a generalization of Newton's mechanics) and in the microscopic world (quantum physics). At the same time another 19th century basic concept suffered. Matter lost its privileged ("indestructible") status when Einstein showed the equivalence of matter and energy, and thus the possibility for matter to "disappear", or "be created", i.e. transform into energy, and vice versa.

Nonlocality

Another attack on realistic and deterministic character of physical theories came with a shocking discovery by Einstein and his collaborators. They formulated the so-called Einstein-Podolsky-Rosen (EPR) paradox that indicated that a direct consequence of quantum physics would be non-local "action at the distance", and tried to use this as an argument against quantum theory (though accepting it as a tool to calculate and predict experimental results!). After many heated discussions the issue was finally settled when the precision measurements (by Aspect, based on the Bell's theorem) confirmed the existence of these non-local phenomena, followed by even more exotic developments, like quantum entanglement and teleportation, quantum cryptography, etc. Quantum physics thus introduced a new element that supports holistic view of reality, in particular with its inherent nonlocality. Due to this possibility (or necessity) of entanglement, particles - even when they are far apart - form and have to be treated as one system. One could even speak of the whole universe as one integrated quantum system, though this is not fully realistic because decoherence soon destroys these properties for a macroscopic system.

So one by one the basic concepts of classical 19th century physics had to undergo dramatic modifications in the process in which modern physics was replacing, or extending classical physics. This was a tremendously successful, healthy and positive development in science, though it required substantial soul-searching and head-scratching, self-analysis, clarification of ideas, especially the critical analysis of the so-called "scientific method" /10/. Most of these, sometimes unexpected developments occurred at the boundaries where science meets other rational approaches to reality, so it required careful determination of the meaning of the scientific results and their limitations, and this process necessarily involved crossing into other disciplines.

Reductionism and complexity

It is necessary to mention briefly another development that undermines the case of scientism and emphasizes the need to approach reality in a holistic way. During a long period when reduction as a method enabled physics - and science in general – to make significant progress, there was a tendency to interpret it as more than a useful method. Its successes were taken as a proof of the deeper, ontological character of reductionism, which claimed that the behaviour of all entities is completely determined by the behaviour of their smallest components. Properties of protons, neutrons and other elementary particles (not any more elementary!) would follow from the properties of quarks and gluons, similarly for atoms and molecules, from physics to chemistry to biology, to the properties of living organisms and life itself, which would thus result from the properties of simple matter and nothing else. Finally in this sequence, these same properties of matter would define social behaviour, including "natural" moral rules and values. (One can here detect the roots of the well-known marxists' "scientific discovery" of the "laws of history", as well as similar nazi "theories", that were used to justify unprecedented oppression and murder.)

This radical reductionism is one of the main arguments for the scientistic claims that science in its progress eliminates the need for and the possibility of the existence of God, or any equivalent intelligent being or Creator. This type of reductionism claims that reality which exhibits hierarchy of many different levels of complexity, can be understood only in terms of *bottom-up causation*, where one or several subsystems influence a system at a higher level, neglecting the possibility that some new properties might arise at the higher level itself. The opposite process, *top-down causation*, would enable the appearance of new properties on a higher level not derivable from those of the lower level, and its influence on the physical and chemical processes at the lower levels, without violating the lower level laws. (The simplest way to exert such an influence is e.g. by imposing specific boundary conditions.)

Modern physics knows of many cases where reductionism fails, and as more complex systems are formed new properties appear which cannot be anticipated from those of their subsystems. A simple – even maybe trivial - example is the water molecule, consisting of three atoms, which can form more complex systems of gas or liquid or solid. Properties at the higher level do not follow uniquely and simply from the laws of the lower level, though they obey them. Nor can quite intriguing properties of a water molecule be reduced to those of constituent atoms, nor can quantities like temperature or pressure in the thermodynamics be described simply in molecular terms – they represent new properties of a more complex system. To this one can add many types of collective phenomena, phase transitions, etc.

We see that together with the usual bottom up sequence or causation, where the lower level properties determine those of higher levels, there is also an additional top down causation or influence, which connects the systems of different complexities in both directions. To this one has to add that this influence is usually restricted to the fundamental laws and properties, while the understanding of many phenomena studied on each level can be achieved relatively independently of the details on other levels. "Normal" scientific research is going on e.g. in elementary particle physics or atomic or solid state physics, or chemistry or biology, not to mention other sciences, simultaneously and relatively independently, except occasionally when the new discoveries require transdisciplinary approach. This is in spite of the fact that each of these disciplines is making progress and continuously undergoing transformation. But it is very unlikely that the new developments e.g. in the Standard Model of elementary particles – though dealing with most fundamental properties of matter - would make any impact on the studies of more complex systems e.g. in chemistry or biology. This fact provides internal stability of the natural sciences, and is also a strong argument against the reductionist dogma.

Classical physics was for practical reasons often restricted to studies of linear or weakly nonlinear interactions. But recently it has been observed, mainly by using the power of computer simulation, that even many phenomena in classical physics show properties which cannot be treated or explained in a reductionist way. These are phenomena connected with the appearance of complexity, self-organization, nonlinearity and (deterministic) chaos, where one cannot even think about the system as a simple collection of subsystems. Also, extreme sensitivity of non-linear systems to the initial conditions makes it impossible to make deterministic statements or predictions.

One of the most impressive examples how far has modern physics progressed from the naïve 19th century mechanistic picture of the world is the string theory /11/ which assumes that the elementary constituents of matter are small vibrating strings of the size given by the Planck length (10 to the power of -35m). Though it promises to give some highly desirable results, string theory requires to be formulated in at least 10 dimensions (9 spatial and 1 time). As we live in a universe where we experience only 3+1 dimensions, it is necessary to reduce their number by "compactifying" them. However, there is no unique way of doing this, and the procedure leads to the possibility to define enormously large number (10 to the power 500) different vacua, i.e. universes with different properties. One is obviously in need to find some well founded prescription how to proceed, and especially how to reduce the theory in the special case to the Standard Model of elementary particles which has been so successfully tested in the last 40 years. The attempts to find this prescription have transgressed the normal boundaries of empirical science and included various highly philosophical speculations, including even the reference to the “Anthropic principle” /12/. But, on the sceptical side, these difficulties and speculative deviations from the standard scientific practices have led many authors to question whether string theory satisfies the basic criteria to be considered as science or not. At the same time there is a growing awareness that science has approached its limits and that there is a need to broaden the discussion by including other disciplines /13/.

Conclusion

We have shown – or at least indicated, that the development of physics in the 20th century has modified many of the assumptions underlying science and specifically physics of the 19th century, and which were taken as the justification for the radical claims of scientism or scientific materialism. These were the strict determinism, ontological reductionism and blind belief in the “scientific method”. Quantum physics, theory of relativity, systematic epistemological analysis of the way how scientific research is indeed performed /10/, especially the hipotetico-deductive method, and recently studies of non-linear systems, all this has undermined the scientistic arrogance and belief in the unbounded powers of reason.

We also realize that there is no inherent conflict between science and religion: they are different but not completely separate ways of approaching reality. However, their relationship is very complex, the boundaries not always well defined and it is extremely important to appreciate specific character of each discipline. This applies not only to the science – philosophy – theology dialogue, but even to the internal differences between various sciences, though in this paper I restricted myself to physics.

This also emphasizes the continuous need for clarification of many concepts and their uses in science, philosophy and theology, respectively, like (in)determinism and causality, relativism and the role of observer, locality, entanglement (and a possible link to holism ?), realism vs. idealism vs. critical realism, reductionism - bottom-up and top-down causality (again: holism?) and the limitations of scientific results. Could we envisage here a link between the epistemological limitations of science and apophatism ? Or at least an analogy? At this point, approaching the boundary to philosophy and theology, it becomes necessary to overcome the limitations of the my scientific background and continue this discussion as a transdisciplinary exchange of ideas.

References

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/3/ Barbour, Ian G., *When Science Meets Religion*, New York, Harper Collins, 2000

/4/ Haught, John F., *Science and Religion, from Conflict to Conversation*, New York, Paulist Press, 1995

/5/ Such radical statements can be found e.g. in P.W. Atkins, P.W. *Nature's Imagination: The Frontiers of Scientific Vision,* ed. byJ. Cornwell (Oxford U.P., 1995) or in Dawkins, Richard, *The Blind Watchmaker: Why the Evidence of Evolution Reveals a Universe without Design*, Norton, New York, 1986.

/6/ See e.g. Dembski, W., *Intelligent Design: The Bridge between Science and Theology,* InterVarsity Press, 1999. A different cultural and religious approach can be appreciated in an interview by Mattin Durani with Reza Mansouri "A way forward for Islamic science" *Physics World* , August 2007, p.12

/7/.Gould, Stephen J., "Nonoverlapping Magisteria", *Natural History***, 106,** 16-22 (1997)

/8/ Among many scientists expressing their opinion on these issues one of the most eloquent was Richard Feynman. Though an atheist of Jewish descent, in a lecture published in *The Meaning of it All: Thoughts of a Citizen Scientist* (Addison-Wesley, 1998) he repeatedly stressed the restricted character of scientific results: "It is not possible to disprove the existence of God as far as I know." Or, "I believe that it is impossible to decide moral questions by scientific technique, and the two things are independent." Or, "Ethical values lie outside the scientific domain."

/9/ See e.g.. Bohr, Niels, *Atomic Theory and the Description of Nature*,Cambridge UP, 1961, or Heisenberg, Werner, *Physik und Philosophie,*Verlag Ullstein, 1977. Standard text is Jammer,Max, *The Philosophy of Quantum Mechanics,*Wiley, 1974.

/10/ The classic texts are Popper, Karl, *The Logic of Scientific Discovery,* Hutchinson, 1972, (German original edition is *Logik der Forschung*, Vienna, 1935; Kuhn, Thomas S., *The Structure of Scientific Revolutions*, University of Chicago Press, 1962; Lakatos, Imre and Musgrave, A.,eds., *Criticism and the Growth of Knowledge*, Cambridge University Press, 1962; Feyerabend, Peter, *Against Method*, Verso, London, 1975. A very interesting analysis that includes the experience of a practising scientist is presented in Ziman, John, *An introduction to science studies*, Cambridge UP, 1974, and *Real science: What it is, and what it means* , Cambridge UP, 2000.

/11/ For a relatively simple overview of the string theory see Chalmers, Matthew, "Stringscape", *Physics World* September 2007 p. 35.

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/13/ See e.g recent articles: Weinstein, Steven, "Philosophy pulls strings", *Physics World* September 2007 p.18, and Scharff Goldhaber, Albert, "Scientific faith put to the test", *Physics World*, September 2007, p.16.