# Science, Historicity and Complexity

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**Abstract** In this contribution the author intends to reconstruct Evandro Agazzi's reflections on the development of contemporary science after the elaboration of the Theory of Systems and the emergence of the perspective of Complexity. Reflections that convinced him that Reality is historical and that, in order to understand it, an interdisciplinary approach and a new definition of Science are needed. As is well known, classical science and its language were incompatible with historicity; Galilei and Descartes claimed to discover the eternal laws that characterize the mind of God, the ontological structure of Nature and the "form" of our intellect; up to Fourier, Darwin and Mach the objectivity, universality and eternity of scientific laws represented a metaphysical assumption that quickly become an undisputed dogma. In 1883, the same year in which Wilhelm Dilthey was still opposing "Sciences of Nature" and "Sciences of the Spirit", Ernst Mach published *Mechanics Exposed in its Historical-critical Development*. In his work, summarizing the results emerging from thermodynamics, electromagnetism and evolutionism, Mach inserted historicity into science using history not only as a reconstruction of the event-science but also as the only way for its theoretical comprehension. By so doing, Mach aroused endless debates involving several non specialized scholars, including, for example, Lenin, who understood very well that the crisis of scientific determinism initiated by Mach would eventually involve "objectivity" and the process of realization of Marxism, and reacted consequently. What that followed has strongly affected the Italian scientific and philosophical debate, marking indefinitely its physiognomy.

**Keywords** Systemicity · Complexity · Historicity · Interdisciplinarity · Scientificity

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## 1 The Specificity of the Italian Situation

In effect, when first introduced in Italy by Giovanni Vailati and Benedetto Croce, Mach's thought caused fierce debates. Vailati didn't suffer their consequences in a direct way, since he had a protector in his master Giuseppe Peano, and he died too young. On the other hand Croce—who unlike Vailati also accepted Henri Poincaré's conclusions—was harshly criticized at once, and from then on he was accused of wanting to "underestimate" science, becoming a victim of a die-hard prejudice until now. This reaction can be explained in some way if we bear in mind the specificity of our (Italian) situation. In Italy when it comes to science, also in a moderately critical key, we live, so to speak, "on the verge of a nervous breakdown". The never completely metabolized condemnation of Galileo has always been seen as condemnation of science as such, and every time it has been called into questions, a sort of indignant defense against "resurgent obscurantism" has sprung up. This situation has also been supported by a typical inclination of the Italian scientific culture, characterized by the lack of great scientists-philosophers. From Galileo Galilei to Carlo Rubbia we had great experimental physicists, but no one with the predisposition or the interest to question science methodologically or epistemologically. This led to the paradoxical case of Enrico Fermi, who in 1934 was unable to understand what he had done, and he thought he had discovered a new element, without realizing he had instead caused the fission of the atom.

Also as concerns historiographical reconstruction, in Italy the history of science has been, in general, the history of the approach to the Galilean revolution, based on the assumption that as soon science was born, there would be no longer "history" but, indeed, only science, or in other words definitive acquisition. Something similar occurred about the way philosophy of science was introduced "officially" in the Italian University by Ludovico Geymonat. Indeed, it has been affected by two background prejudices, a theoretical and a political one. Geymonat introduced logical neo-positivism in Italy not as a philosophical movement worthy of being known on the historiographical side, but as an alternative theoretical proposal opposing the Crocean underestimation of science, without taking into account that—in the meantime—the neo-positivists themselves had already considered their initial program obsolete. Furthermore, he extremely politicized it, overstating a connection with Marxism that, as a matter of fact, had represented only the personal choice of some neo-positivists. A clear testimony of all of this, limiting myself to just one example, is the way he structured his *History of philosophical and scientific thought*, in which he emblematically dedicates very little space to Mach and Croce, but around forty pages to Louis Althusser. In accordance with these choices, the Italian scientific debate on the subject has developed in a generic and sometimes superficial way that essentially remained the same up till now if, even after more than a century, some people still talk about Crocean "underevaluation" of science in allusively and quick way, without accurate arguments presented on scientific papers or specific monographs, but just through rapid and vague hints, expressed in general terms, as we feel compelled to do with what is “obvious” (cfr. Gembillo 2006). In other words, a large part of the Italian philosophy of science, before opting for bracketing the problem and identifying itself almost completely with the scientific procedures, manifested itself as a direct or indirect polemic against Mach and Croce. Most certainly there have been important and honorable exceptions, one of which is represented in an eminent manner by the thought of Evandro Agazzi.

## 2 Teoreticity and Historicity in Agazzi’s Thought

As a matter of fact, Evandro Agazzi has always maintained a great balance in evaluating the various theoretical conceptions. This was due to the fact that he always based his findings on a rigorous and careful historical reconstruction that allowed him to enunciate theoretically relevant judgments, fitting the specific nature of the subject he was gradually taking up. Above all, he thought over and reconstructed with great attention the history of post-Galilean science, going upstream against the Italian tradition. To this purpose he wrote several works on the history of physics, he edited two volumes in the history of science, he translated James Clerk Maxwell’s *Treatise* (Maxwell 1973) with an interesting and well-documented historical introduction. In other words, his originality lies in the fact that each of his theoretical works has always been grounded expressly on a comparison and on a solid historiographical basis, and this basis covers everything that has happened historically and theoretically from Galileo up to the present day. Since his first work in this sense, *Temi e problemi di Filosofia della fisica* (1969), he has dedicated, for example, wide historiographical reconstructions and epistemological discussions to quantum physics and to the relativity theory.

Given the impossibility to talk about all the works he wrote about the relationship between science, historicity and complexity, I will limit my discussion to some thoughts expressed in one of his most theoretically mature and clearer texts in terms of argumentation and training: *Le rivoluzioni scientifiche e la civiltà dell’occidente* (2008), that specifically includes the issue of Complexity. I will focus specifically on the problem, which he discussed in detail, “of the widening of the scientific landscape in the 20th century”.

After recalling quickly some of the most significant developments that characterized science and technology in the twentieth century—namely quantum physics, space travels, the moon landing, the discovery of DNA, the techno-sciences, etc.—Agazzi makes an interesting reference to the methodological and theoretical aspect that more deeply marked the difference between classical science and that of the twentieth century, highlighting that the reference to the twentieth-century science is not enough

> to give us the measure of the new intellectual model that characterizes in its entirety contemporary science, which is distinguished from modern science especially by the abandonment of a strictly deterministic and analytic perspective in the name of a fair appreciation of the complexity and globality (Agazzi 2008: 152).

From this observation he draws the motivation for a historical-theoretical reconstruction of the disciplines, which were decisive to impose the methodological turning point that he mentioned, a turning point that refers "to the theme of complexity, systems theory, cybernetics" (ibid.) From these new sciences, Agazzi draws inspiration to support and transform the realism that has always characterized his thought. Now the concept of "form" in the active sense of *Gestalt* suggests him that "here emerges the most notable feature of the modern dynamic complexity compared with the previous types of complexity: the forms generated by the nonlinear dynamics, are not just 'beautiful', but often also remarkably similar to those of natural objects, especially those that characterize living organisms" (ibi: 160).

In this concrete horizon it is possible to get the meaning of the self-development that characterizes all the living forms, or more clearly that "shows a spontaneous tendency toward the growth of complexity itself, even starting from situations that did not seem to prepare it (a phenomenon called self-organization), just as it happened many times in the course of natural evolution" (ibid.). Agazzi knows that these considerations—starting from the second half of the twentieth century—have been increasingly corroborated at all levels, and he notes that this is "why someone has started to think (and in some cases it has been shown) that at the heart of many—if not all-of these extraordinary structures there are natural dynamics of this kind" (ibid.). He avoids carefully the temptation to prefigure or endorse some new form of biological determinism, and to this purpose he specifies first and foremost that "with that we would not have a surreptitious return to reductionism" (ibid.).

However, he seems to attribute the impossibility, in these cases, to make exact forecasts, to our inability to follow the complex evolution of an organism, and not to its intrinsic impossibility. In his opinion, that is,

> this 'creative' aspect of complexity never suppresses the irreducible limit to our ability to calculate. Therefore, even if we could determine the dynamic that governs the genesis of a certain structure, as the structure generates itself, our ability to forecast will decrease, and therefore we couldn't know in any way what will be the global properties of the structure itself, except by letting it evolve and then seeing the result (ibid.).

We couldn't know it also because the developments are not determined by an abstract law, but by the concrete historical and evolutionary Reality.

> In other words, it will never be possible, in general, to predict the behavior of a structure that is the result of a nonlinear dynamic starting from the law that governs this dynamic; to get a prediction we will identify some new law, which must be obtained from the analysis of the direct reality and not deduced from the previous law (ibid.).

In other words, contrary to what was supposed by classical science, the top level is not explained by the lower level, and therefore not reducible to it, and "this applies to all levels of reality: atoms with respect to molecules, molecules with respect to cells, cells with respect to the body, and so on" (ibid.).

For this reason there is no direct affiliation between the different disciplines, since for each of them the main reference is always concreteness, in the sense that "every time you go one level up it is necessary, so to speak, 'to return to reality', looking for it in its own objects, according to specific methodologies, with the very important result of ensuring again the autonomy of the different sciences, which are therefore, each in its own order, all equally 'fundamental' as physics" (ibid.). In this way, the classical hierarchy is replaced by the network interactive relationship where what counts are equal relations, and not hierarchical dependencies. This is what emerged from today's complexity theory and the historically complex processing systems.

## 3 From Atomism to Complexity System, the Cybernetics

Agazzi unites properly the concept of Complexity "to the idea of an organized, structured system, different from a pure multiplicity consisting of elements essentially of the same type" (Agazzi 2008: 163). In order to better clarify this concept he uses a particularly effective comparison, based on a fundamental shift suffered by the mathematics of the late nineteenth century (Cantor), noting that "the relationship between the components of an object or the complex process and the object itself considered as a unit is not the relation of 'membership of an element in a set', but that between 'the whole and its parts'"(ibi: 164). He intends to further clarify the differences between set-theoretical approach and complex approach by noting first of all that

> in set theory the axiomatic construction can be done using as the only primitive notions that of element and the relationship of membership of an element to a set. This means that *the nature of the elements* is completely irrelevant, and that they are not supposed to be provided with structures or internal relations. We could say that the ontology of set theory (i.e. the type of entities that it presupposes) is *atomistic* (ibid.).

Understanding perfectly the meaning of the perspective of complexity, he notes that

> vice versa, if we consider, for example, a living organism, it is naturally conceived as consisting of 'parts' and not by 'elements', and these are the various 'organs', all different from each other, characterized by specific structures and functions and at the same time connected and cooperating to form a unity, namely a *whole*, provided with its overall properties as well (of which the most notable is precisely life). Moreover, these parts are themselves a 'whole' compared to the other parts that constitute them. The ontology underlying this concept is holistic (ibid.).

To be more precise and to achieve a better comprehension, and with different arguments, of the difference between the atomistic and the holistic approach, it should be duly noted that "in the holistic perspective the structure and functions of the parts are of considerable importance, and the relationships between parts and whole are not of mere membership, but of correlation, interaction, and also lie on other relations established between the different parties" (ibid.). The difference between the two perspectives is really radical since, unlike the set theoretic approach, within the systemic-relational approach "as a result of all these relationships, it is said that each whole *is more than the sum of its parts* in the sense that it has properties that are not typical of any of its parts, and it does not even appear to be a sort of sum or combination of them" (ibid.).

Agazzi rightly insists on "the feature of *originality* or *creativity* that characterizes the complex systems", and observes that, considering the problem from a more rigorous historical perspective,

> the holistic point of view has always been implicitly subtended to the life sciences, but only in the twentieth century it emerged with strength and explicitness, casting a new light on many problems and resulting in refined conceptual elaborations that can be rightfully considered as clarifications and developments of the notion of complexity (ibid.).

In a sense, this point of view has been integrated by System Theory and by Cybernetics, issues on which Agazzi develops a broad, structured and rigorous discourse, which in this context cannot be examined in depth, but cannot be completely omitted, either. I will briefly mention it, beginning with the "General System Theory", highlighted by Agazzi both for its methodological originality and because—precisely for this reason—it has encountered many obstacles and aroused fiery controversies. As a matter of fact, although the concept of system has always accompanied philosophical and scientific thought, actually

> systems theory is relatively young, since it achieved success in the second half of the twentieth century, being at first the object of animated debates and controversies. This is not surprising, since any 'new' discipline has to face a more or less controversial debate in order to establish its titles of scientificity (ibi: 171–172).

Agazzi prevents the objection that such a finding could not always be true, and there are several examples of disciplines that have developed peacefully: he grants that this

> is true, but everything depends – so to speak - on the degree of intensity with which are combined the claims of scientificity and those of novelty: in other words, the instinctive reaction of the scientific community, in front of a new discipline, seems to be the statement according to which, if it is really new it is not science, and that if it is really science, it is not new (ibi: 172).

To avoid misunderstandings we should clarify that we need to be careful and, for example, point out that throughout the history of Western scientific culture it usually happened that

> when novelty comes not in the sense of 'a new development' of an existing framework, but in the more challenging sense of being able to make claims that 'do not fit' in the previous framework, in that case the most common reaction is to state that the new claims are actually 'unscientific' extrapolations or digressions (ibi).

For this reason, Agazzi rightly notes "systems theory has been the object of controversy, not for its content, but because it presented itself as a way to conceptualize and theorize that wanted to be 'new' compared to the already tested and established scientific criteria, considered too narrow" (ibi). In other words, although the concept of system has been historically used to describe coherent theoretical philosophical constructions or, for example, even those of Newton and Linnaeus, the new theory inspired by it aroused skepticism "since the concept of system was used in a partly new and even alternative sense, compared to its traditional sense" (ibi).

Connecting these observations to those expressed earlier about the idea of complexity, Agazzi—to avoid any misunderstanding or possible confusion—reminds that the classical system "corresponded to the need for *unification*, *reduction of multiplicity to one*, about which we have already discussed, which had found its fullest expression in the mechanical determinist reductionism" (ibi: 172–173). As is clearly shown by all that has been said, "vice versa, the new systems theory would be an attempt to understand the role of *diversification* and the peculiar type of structured and ordered unity that it entails" (ibi: 173). Moreover, if we face the problem without bias and with the necessary calm, we can agree that, on closer view, it

> gave a framework and a rigorous and harmonic characterization to a number of concepts, such as the one of ordered whole, of functionality, of hierarchical structure, of organism, of development, of adjustment, of interrelation between individual and environment, of centralization, of self-preservation, of finalized process, which are frequently used and indispensable in several sciences (from the biological ones to the psychological and social ones), but that had been used with an almost exclusively intuitive meaning, or with a meaning just a little more specific than in common language (ibid.).

The most common reaction to this attitude was, as Agazzi precisely emphasizes, a kind of "temporary tolerance", waiting and hoping that the approach would adjust to the traditional scientific standard. But complex systems theorists, starting from the founder, Ludwig von Bertalanffy, were not disposed to align to this wishes, and defined in a more precise way their methodological and ontological approach, converging in outlining a "generalist" perspective whose "aspect of interest and originality lies in 'breaking' the traditional scheme, and thus introducing new and prolific perspectives in many disciplines, not only belonging to the natural sciences" (ibi: 176).

This is, essentially, what Agazzi intended to say about the new approach to the Real. However, "to better understand the meaning of systems theory we should consider in any case another almost coeval and strongly linked discipline, cybernetics, and also the contribution that systems theory itself gave to a new scientific methodology, interdisciplinarity" (ibid.). To coherently realize the latter, one didn't need only cybernetics, but also information theory, soon named computer science, and the life sciences. After a due reconstruction of the essential events related to these new approaches, Agazzi rigorously explains why the relations between disciplines should be investigated in all their complexity, drawing conclusions on which we shall now linger to enucleate their most innovative aspects.

## 4 The Meaning of "Interdisciplinarity"

At this point Agazzi, facing the issue of interdisciplinarity directly, declares himself convinced that

> starting from what has been exposed above, it is clear that systems theory, information theory, cybernetics, complexity theory are subjects whose concepts, methods, and principles find direct application in many fields of scientific research, technological achievements, production structures, social institutions, and the organization of various services in the contemporary civilization (Agazzi 2008: 185).

This means that they have "interdisciplinary" character. In this regard, however, for the sake of clarity he states that this is a sort of "transdisciplinarity", that should not be confused with the "multidisciplinarity", defined by the exterior combination of different disciplines that do not really come into interaction. As he exactly explains,

> what characterizes interdisciplinary as something different compared to the simple 'co-existence' of various disciplines (which is often referred to as *multidisciplinarity*) is the fact that the interdisciplinary perspective aims to achieve a convergence, a coordination, a mutual exchange between different disciplines in order to solve a particular problem (or certain problems) of cognitive or practical nature. In this sense it is an effort of "unification" which is the opposite of the *reduction* (ibi: 185-6).

In other words, we are dealing with something substantially opposite to the traditional approach, since

> the unity we try to propose is not considered as a reduction of the complex to the simple, of the differences to the uniformity, but as the comprehension of the *complexity* through the coordination and the synergy of the different *parts* of a *whole* that is holistically comprehensible, since each part contributes specifically to the operation of the whole and to the formation of its irreducible features (ibi: 186).

He insists on the close connection between this approach and the one that emerged in systems theory and complexity theory, and adds that the need for interdisciplinarity has to be understood also in the light of the practical need to make decisions in complex situations. Also, he points out that this approach should not be interpreted as a kind of substitute for specialization, but it should represent an appropriate integration to it. If it is true that the inclination towards what Ortega y Gasset rightly called "barbarism of specialization" (Ortega 1930) is very negative, it is also true that without specialist proficiency the integration of knowledge would suffer of over-generalization. By specifying this, Agazzi appropriately reaffirms the distinction between *Interdisciplinarity*, *Multidisciplinarity* and *Transdisciplinarity*, and once again underlines that only the first "has the acceptance of the complexity as a prerequisite, and aims to understand it (Agazzi 2008: 188). But to be understood it needs to be based on the interaction between rigorous and precise experiences in the sense that

> the needs of interdisciplinarity cannot be considered satisfiable by a suppression of specialization. This is certainly a consequence of the increase of knowledge, but it is also one of its *conditions*, so that giving up the specialization would mean to deprive ourselves of increasingly reliable and advanced knowledge for our practical achievements, apart from giving up an increase of knowledge (ibi: 188-9).

Furthermore, an equally important aspect, "every science is provided with its own *methodological criteria* and inferential processes (i.e. *logics*)" (ibi: 189). For this reason it seems appropriate to mention, in line with what Agazzi is highlighting here, the "polilogics of complexity" (Gembillo 2008). From this originates the coherent conclusion that true interdisciplinarity

> is built *starting from the disciplines* and respecting the seriousness and commitment of their technical investigation. Secondly, it is clear that the impossibility to dominate many specializations is not linked to the inability to contain an excessive mass memory of

> knowledge, but rather to the inability to adopt simultaneously many perspectives, many mental habits, many different methodological settings and master also the related concepts and operational methods (Agazzi 2008: 190).

Another reason is that, as discovered by Humberto Maturana, our brain develops in a certain direction, and from that direction it "*looks at reality*" (Maturana 1995). But since, as Goethe said, "everything has been given to man both as a treasure and as a curse", also in our case,

> all this represents undoubtedly an obstacle, but also constitutes a richness: once again, not because accepting the plurality of disciplines you know *more* of the real, but because you know it *better*; in other words it is possible to get more aspects, exploring more deeply its richness, since we are able to appreciate more adequately its *complexity* (Agazzi 2008: 190).

Achieving this is difficult, since "the unity of the thing does not guarantee by itself the unity of knowledge" (ibid.), because who assumes the task of understanding the complexity of the events must have an unordinary capacity of synthesis and be fully aware of the fact that

> the truly interdisciplinary discourse is established when one admits that, in front of a complex problem, different optics are *necessary* for its comprehension, and one makes an effort to consider it under each views, comparing them and trying to see how each one contributes to the comprehension of the whole. (ibi: 191).

We could say, at the end of the short *process* outlined until now, that

> the successful completion of interdisciplinary work is the achievement of a certain *synthesis*. This however cannot be understood as the achievement of a unique and definitive *image*, but rather as the overcoming of the one-sidedness of the individual views, through the awareness of their differences, their partial mutual translatability, the existence of interconnections, homologies, and analogies, that increase our comprehension of the studied reality, without *exhausting it*. The unity of the 'thing' corresponds, by now, also to a certain unity of our knowledge of the thing, but the inherent complexity of the latter is never completely captured (ibi: 192).

If this is true we cannot deny that "interdisciplinary work therefore is never fully accomplished: it is reasonable to stop when one has reached the desired *objectives*" (ibid.). Given that all this is based on the clear recognition of the historical and temporal structure of each existing thing at any level, then, "claiming that this work comes to a definitive and absolute end would correspond to the pretension of being able to ultimately know the truth, which instead is an endless challenge for the human being" (ibid.). And this happens not only because the individual subject cannot possess the ability to dominate all the possible points of view on reality, but because, as we have pointed out elsewhere, Reality is constantly changing and so it is never subject to a "full" and complete description of it (Gembillo and Anselmo 2013).

Agazzi's reasoning culminates ideally and theoretically with the consideration that what emerges from all this is the need to redefine the concept of science starting from all the objects of which it is responsible. To this purpose he takes as an example three sciences: "Cosmology, climatology, and the science of new materials, since they are significant examples of these new settings, linked to interdisciplinarity, complexity, systemic vision, that characterize the new spirit of contemporary science" (Agazzi 2008: 193). Of these three sciences I will focus only on the one that, having a longer historical tradition, allows not only for an adequate theoretical analysis, but also a concrete comparison between old and new conceptions of scientificity. I am obviously talking about that "science" that strives to understand the Cosmos.

For this purpose, Agazzi first underlines a serious limitation, wondering:

> The fact that in practice modern cosmology studies the universe using as sources only cognitive theories of physics (general relativity and quantum theory) is not perhaps in contrast with the complexity that the universe obviously possess (from a certain point of view, it should be the most complex object of all)? (ibi:166).

This and many other questions of the same content imply, as we will see now, just a new idea of scientificity, which does not escape the analytical sensitivity of Evandro Agazzi.

## 5 A New Idea of Scientificity

The new idea of scientificity emerges starting from Cosmology, the discipline that Kant defined structurally unscientific, because inherently unable to draw on possible experience. On the contrary, for Agazzi, after the scientific revolutions of the twentieth century, "the most interesting aspects for us originate from the fact that this discipline, which is now recognized as a science, and moreover a physical science, can be considered so only by widening the usual scientific criteria of natural science" (Agazzi 2008: 195–196). Obviously we should not hide the difficulties, nor is it appropriate to face the problem superficially, because we have to take into account that the issue is complicated by the fact that "it is difficult to identify the object of cosmology" because in order to do so correctly you must be able to answer the question "What kind of object is the universe?" (ibi: 196). Clearly the most difficult problem is that it does not occupy a visible space in its entirety, nor has boundaries defined with precision, since it expands in all directions. Precisely for this reason, "it cannot be empirically denoted as a well-defined system of things, neither can it be characterized as a structured set of certain attributes or properties (as in other sciences)" (ibid.). Therefore we cannot omit the fact that, apart from what noticed so far, "compared to the natural sciences (to whose context it purports to belong) cosmology does not fulfill the requirement of empirical controllability, i.e. the ability to prove its theoretical hypotheses" (ibid.).

Therefore its scientificity lies somewhere else, in a meeting point that until some decades ago seemed inadvisable, because it was linked to the already mentioned contraposition, between science and history. On the other hand, Agazzi, inheriting the best of what in another occasion I have defined as "complex neo-historicism" (Gembillo 1999), expressly states that

> difficulties of this type can be overcome by recognizing that cosmology - since in essence it makes an effort to reconstruct a history of the universe - has the right to claim the conditions of scientificity that are recognized for historical sciences, which in fact are not of

> experimental nature, and cannot avail themselves at will of the past data, even though they are "empirical" (i.e. they cannot avoid to be based on factual data), yet they try to offer not just descriptions, but also interpretations and explanations (Agazzi 2008: 196).

This does not mean that cosmology should belong to a different "context", abandoning the field of classical sciences to enter among the human sciences, since an important aspect links it to the former context, namely how it implements "interpretations and explanations", since

> to provide the latter, cosmology draws on the physical sciences and their theories, so it would seem that it is able to adopt that 'nomological-deductive' model of scientific explanation that (at least according to the current epistemology) characterizes mature science and physics in the first place (ibi: 197).

Agazzi rightly believes that, however, this is not the correct answer to the problem of the scientific status and the sense of Cosmology, since it goes beyond the methodology of classical sciences. He adds that "you cannot say that either," and he justifies his considerations by inviting us to reflect that "the laws of physical theories—confirmed now—serve to explain phenomena that take place *within* the universe, but there are no laws to explain the phenomenon *of the* universe taken as a whole" (ibid.). Therefore it is no longer possible, either in this specific case or in general, to appeal to any form of reductionism, since it is now clear that the Whole cannot be explained on the basis of its individual parts, and

> this fact blocks the way to a possible analytical-reductionist solution, as seen above, that would consist in showing that the properties of a 'whole' result from the composition of the properties of its parts, in other words, that the laws that govern the parts allow to deduce the laws of the whole (like, for example, some people think that the properties and laws studied by biology can be derived from those of chemistry) (ibid.).

This dream, already secular and difficult to erase completely despite its already clear illusoriness, still does not take into account the specific nature of that "whole" represented by the Universe in its entirety, nor the fact "that there are no laws or properties of the universe as a whole that can be established with a minimum of explicitness, in order to show later how they are derived from the laws of physics" (ibid.). The solution to the problem lies in the idea of commonality that has already emerged clearly, for example, in scientists like Ilya Prigogine, and here appropriately stressed by Agazzi, who notes that

> these, that in the eyes of many scholars are among the objections that one can address to the recognition of cosmology as a science, actually lose almost all their strength if we stress again that the epistemological characteristics of this discipline are very close to those of the historical sciences, and it represents a noticeable example of a *historiographic* natural science (ibid.).

Agazzi with his usual grace argues in this way an issue that has aroused fierce controversies and sharp contrasts among the most important scholars of the twentieth century. On his part, he adds that

> therefore, as the 'scientific' historian may use sectorial knowledge related to various spheres of human history in which perhaps some 'laws' or at least 'regularities' can be traced, without thereby being forced to recognize the existence of 'laws' of history as a

> whole, so the cosmologist uses different contributions of theories provided with laws concerning certain aspects of the evolution of the universe, in order to reconstruct the lines of such a development, and to tell such a story as *objectively* and *rigorously* as possible (ibid.).

The guarantee that everything respects the parameters that make an approach rigorous is provided by the fact that it must be recognized that "this research for objectivity and rigor is already the necessary and sufficient mark to qualify as scientific a cognitive endeavor (even if, of course, its results should be judged and evaluated in the light of the requirements of rigor and objectivity actually achieved)" (ibid.).

These conclusions were made possible precisely by the methodological turning point occurred thanks to systems theory and the perspective of Complexity that have shifted the attention from the elements to the whole, from the parts to the whole. Agazzi does not fail to highlight it, stressing that what said so far

> might be enough to report the interest and the peculiarity of this new science that, in particular, has been set up thanks to the legitimation of the 'holistic' point of view that characterizes contemporary science, which has completely overcome the narrow overspecialization of the strictly analytical approach (ibi: 198).

Having said so, and to support all the arguments carried out so far, it should also be noted that "cosmology is an interdisciplinary science in the right sense that we have already made clear, namely in the sense that it seeks 'contributions' not from a wide array of different disciplines, but just from those few disciplines that are really needed to investigate the problems it studies" (ibid.). In this case it is important to insist that "in the essence physics, astronomy, astrophysics, mathematics" (ibid.) are the ones whose interaction provides methodological credibility to Cosmology at the moment when it presents itself as a rigorous "historical reconstruction" of an inherently historical entity as the Universe turned out to be. The reference to these few disciplines might seem restrictive for the interdisciplinary character that Cosmology presents, but

> watching things a little deeper we notice that it simultaneously uses two fundamental physical theories that, until now, could not be 'unified', namely the theory of relativity and quantum theory, but it uses them avoiding their insurmountable collisions, in the sense that relativity essentially serves to determine the choice of a 'model' of the universe (for example the expansion model rather than the steady state one), while quantum physics, even in its more advanced parts regarding the elementary particles, is used to 'fill in' the model and actually write the different chapters in the history of the universe (ibid.).

Naturally, Cosmology can pursue its proper goals not in a vague and extemporary way but "only thanks to a sophisticated mathematical processing of selected models, and by using the tools and results of astrophysics and astronomy, which can provide those few but significant empirical findings upon which it can rest" (ibid.).

A similar debate should be carried out for the other sciences that have characterized the twentieth century, making it a fundamental theoretical turning point. However, even limiting myself to the considerations taken into account so far, I think I gave a basic idea of how Evandro Agazzi managed to get in tune with the ensuing scientific and epistemological issues and to show the way for a deep renewal of science in our time. To wit, a renewal that finally leads to heal the wound that science itself opened at the moment of its birth and then had to heal. Today this is happening, or at least this is the direction taken by those who have had the taste and the courage to question the activities that they themselves were helping to strengthen and renew. It is not easy to take note of all this for those epistemologists who bet everything on the perspectives proposed by the old science, that seemed too good to be abandoned. Agazzi, however, fully belongs to those who understood that being practical and realistic does not mean believing in a static and abstract reality, but conforming oneself to its "perennial historicity".

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