The Aristotelian-Thomistic Concept of Nature and the Contemporary Debate on the Meaning of Natural Laws

Published in in «Acta Philosophica», 6 (1997), pp. 237-264.

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Introduction

In the domain of nature, encounters between philosophy and science are unavoidable. The observation of nature, in fact, has been a primary object of speculation for both science and philosophy. Since the VI century B.C., pre-socratic Ionian philosophers began to reflect on the causes of reality, taking their cue from the examination of natural phenomena. It was Aristotle, two centuries later, who first gave to the philosophy of nature the status of a specific discipline, organizing a large number of empirical observations within a coherent body of philosophical reflections. On the other hand, it was also starting from the observation of nature that science set out on its own path. Once human beings were able to analyze the phenomena of the physical world in terms of computable formalism and began to study them with the aid of reproducible experiments, then scientific research separated from philosophy and developed as a specific branch of knowledge. However, distinction does not mean extraneousness or lack of relations. It is significant to recall that around the end of the XVII century both physics and philosophy were still using almost the same vocabulary, as indicated, for instance, by the title of Newton's masterpiece *Principia Mathematica Philosophiae Naturalis,* published in 1687.

An example of a close encounter between philosophy and science is the contemporary debate on the meaning of natural laws or, generally speaking, on the meaning of the intelligibility of nature. If the literary production in this field has noticeably increased in the last twenty or thirty years, we owe it not only to the interest manifested by philosophers of science in these themes, but primarily to a large number of popular essays written by professional scientists.[1]

Due to the tremendous advances of present century science, medieval or ancient philosophy is usually thought to play a minor role in this debate. The new horizons unveiled by contemporary cosmology, the severe constraints to knowledge and predictability posed by quantum mechanics, and more recently by complexity, are such as to have greately changed our philosophical approach to nature, when compared with the one we find used in the past. Moreover, it is known that the concept of nature the Medieval thinkers inherited from the previous ages and fashioned in their own way, was forged within a strong theological outlook. The idea of eternal and stable laws, in fact, was of its own associated with an image of God commonly understood as the law-ruler of the universe. Now, once the resort to the notion of God is no longer necessary to explain the world of nature, the interest in philosophical questions such as the origin, the coherence or the meaning of laws, is expected to decrease accordingly.

If, answering by guess, one could think that the current state of affairs is close to the one depicted above, a deeper analysis would show that the philosophy of nature produced by authors such as Aristotle or Thomas Aquinas is perhaps less out-of-date than expected. When contemporary philosophy faces problems posed by present century science, besides the emergence of qualitatively new puzzles to disentangle, it continues also to cope with a number of recurring and unchanging fundamental questions, many of which were already tackled by ancient or medieval thinkers.

It is easy to recognize that a number of such fundamental questions, like the stability and the specificity of the physical world, have been re-encountered and philosophically revisited all along the XX century. In a famous page which deserves to be quoted at length, Albert Einstein expressed his feeling thus:

> "You find it surprising that I think of the comprehensibility of the world... as a miracle or an eternal mistery. But surely, a priori, one should expect the world to be chaotic, not to be grasped by thought in any way. One might (indeed one should) expect that the world evidenced itself as lawful only so far as we grasp it in an orderly fashion. This would be a sort of order like the alphabetical order of words. On the other hand, the kind of order created, for example, by Newton's gravitational theory is of a very different character. Even if the axioms of the theory are posited by man, the success of such a procedure supposes in the objective world a high degree of order, which we are in no way entitled to expect a priori. Therein lies the *miracle* which becomes more and more evident as our knowledge develops."[2]

Forty years later, John Barrow has commented in a similar fashion his surprise at the stability of the fundamental parameters of elementary particles. In words

that recall Einstein's reflection, he too considered this property a sort of "miracle":

> "one feature of the elementary-particle world, which is totally unexpected when compared with our experience of everyday things, is the fact that elementary particles come in populations of universally identical particles... We could imagine a world in which electrons were like footballs--everyone slightly different from all the others. The result would be an unintelligible world."[3]

Contemporary science manifests also the need to approach many phenomena in the light of their "unbroken wholeness", a category which could resemble another old philosophical notion, that of *form*. The resort to such a classical category turns out useful to study phenomena in terms of some recurrent functional patterns, not only in the field of biology, as occurs for instance in the case of the spontaneous self-organization of chemical and biological systems, but also in the field of physics, including quantum mechanics and complexity:

> "Complex systems cease to be merely complicated when they display coherent behaviour involving the collective organisations of vast numbers of degree of freedom. It is one of the universal *miracles* of nature that huge assemblages of particles, subject only to the blind forces of nature, are nevertheless capable of organising themselves into patterns of cooperative activity."[4]

The list of *miracles* could go on and on. Besides wondering at the stability and at the large-scale unity of physical laws, contemporary scientists also ask why is nature intelligible, why is mathematics so adequate and so successfully employed in describing the world of physics. Finally, as recently indicated by the lively discussion associated with the Anthropic Principle, present century cosmology is not afraid to cope with a last, ultimate why, i.e. the fundamental question about the great coherence of the universe as a whole, and the grand design it might contain.[5]

Within the broad interdisciplinary context just outlined, I will focus in this paper on a more limited issue: is the Aristotelian-Thomistic concept of *nature* consistent with the analysis of the natural sciences? Also, has that concept any relevance for a better *philosophical* understanding of the activity of science? I will begin by analyzing this concept as it appears in Thomas Aquinas' Commentary on Book II of Aristotle's *Physics* (though passages from other works by Aquinas will be considered as well), emphasizing its originality when compared with other views or conceptions (Section I). Then I will briefly discuss the possible role it has in understanding the philosophical rationale underlying the notions of natural properties and natural laws, especially as they are employed by the physical sciences (Section II). An

Epilogue will offer some concluding suggestions about the import of this Thomistic approach in the contemporary dialogue between science and theology.

I. The Aristotelian-Thomistic Philosophical View of the Concept of Nature

According to the etymology of the Latin verb *nasci* (=to be born, to generate) and of the Greek verbs fuvsqai (=to grow) and fuw (=to originate, to produce), the first meaning of the word nature (fuvsiı, in Greek) is "the genesis of growing things". This broad semantic field gives rise to the twofold common usage of this word: i.e. *nature as the natural world* (Nature is then the whole ensemble of things that have had a genesis), and *nature as the essence of something* (nature is then what is natural for something). Following this second usage, it means "what the growing being grows from", that is, a source within the growing being. From this comes the idea of nature as the primary intrinsic source of movement or change belonging to something by virtue of what it is.[6]

1. Aristotle and Aquinas on the concept of nature

In Aristotle's philosophy, the concept of nature involves both a metaphysical and a physical outlook. On the one hand, since it refers to the "essence" of a thing, it can be said of every substance, and so deserves some place in the reflection of metaphysics (*ens ut ens*) on ultimate causes. For this reason, introducing his comment upon Chapter IV, Book V of Aristotle's *Metaphysics*, Aquinas affirms that "though the consideration [of nature] does not seem to belong to first philosophy [i.e. metaphysics], but rather to natural philosophy, Aristotle nevertheless distinguishes the meaning of this word here because nature according to one of its meanings is said of every substance."[7] On the other hand, it concerns the world of physical elements insofar as it deals with their properties, changes or movements (*ens ut mobile*), because nature is an inner principle responsible for how a thing can act and how it can be acted upon.

In that same Book of his *Metaphysics*, the Greek philosopher runs through six different meanings of this concept.[8] In any case, in its primary and strict sense, it is to be seen as a source of movement or rest intrinsic to all corporeal entity. This is basically the acceptation he adopted in the context of natural philosophy, which we find in Book II of *Physics*; there he will define nature "as the principle or cause of movement in that in which it is primarily,

in virtue of itself and not accidentally."[9] Though Aristotle's insight was certainly triggered by the observation of living beings, the philosopher clearly distinguishes nature from *life*. Nature is not the same as the self-movement diplayed by animals or plants, because it concerns non-living beings as well. Aquinas, too, is well aware that the notion of nature can be framed within a broad context, which embraces also inanimate bodies.[10]

The concept of nature expounded in Aristotle's *Physics* shows a number of interesting philosophical nuances. In his Commentary, Thomas Aquinas seems to underline three main contents associated with that concept. In the first place, nature recalls the idea of stability and formal specificity; secondly, it functions as both an active and a passive principle, so playing the role of an inner code capable of governing all the natural changes that a certain entity is subject to; thirdly, the concept of nature is associated with the idea of finality.

Before going through the above three contents, it is worth mentioning that Aquinas' perspective is implicitly enriched by the knowledge of the biblical doctrine of creation. To know that the cause of the being of creatures is a transcendent God, plenitude of Being, who created the universe *ex nihilo* at the beginning of time, and drives it according to a purposeful plan, does not lead St. Thomas to a different comprehension of the Aristotelian idea of nature. This latter is still understood as the operating principle intrinsic to each entity, but the notion of creation allows him to gain an insight into the deeper link existing between the "metaphysics of nature" and the role of God the Creator.

In the light of Aquinas' doctrine of creation[11], creatureliness (*creaturalitas*) has at its root an *act of being* transcendentally participated from God, coupled with a specific metaphysical essence. In this way things *are* and *are something*. Since the act of being is the most intimate act in a creature, God, on whom each participated act of being fully depends, can operate as a transcendent agent who is also immanent in each entity.[12] Now, since the act of being of the essence is nothing but the act of being of the creature as such, God can operate through the created nature of things.[13] Moreover, Aquinas' way of understanding the order and harmony in Nature (when it indicates the whole of natural world) is different from the Greek concept of a closed Fuvsi". The source for the cosmic order is not a necessary causality which is immanent to an eternal and self-consistent universe, but the provident plan of a transcendent and freely willing God, who steers *suaviter et fortiter* each thing toward its proper end.[14] Aware of the deep harmony governing the relation between God and creatures, St. Thomas could plainly affirm that "quidquid a Deo fit, est quodammodo naturale."[15]

2. Nature and the formal properties of each thing

In Book X of his *Laws*, Plato pointed out that all things are the result either of art (tevcnh), nature (fuvsi"), or chance (tuvch). Our ordinary language, for instance, continues to recognize these three different outcomes when we call a thing "natural" as opposed to "artificial", or when we talk of something naturally expected as opposed to something unexpected, which occurs by chance or accidentally. In line with this plain reflection, we find that Thomas Aquinas understands the philosophical content of nature as a cause: "Dicit ergo primo quod inter omnia entia, quaedam esse dicimus a natura; quaedam vero ab aliis causis, puta ab arte vel a casu".[16]

The concept of nature arises from the observation of stable and regular movements. Quoting the same words of Aristotle, Aquinas states that

> "nature is nothing other than a principle of motion and rest in that in which it is primarily and in virtue of itself (*per se*) and not accidentally (*per accidens*)."[17]

It signifies an active principle of spontaneous behavior, a kind of *formal specificity* that rules the phenomenology of each creature. *To have a nature* means to possess a specific way of being and operating as something its own. According to this insight, in the *Summa* it will also be stated that "a particular nature is the operating and conserving power proper to each thing."[18]

The two last quotations agree in affirming that nature concerns not only motion, but also rest (*principium quietis*); it involves not only an operating power, but also a conserving one (*virtus conservativa*). In other words, we can legitimately speak of nature in terms of a "property" or "stable quality", despite the fact that it would appear as such because of some outer movement.

Although the term nature can indicate either a material or passive principle (see below), it primarily fulfills the role of a "form". Contrary to artificial things, whose movements or transformations are forced by the action of an external will responsible for the determination of some new form, things which act by their own nature, i.e. *a natura*, must have a previous *natural* inclination, that is a form, to receive other specific forms. On the other hand, the form itself can be seen, conversely, "as nature", because in making the thing to be what it is, the form is the metaphysical root of all specific activities or tendencies to change. As a result, the universe is endowed with a number of *natural* qualities, regularities or characteristics, which determine the constant behavior of each entity, according to its own essence. All activities we observe in the world of phenomena, especially that which concern intrinsic properties, changes or movements, stem from the causality of specific natures. The

reference to stability or regularity is of key concern to understand the philosophical force here contained. Aquinas will notice later on in his Commentary: "For those things are said to be according to nature which are moved continuously by some intrinsic principle until they arrive at some end--not to some contingent end, and not from any principle to any end, but from a determinate principle to a determinate end. For progress is always made from the same principle to the same end, unless something impedes it."[19]

Another interesting feature to point out is that nature is certainly something intelligible, but *non demonstrable*. We have no proof of it, because the existence of nature is evident in itself and it stands as a principle for knowledge: "It is ridiculous for anyone to attempt to demonstrate that nature exists. For it is manifest to the senses that many things are from nature, which have in themselves the principle of their own motion.(...) The existence of nature is known *per se* insofar as natural things are manifest to the senses. But what the nature of each thing is, or what the principle of its motion is, is not manifest."[20] Contrary to Avicenna's view, Aquinas adds that the principles of nature, upon which our sensory knowledge is based, are not to be demonstrated, because they are known *per se*. Thus nature is non demonstrable not only because its existence is too obvious to prove at all, but also because it transcends the scope of natural philosophy, which takes it as a starting point for its knowledge. In addition, the *specific* nature of a thing, i.e. *what* a nature is, is not nearly so evident as the sheer fact that it has a nature. In other words, we cannot deduce the ultimare reason for why it is as it is: we barely *receive it*.

The lawful and regular aspect of nature is better grasped if compared with the notion of chance. Both are notions of *causes*, but the difference lies in the fact the former always attains the same end, unless something impedes it, whereas the latter is by no means adequate to attain the knowledge of the effect. The first one is a cause *per se*, the second one is a cause *per accidens*. The additional information "unless something impedes it" (*nisi aliquid impediat*; other similar expressions are: *semper aut frequenter*, or *vel semper, vel ut in pluribus*[21]) is here necessary because, in Aquinas' cosmos, we deal with sublunar realities, whose activity must be seen under the light of contingency. If a nature does not display its foreseeable effect, it is not for lack of specific and regular behavior, but because something has happened in the environment, in the chain between the cause and the effect, or in the level of the effect itself. Something has changed--we would say in today's scientific language--in the boundary conditions of the system. In this respect, the necessity of nature is not an *absolute* necessity, and their stable and regular

outcomes are *in a certain way* relative to the extension of the considered system.

3. Nature as both matter and form

The presence of a specific nature owned by an entity governs its behavior and interactions in a twofold fashion: as a passive principle or as an active cause. Thus, it may display either the character of matter or the character of a form:

> "Those things which have in themselves a principle of their motion have a nature. And such are all subjects of nature. For nature is a subject insofar as it is called matter, and nature is in a subject insofar as it is called form."[22]

The passive material principle puts in light the receptive aspect of nature, while the active formal principle corresponds to the formal perfection which rules the change or movement toward the completion of its proper act. A similar analysis will be offered by Thomas Aquinas in the *Summa*.[23] We will see below that both principles manifest the character of finality associated with the notion of nature: as a passive principle, nature indicates an appetite or a desire for the fulfilment of a specific end.

A crucial point is that this potentiality manifests the "natural" capability a thing has of being transformed and put in act by other "natural" agencies, i.e. to receive a new form according to its proper nature, contrary to what happens in changes caused by artificial or chance agencies. In the case of an artifact, the potency of matter is informed by the act of an *extrinsic* agent, whereas the potency of what is natural is *intrinsically* related to a certain act, and so it fulfils the role of an end or an appetite. In the case of chance happenings, the process giving rise to a new form is accidental, due to the concurrence of more independent causes. One of (or some among) the causes intervening in the chance occurence, was not naturally disposed for the new act emerging from that casual encounter, and so the outcome, whatever it is, is non-natural.

Understood as a passive potentiality with respect to the act of forms with a higher degree of perfection, the concept of nature allows that interplay between matter and form which precisely underlies the logic of any operating principle. To consider nature in the light of a potency--and remembering that it indicates a principle of movement *in virtue of itself and not accidentally*--proves useful to interpret the growing of a living creature as a change in which a new *causa formalis* can be drawn out from the potentiality of matter.[24] In this way, even the evolution of the cosmos as a whole, or the continuous transformation of the different cosmic elements, particularly those

transformations which are possible because of the action of stable and specific qualities, are linked to the coordinate action of a number of natures, and not to the outcome of chance.[25]

Both matter and form are "nature" but each in a different way, since *form is nature more than matter is*. The relation between nature and essence is such that nature embodies in the first place the role of a form: "For a thing is more properly said to be what it is when it is in act than when it exists only potentially. Form, according to which a thing is natural in act, is nature more than matter, according to which a thing is something natural in potency."[26] It is because of this priority that it is correct to conceive nature primarily as source of formal specificity.

A last important remark is that the concept of nature, precisely thanks to its twofold character as both an active and a passive principle, is a notion *open* to the multiplicity and richness of the wide world of phenomena, and so capable of joining an almost infinite number of connections and different relations. The openness of the world of nature is such that "in natura est alterum propter alterum."[27] The nature of an entity, again, is a relative and not an absolute concept; not only for some dependency on the system to which the entity belongs, but also because its very name (from *nasci*) tells of a generation, i.e. of a relation of origin which involves something else.[28] All the material/formal activity manifested by each nature is the source for continuous, but lawful interconnections and feedbacks in the whole process of becoming of the physical world.

4. Nature and final causality

The correspondence between nature and finality deserves here more attention. It is nothing but an aspect of the strong correlation among the four Aristotelian causes, particularly the correlation existing between formal and final causes.[29] The best locus for the study of this subject is, again, Aquinas' Commentary on the Book II of *Physics*, though passages of interest can be found elsewhere, especially in the commentary on the books of *Metaphysics*.

In the first place, the presence of finality is pointed out by the regular and stable character of nature:

> "Everything which happens either happens by chance or for the sake of an end. Now those things which happen outside the intention of an end are said to happen by chance. But it is impossible for those things which happen in every instance or in most instances to happen by chance. Therefore, those things which happen in every instance or in most instances happen for the sake of something.

> Now whatever happens according to nature happen either in every instance or in most instances, as even they admitted. Therefore, whatever happens by nature happens for the sake of something."[30]

Finality in nature is not confined to what we could infer observing motions or changes only: nature, in fact, "is a principle of motion and *rest*". That is, the properties or qualities owned *per se* by a natural entity at rest (*natura ut virtus conservativa*) are a manifestation of finality as well. The primacy of form over matter is such that these properties do not spring from the necessity of matter, but rather from the formal and final causes involved in the concept of nature: "We do not say that there must be such an end because the matter is such. Rather we say conversely that since the end and the future form are such, the matter must be such. And so the necessity is placed in the matter, but the reason for the necessity is placed in the end. (...) And one ought to determine both causes of a natural thing, i.e. both the material and the final cause, but especially the final cause, because the end is the cause of the matter, but not conversely. For the end is not such as it is because the matter is such, but rather the matter is such as it is because the end is such."[31]

In the second place, nature embodies a kind of natural tendency or appetite, intrinsic to its formal essence and in agreement with its potential receptivity. In other words, to be *according to nature* means to behave always in relation to a proper end:

> "Things which happen naturally are done so that they lead to and end. Therefore they are disposed to be done in such a way that they are for the sake of an end. And thus nature seeks an end, i.e. nature has a natural disposition for an end."[32]

Though Aquinas' commentary bears on the philosophy of nature, his mind cannot ignore a more general framework, which is theological in character. He looks at the whole of nature *as creation*, whose being and behaving depend on God's purposive plan. Nature is then compared with a sort of *art*. The good of each creature lies in fulfilling the intrinsic program it has been created for: "Hence, it is clear that nature is nothing but a certain kind of art, i.e. the divine art, impressed upon things, by which these things are moved to a determinate end. It is as if the shipbuilder were able to give to timbers that by which they would move themselves to take the form of a ship. (...) It is clear that nature is a cause and that it acts for the sake of something."[33] In this case, the resort to the notion of "art" is made in a different context. Here, what Aquinas wants to stress is no longer the opposition between a natural thing and an artifact, but rather the observation that the more the skill of an art is put into practise, the more it resembles

something "natural". Since inanimate bodies lack freedom, nature cannot *deliberate*, but it is not an handicap to the beauty and the perfection of its corresponding act: "Nor does the artisan deliberate insofar as he has the art, but insofar as he falls short of the certitude of the art. Hence the most certain arts do not deliberate, as the writer does not deliberate how he should form letters (...). From this it is clear that an agent does not deliberate, not because he does not act for an end, but because he has the determinate means by which he acts. Hence, since nature has the determinate means by which it acts, it does not deliberate. For nature seems to differ from art only because nature is an intrinsic principle and art is an extrinsic principle."[34]

God, the primary cause of the whole of creation, steers the universe towards its end, precisely through the action of each created nature. In a famous passage from his comment on Book XII of Aristotle's *Metaphysics*, Aquinas will say: "The nature of a thing whatsoever is a sort of tendency that the prime mover has inscribed in it, so aiming it toward a proper purpose. For it is clear that natural things act for a purpose--although they are not aware of this purpose--since they have received their tendency toward such purpose from the primary intelligent cause."[35] In the *Summa* a similar argument will introduce the comment on the well known *fifth way*.[36]

God's overall plan for creation, that is, the history of the universe, is written in the formal specificity, i.e. in the nature, of each entity. Final causality operates from within, because of the intimacy of the act of being, and because nature is part of the metaphysical essence that each entity received as its own. Aquinas' universe is an ordered whole composed of parts so interrelated among themselves that they are acting upon one another or being acted upon by one another, in a way that everything is related to something else for the good of the universe as a whole. The more one thing is ordered to God, the more it results ordered with respect to all the other creatures.

Finally, when nature is considered as the complete ensemble of all that exists, its relation with God seems to be no longer that existing between primary and secondary causality, but that of the instrument with respect to its main agent: the whole of creation is a great instrument of God: "The whole of non-rational nature is compared to God as an instrumental to a principal cause."[37]

5. The originality of Aristotelian-Thomistic view of nature

When compared with other views shaped in the forge of ancient Greek culture, Aristotle's conception of nature looks quite original. The kind of

natural philosophy performed by pre-socratic thinkers was aimed at finding out a "special" single element, a sort of "first source" responsible for all the behavior and activity occurring in nature, but the search was confined within the domain of matter. When the quest for this first source was shifted from a single archaic element to the logic of infinite atoms of different species, the overall view remained strongly mechanistic in character. It was Plato, as is known, who gave an important turn to this philosophical reflection, stating that the source for the natural order, growth or activity of things, in order to be stable and real, had to transcend the material world and belong to the world of eternal ideas. The truth of nature is then absorbed in the idea of a cosmic Soul and, finally, in the idea of God. However, once the truth of all natural activity is detached from the world, the autonomy of nature is put up for discussion. The key for knowledge is then shifted from the realism of natural observations to the quest for mere coherence and rationality; the logic of discovery is replaced by the logic of abstract reasoning.

According to the Aristotelian view, indeed, natural things have *in themselves* the source for their order, growth and activity: coherence follows observation. The nature of each thing is not an idea, but a form; it is not the weak image of a truth which lies out of the physical world, but rather an inner principle which let this truth to be known. At the same time it is not a material principle, but mainly a formal one: the priority of intellect over matter is then maintained (as Anaxagoras and Plato set forth), but the *reality* of nature is simultaneously affirmed and so rescued from the world of ideas.[38]

Moreover, the "intrinsic" character of nature has another aspect of originality. It is not conceived as a kind of power or occult quality which dwells in a thing by virtue of an extrinsic agent, a common view among almost all pre-socratic philosophers. Aristotelian philosophy of nature is foreign to any kind of vitalism. Nature is neither a sort of hidden motor-god which moves things from within ("all things are full of gods"--Thales would have said[39]), nor a particle of a cosmic intelligence the whole universe should be imbued with. In order to be an active principle, the Aristotelian concept of nature, as St. Thomas stressed in his Commentary, does not need to be either a *vis insita rebus* or a conventional efficient cause: it is enough for it to function in the line of a genuine formal causality.[40]

If we recall Plato's threefold causal partition among art, nature and chance, we should say that if in Plato's view the behavior of material things is mainly seen as a product of the art of God, and in Aristotle's view it is mainly the expression of their own nature (though in the level of secondary causality),

Aquinas' conception achieves a further synthesis. His insight on the metaphysics of the act of being and on its composition with the essence clarify the harmony existing between the autonomy of the essence and the transcendental participation of being: the cosmos is indeed the work of art of God, but a work that God performs precisely through the autonomy of each created nature.

The originality we are speaking about seems to hold also if we turn to other conceptions of nature employed by modern and contemporary philosophy. On one side we have a number of attempts to interpret the behavior of what is natural in terms of material and mechanical causes only. In other words, Nature is assumed to be a machine. This was, in some way, the belief of Descartes, Spinoza and Comte, of the philosophers of the Enlightment, of the dialectical materialism and then of neopositivism up to the beginning of the XX century. Although showing a spectrum of different colors, the light of their perspective is the same, and remarkably inclined towards a mechanistic view. On the other side we find those attempts originating from the thought of Hegel, and especially from the German *Naturphilosophie* developed by Schelling. They are perhaps the best example of how an idealistic view of Nature is capable of balancing the scale towards the opposite bent. In this second philosophical perspective occurs the revival of modern vitalism, in some way hidden in the thought of Leibniz, and then brought into light by the Romantic reaction to the mechanistic theory of the Enlightment. Similar to some ancient cosmovisions, Nature is seen again as a living organism, moved by a cosmic soul, or by the action of non-mechanical laws, which endow every thing with coherent and vital forces.

A last consideration regards the concept of nature, more precisely that of *reality*, underlying Whitehead's process philosophy. It is worth mentioning that an author like Weisheipl was inclined to find a remarkable similarity with the Aristotelian conception, once the Whiteheadian idea of "life" is grasped in the correct way.[41] I would only add that a careful study of the theme is certainly desirable and it would play a key role in contemporary philosophy of nature. It is known, in fact, that Whitehead's philosophy has a great influence over both scientific and theological circles, many of which are not insensitive to the need to reach a more satisfactory explanation of the relation between God and Nature.[42]

II. Nature, Natural Sciences and Natural Laws

Turning to the questions we put forward in the Introduction, one might ask whether the philosophy of nature of Aquinas' Commentary to the *Physics* has any relevance for a better understanding of the epistemology of the natural laws of physics. Do the elementary properties, the numerical constants or the fixed qualities associated with a phyisical entity, have any relation with the *nature* of that thing? Are the physical laws that science discovers and tries to represent by means of a mathematical language, a visible effect of that regular operating principle expressed by the concept of nature? The entire question, of course, is much more problematic than what, at first sight, a plain correspondence between the philosophical and the physical aspects of our subject might suggest. We should begin by asking, for instance, whether elementary properties of matter have only a conventional value or, by contrast, reflect an objective aspect of the physical world. Concerning scientific laws, we are asked to reconcile the regularity required by the philosophical notion of nature with our approximate, ever changing, or even revolutionary ways of doing science. As we mentioned above, quantum mechanics and complexity are thought to set, in this respect, a noticeable challenge.

Since the previous questions are much more general and profound that the aim of this short essay, my concern will be only to supply some basis to prove the two following statements:

a) the philosophical content we associated with the Aristotelian-Thomistic notion of nature is consistent with the more usual epistemological frameworks employed by contemporary science;

b) the philosophical concept of nature is a notion which both the activity and the intelligibility of natural sciences implicitly rest upon.

We would like to add that the philosophical reflection of scientists, when they comment on their research work, will provide useful insights to achieve this goal. But prior to entering into the theme we need an epistemological clearing up.

1. Nature and determinism: an epistemological clarification

At a first glance, a philosophy of nature sensitive to the notions of regularity and stability could seem more in tune with those mechanistic and deterministic views of physics which have been placed in question by contemporary science. Heisenberg's uncertainty principle, the problem of a *non-local* theory posed by the Einstein-Podolsky-Rosen paradox (or EPR

experiment), by Bell's inequality theorem and, more recently, by the unusual outcome of Aspect's experiment, are all results that have definitively pointed out the limits of that *classical* view of doing science. The physics of irreversible and complex processes has shown that predictability is a privilege owned by quite a few departments of natural sciences. From a more general standpoint it is thus necessary to clarify whether the Aristotelian-Thomistic concept of nature actually involves a deterministic view of physics.

First of all, we should distinguish which kind of indeterminism we are dealing with. If by indeterminism we mean the sheer absence of any ontological determination, that is to deny the possibility that a material entity could be *something specific*, at least under some definite aspect, it is clear that such a view is not reconcilable with that concept of nature we discussed in Section I. The philosophical perspective implicitly assumed by this kind of indeterminism is that of an indefinite, ever changing process of becoming, seen as the *ultimate* explication of what reality is. What such perspective is intended to hold is not only the opinion that reality is a process (a fact about which everyone, though with some nuances, would agree), but that also within and at the bottom of this process, there is no subject at all. The physical world would be the result of indeterminate free choices of indeterminate material elements, without any kind of real persistent principle or rule other than the logical and subjective rules of our reason.

Conversely, if by indeterminism we mean the lack of a mathematical formalism capable of bridling a phenomenon into a predictable space-time history; or, also, the impossibility of foreseeing the whole spectrum of interactions that a certain particle or process might display, including the absence of any reliable algorithm to compute the probabilities associated with that spectrum, then this second kind of indeterminism does not oppose the philosophical concept of nature. The existence of a specific nature of a thing, in fact, means neither the computability of its complete physical behavior (in the sense of the representation of all its possible operations by means of a Turing machine), nor the mind's *a priori* control over all the interactions it might realize. It only means the persistence of a real subject whose way of being and operating is always the same, according to a specific metaphysical substratum. If we assume that reality is a process, then the process itself must be something definite, with principles that are not processes.

We can argue in a similar way concerning the relation between the notion of nature and the old mechanistic view of Nature that present-century science has now disowned. The rationale of that view was to analyze physical

structures in terms of their component elements and to define them reductively, on the basis of the control we achieved over them with the help of a powerful physico-mathematical formalism. The rationale of the Aristotelian-Thomistic concept of nature, on the contrary, is to put the source for intelligibility in the behavior of natural phenomena themselves, leaving them open to the richness of their phenomenology, which is something received from the outer world and not imposed by our mechanistic formalism. The notions of regularity or stability are linked to nature's ontological *relative* necessity, not to its empirical determinism. Moreover, since nature is primarily meant as a form, it fosters precisely the grasping of those unifying and coordinated principles whose role is particularly relevant for today's science, especially for those phenomena or processes that must be approached in terms of their *unbroken wholeness*.[43]

Finally, it should be added that mechanism and determinism, as they were developed especially in the natural sciences of the modern age, did not stem *directly* from the belief in eternal laws imposed by the will of an immutable law-ruler. They were rather the result of the irruption of mathematics and exact computing tecniques into a philosophical environment consistent with that belief. Medieval embryonic science was much less deterministic than the science of the Enlightment, certainly better prepared to endorse Laplace's famous project.

2. The specific nature of physical reality

When scientists approach the study of the material world, they look at natural phenomena trusting in two basic tenets: the principle of *lawfulness* and the principle of *uniformity*. In identical conditions, using the same experimental layout, or within the same logical framework, nature is expected to behave in the same way. When something unexpected occurs, we do not invoke the bare indetermination of reality as a satisfactory explanation for that oddness. The researcher first tries to enlarge his conceptual context, and then searches for a more general or deeper regularity of behavior. Without this presupposition of lawfulness in nature, there would be neither science, nor a universal and communicable know-how.[44]

Stability and regularity are always seen in relation to the *specificity* of the physical world. Nature is not only "something", but "something specific". The fixed physical parameters of an electron; the identical behavior of a photon in identical boundary conditions; the existence of a gravitational field which is always associated with a mass: these are all examples of properties that,

insofar as they are incapable of being furher grounded on ever more basic elementary behaviors, can be legitimately considered *natural* properties. They must embody, at some level, a sort of physical correspondence to the *meta*-physical notion of essence and, when seen in the light of an operating "principle of motion and rest", to the philosophical notion of nature.[45]

A good example of how relevant is an implicit concept of nature for the activity of science, is the reflection of many researchers on the role played by those physical or chemical constants called *constants of nature*. Contemporary cosmology has shed much more light on their importance, by pointing out the fine-tuning they provide for the very existence of the universe and for its coherent evolution towards organized structures, life included.[46] However, well before the more recent discovery of their *anthropic* fine-tuning, Max Planck emphasized that, thanks to their universality, many of these constants allowed us to derive units of mass, length, time or temperature that "are independent of specific bodies and substances, and necessarily keep their meaning for all times and for all cultures, even for extraterrestrial and extrahuman cultures, and which can be designated as natural units."[47]

Such reflections were not offered only by Max Planck or Albert Einstein, whose well known epistemological realism prompted them to maintain that physical constants were something *given* in the deepest ontological sense. Even a scientist like Niels Bohr, whose epistemological framework was notably inclined towards idealism, was impressed by the stability of matter. In a dialogue reported by Heisenberg, Bohr seems to refer to a concept which recalls nearly that of a metaphysical *form*:

> "But for me the starting point was the stability of matter which from the standpoint of traditional physics is a pure wonder... By stability I mean that the same substances always occur with the same properties, that the same crystals are formed, that the same chemical compounds arise, etc. *There is then in nature a tendency to produce specific forms*--I employ the word forms now in the most general sense--and to always reproduce anew these forms, even when they have been disturbed or destroyed."[48]

When expressed in terms of contemporary scientific thought, the Aristotelian-Thomistic perspective is nothing but the suggestion that all natural phenomena rest upon an ontological substratum which accounts for their stable properties and regular interactions. The *stability* of natures, however, does not mean that any change in the value of physical constants or of other basic natural properties would be absolutely impeded; it only means that all natural phenomena must be understood in terms of some ultimate principles of specificity, which allow the world to be precisely what it is and the way it is, and not otherwise.

In agreement with the philosophical realism shared by the largest majority of scientists, such principles are something that science does not create, but receives: natural properties of matter have a character of *givenness*. Science is possible because things have a nature, and things of the same nature have an identical behavior, in the same identical conditions, in different regions of space-time. Within their own method, the natural sciences do not deal with the cause or the origin of those intrinsic principles or of that ontological substratum, because the necessary condition for them "to have a method" is precisely that all that must exist. The philosophical concept of nature stands for science as a source of intelligibility, which anticipates and gives foundation to any experimental description or observation performed on the empirical level. This ontological perspective holds no matter how deep or varied the analyses of science may be, because this ontological perspective concerns a distinct formal object.

3. The world of quantum reality

Are the principle of *lawfulness* and the principle of *uniformity* still meaningful when we turn to the strange quantum world? Without any doubt, the phenomenology of quantum physics involves a concept of *reality* not identical to that employed by our common-sense experience, which is based on a strictly causal, almost deterministic space-time. Here we encounter conceptual entities which seem to be *superpositions* of different realities, as occurrs for the particle-wave dualism, or for the ensemble of quantum states we need to describe the actual state of a particle by means of its Schrödinger's equation. In such a quantum world, Heisenberg's principle puts severe constraints on the determination of what exactly happens, and "a spooky action at a distance" (to quote Einstein's words) seems also to work, at least to account for some odd aspects of non-locality.

If, instead of analyzing which kind of reality might underlie the phenomenology of the quantum world, we simply ask whether such reality is consistent--at least at a certain level--with the presence of those "intrinsic principles of specificity and regularity" we discussed in the previous subsection, I conjecture that the uncertainties introduced by quantum mechanics do not compel us to reject the philosophical concept of nature.

A non-negligible fact is that the odd *microscopic* reality ruled by quantum theory is able to explain the stable and regular behavior of *macroscopic* properties of physical elements and chemical compounds. The computer I now use to prepare this paper, for example, works thanks to the electronic quantum

interchanges put in act by its microprocessors, but I am absolutely sure that the screen will display the same symbols at the action of the same keys and that, once I turn it off, the whole device will work again in few hours--exactly in the same way and without loosing any piece of the typed text.

In addition, many of the physicals constants whose invariant value was seen by scientists as a sort of miracle, are complex combinations of numerical quantities which have a fundamental role in the whole physico-mathematical set-up of quantum theory. The gyromagnetic ratio of the proton g_p, for instance, is a quantity which depends on all the details of strong interaction physics, and it is uniform, within a high degree of accuracy, over the whole observable space-time marked by the positions of distant galaxies and quasars.[49] Similar considerations could be applied to the adimensional constant of electromagnetic interaction α_{em}, which most of the behavior of the atomic structure is based on, or to other physical constants.

As pointed out by John Barrow, a quantum world, along with all its strangeness and indeterminacy, and not a deterministic Newtonian world, is precisely what we need to have stable and regular properties of matter:

> "Although the uncertainties introduced by the quantum picture of reality are often stressed, this same quantum structure is absolutely vital for the stability, consistency, and intelligibility of the physical world. In a Newtonian world, all physical quantities, like energy and spin, can take *any* values whatsoever. They range over the entire continuum of numbers. Hence, if one were to form a «Newtonian hydrogen atom» by setting an electron in circular orbit around a single proton then the electron could move in a closed orbit of any radius because it could possess any orbital speed. As a result, every pair of electrons and protons that came together would be different... There could not exist a well-defined element called hydrogen with universal properties, even if there existed universal populations of identical electrons and protons."[50]

As remarked by John Polkinghorne, "we are presented with a picture of the physical world that is neither mechanical nor chaotic, but at once both open and orderly in its character. A simple everyday notion of objectivity is too limited an account even for physical reality."[51] Thus, the hesitation in accepting an objective reality at the basis of the quantum world depends more on the awareness that our common-sense concepts are inadequate to describe that reality than on the inadequacy of a real and objective world as such.

There is no doubt that the assumption of a completely idealistic perspective, insofar as it states not only a gnoselogical, but also a deep ontological indeterminism, is hard to reconcile with that "intrinsic principle of specificity and regularity" entailed by the philosophical concept of nature. However, none among the milestone experiments of quantum mechanics compel the observer to reject the existence of that realistic, non-indeterministic

substratum of specificity[52]. The rejection of this latter is rather the backlash of an idealistic framework assumed to interpret the odd behavior of some experiments.

The philosophical discussion associated with von Neumann's theorem about the impossibility of "hidden variables" and the discussion related to the "Copenhagen interpretation" of quantum mechanics are perhaps the best known examples of how that idealistic backlash can work. Actually, well before 1966, when John Bell provided a successful criticism of von Neumann's theorem, David Bohm developed at the beginning of the 1950's an interpretation of quantum mechanics, based on the role of hidden variables, which worked as well as the Copenhagen interpretation, but with a much more realistic view of quantum phenomenology.[53] More recently, starting from Mach's original principle of a global action of the universe over every single event and using the ideas contained in the Wheeler-Feynman model of electromagnetic radiation, John Cramer has suggested a "transactional interpretation" of quantum mechanics, which avoids the uncomfortable Copenhagen rule that the status of a quantum event is determined by the observer, whose measurement forces reality to collapse into a specific actual state. The "instantaneous feedback" of an action-at-a-distance process claimed by the Einstein-Podolsky-Rosen paradox (1935), or by the Aspect experiment (1980s), as well as the interference pattern of heavy atom diffraction waves observed in the early 1990's, can all be interpreted in the framework of Cramer's theory, which provided a different view of wave propagation in time when we turn to the microscopic scale.[54] In summary, there are no sound bases to maintain that the principle of lawfulness and the principle of uniformity are not valid also for the quantum world, since the rejection of those principles depends more upon the philosophical perspective assumed *to interpret* that world, than upon the experimental results in themselves.

4. Natural laws and scientific laws[55]

Most of the scientists' reflections quoted above continue to hold when the notion of "natural properties" is extended to include the notion of "natural laws" as well. The belief in their stability and universality underlies the conceptual frameworks of almost all the most productive scientific theories. The principle that physical laws determined in our laboratories apply at all points of space-time is, for instance, the fundamental assumption of cosmology.[56] It is hardly a daring assumption, given that Maxwell equations,

to cite but an example, are accurately valid over a range that spans about 36 order of magnitudes (10^{36}), from the subatomic particles up to size of galaxies.

Although originated in an intellectual context many miles away from that of contemporary science, the philosophical perspective discussed by Aquinas, besides rendering the idea of "natural properties" more understandable, allows the expression "laws of nature" to acquire an objective and meaningful connotation. If the nature of a material entity is the the *principle of motion and rest* inner to each entity, something owned *per se* and not *per accidens*, then the laws of nature that a particular entity is subject to, are nothing but a sort of *ontological substratum* sustaining the whole ensemble of its permitted physical interactions, according to the active/passive operative dispositions proper to the nature of that entity. A similar framework, of course, is consistent only with a realistic, not entirely subjective, intepretation of laws. But where does the realism of natural laws lie?

First of all it must be said that such a realistic view does not imply that the *mathematical* formulations which describe the known physical processes are in nature *as such*. Nor are we obliged to think that the regularities and symmetries we observe are the *real* structure of nature in itself. Though scarcely recognized in many philosophical essays, the point is to realize that the *nature* of an entity (part of which is, for example, the fact that a mass always attracts another mass) is not conceptually identical with the *scientific laws* we formulate to describe its phenomenology (that is, the laws of motion of the newtonian theory of gravitation or the geometrical properties of space-time associated with the field equations of the general relativity theory). We can formulate and manipulate only scientific laws, which are accurate only to a certain degree and are subject to revision. Nevertheless, their knowability and intelligibility rest on the very notion of nature, which makes possible those patterns of regularity and stability among natural phenomena which allow scientific laws to be discovered and expressed in a mathematical fashion. Since scientific laws intend to represent reality as well as possible, the revision of their physico-mathematical form is nothing but a continuous effort to bring science closer to experimental facts.

These formulations cannot reach the laws of nature in themselves but, nevertheless, their own *law* is to describe better and better the underlying regularities of nature. In this way, we can speak meaningfully of scientific progress. The asymptote shown by the increasing improvement of scientific laws is not a matter of mathematics, but rather a matter of philosophy. As we discussed in Section I presenting the notion of nature offered by Aquinas in his

commentary on Aristotle's *Physics*, what a *nature* of a thing is in itself remained something not formally demonstrable, because the ultimate reason of its existence transcended the scope of natural philosophy. Now, we must add that it transcends the scope of empirical analysis too, because such an ultimate reason is the foundation of the domain of science and thus goes beyond its reach. Scientific laws can be discovered, but what nature is, can be only received. Newton offered a good summary of this state of affairs when he said that "from the phenomena of nature we must learn which bodies attract each other, and according to which laws and in which ratios the attraction takes place, before we ask for the cause that produces it."[57] In other words, by the law of gravitation we are able to explain everything except what gravity is.

Despite the skepticism of philosophers of science about the knowledge of an objective reality, the large majority of scientists down through the ages have shared along the epochs a certain epistemological realism with regard to the laws of nature. It was the philosophical stance of authors such as Newton, Maxwell, Planck, Einstein, de Broglie, etc. and, to some extent, that of Heisenberg, Bohm or Feynman.[58] Having in mind what we said above about the distinction between natural and scientific laws, it is worthwhile to read what was recently stated by Paul Davies:

> "It is important to understand that the regularities of nature are real. Sometimes it is argued that laws of nature, which are attempts to capture these regularities systematically, are imposed on the world by our minds in order to make sense of it... Nevertheless, I believe any suggestion that the laws of nature are similar projections of the human mind is absurd. The existence of regularities in nature is an objective mathematical fact. On the other hand, the statements called laws that are found in textbooks clearly *are* human inventions, but inventions designed to reflect, albeit imperfectly, actually existing properties of nature. Without this assumption that the regularities are real, science is reduced to a meaningless charade."[59]

Davies backs his argument with two more observations. The first one is the novelty of many discoveries with respect to the physico-mathematical establishment in which a new law was expected; in a purely idealistic view, in fact, a new law would be recognized only insofar as it is deductively reducible to previous mathemathical theories. The second is the ensemble of connections and open questions that a new good law is able to explain, *beyond the specific field or context* in which a certain regularity was searched for, or the original experiment to check it was planned. If we recall that Richard Feynman spoke of natural laws as "a rhythm and a pattern between the phenomena of nature,"[60] we have to add that the one who plays the music and marks the rhythm is nature itself, not man.

5. The nature of complexity: laws without laws?

If the intriguing aspects of quantum mechanics have prompted some philosophers of science to put in doubt the existence of an objective reality, the physics of indeterministic processes, now commonly called *chaos*, is usually associated with a claim against the very existence of laws as such. Since the emergence of new and richer structures is mainly due to the action of chance fluctuations, the action of eternal and regular laws, if they exist at all, is seen as a restraint upon the development of the creative potentialities of Nature. The origin of new levels of a more complex order is possible only *out of chaos*.[61] In addition, the outcomes of complex processes can be neither formally computed, nor rigorously predicted, because a small change of the initial conditions of the system evolves through the whole process in a highly non-linear way. Having that in mind, is there any room for the Aristotelian-Thomistic concept of nature within the uncommon behavior of complexity?

In the first place, the very idea of *natural* law, as discussed above, does not depend on the predictability of our scientific formulations, and thus mathematical indeterminism does not remove that ontological substratum of formal properties existing in nature. Fluctuations themselves, which provide the birth of new, unpredictable structures far from the equilibrium conditions of high-entropy systems, are described in terms of a precise mathematical framework; it is starting from a definite set of equations that we could evaluate in which conditions and out of which parameters the system becomes *unstable*, and then a totally new equilibrium is able to arise.

In the second place, chaos implies neither the absence of definite information in the nature of things, nor the failure of some regular activity, because the whole chaotic system also develops owing to the action of specific laws. As an example, consider an isotropic and homogeneous interstellar gas cloud. When density oscillations of small amplitude are induced, the system is called back to its previous equilibrium situation. If the amplitude of the oscillations is large enough, then one or more high density lumps soon form and the matter of the gas cloud is subject to a gravitational collapse, giving rise to a star formation burst. The new system, namely a star cluster, is much more organized and much more abounding in physical novelties than the previous one--the difference between them being as evident as the difference between the darkness of the cloud and the brightness of the new group of hydrogen burning stars. However, the reason why something qualitatively new has occurred is not the game of chance but, again, the very action of gravity, which let the oscillations become irreversible and the system collapse; that is,

something which rests upon a specific natural property or, if you want, upon a law of nature.

Analogously, Bénard instability or other types of well known physical instabilities, like the Kelvin-Helmholtz instabilities occurring in the plasma jets of many radio galaxies, are but examples of far from equilibrium conditions of a stationary state which give rise to phenomena of spontaneous and highly ordered self-organization. Nevertheless, they always occur within a specific theory and whenever a number of specific conditions are given. In the case of Bénard instability, for instance, the coherence and the richness of the new highly organized convective structure is not more spectacular than the fact that the water in which convection cells originate has a constant boiling point; or, also, that the instability always occurs when the same temperature gradient is reproduced. It is not without reason that Prigogine himself recognizes that "self-organization processes in far from equilibrium conditions correspond to a delicate interplay between chance and necessity, between fluctuations and deterministic laws."[62]

Similar to the rich, open view of nature now brought about by complexity, forty years ago David Bohm introduced the notion of "qualitative infinity of nature" to provide a more general concept of natural law capable of overcoming the inadequacy of Laplacian determinism.[63] Once the Aristotelian-Thomistic notion of nature is understood as an *open* notion, there are no difficulties, in my opinion, in making it in some way compatible, or even combined, with the philosophical outlook of Bohm's view. It is reasonable, as required by the physicist, that the number of "natures" (in the Aristotelian-Thomistic sense) active in universe must be non-limited, because they represent that "infinity of potentially or actually significant qualities" at the very basis of physical reality.[64] Although his suggestion is basically that of a continuous process of becoming, open to an infinite level of new transient determinations, the infinity he is dealing with does not necessarily imply indeterminism. Nor does the dependency of the qualities of the material entities on the global physical background imply the absence of stable and regular properties: "that the behaviour of the world is not perfectly determined by any possible purely mechanical or purely quantitative line of causal connection", he states, "does not mean, however, that it is arbitrary."[65]

According to Bohm, we cannot handle the qualitatively infinite richness of the universe, and so we perform abstractions and approximations: the task of science is to find the right kind of things that can be abstracted. Such a remark is not far from an implicit distinction between natural and scientific

laws. An objective substratum of intelligibility must exist since our laws "have an objective content, in the sense that they represent some kind of necessity that is independent of our wills and of the way in which we think about things."[66] A purely relational view of being, on the other hand, is not adequate to account for the whole of reality: all the process of becoming, to be intelligible, must rest upon this ultimate necessary substratum.[67] We wish to add that although at a first glance Bohm's perspective seems more in tune with Whiteheadian process philosophy, a view of qualitative infinity of nature is not far from the notion of reality as discussed by Michael Polanyi. In the thought of the hungarian scientist and philosopher, reality is seen as an open system, consistent with an increasing number of hierarchical levels of depth. Each of them reveals an increasing amount of truth and objectivity, in a way that the intelligibility of the outer layers rests upon that of the inner ones.[68]

Finally, a broader context in which the meaningfulness of natural laws has been recently questioned is that of cosmic evolution. Some authors have suggested that the present state of a *lawful* universe would result from the unavoidable development of a primeval state dominated by initial chaotic conditions and characterized by the absence of any law. A different suggestion, within a much wider many-worlds scenario, is that the statistical probability of the existence of an intelligible world endowed with laws of coherent and regular behavior is non-zero, but precisely *that world* is *anthropically selected* by the presence of intelligent observers; their biological evolution, in fact, was possible only in a lawful universe. The full spectrum of all these possible universes could be either the result of some classical machinery, like an eternal pump for cyclical big-bangs, or the infinite number of states of some quantum cosmological function, of which our universe is a particular fluctuation.[69] These two pictures, however, are hardly convincing. They lead, rather, to the contradiction of a universe of "laws without laws". In the first case we could ask by the action of what cosmic evolutionary meta-*law* the present state of the universe was necessarily triggered, since what the initial chaos postulates is precisely the absence of any laws at all. In the second case, we would warn the public that probabilistic regularities or statistical laws are mathematical laws just as good as those of other departments of mathematics.[70]

Epilogue

The contemporary debate on the meaning of natural laws involves in some way also theology, because one might ask whether the epistemological status of these laws could yield any conclusion about the necessity of a Creator. A *realistic* interpretation of natural laws is usually seen to be more in tune with the existence of an objective rationality in nature, and so demanding a transcendental source for that rationality and order. By contrast, an *idealistic* view that puts the idea of a stable and ordered nature only in the subject's mental categories, seems to rule out the existence of an intelligent Creator.

If we assume the first interpretation to be right, a coherent view of the relation between God and Nature has to answer the following questions:

a) How can the autonomy of scientific analysis be adequately understood, especially when the being of the world is seen in the light of its metaphysical dependency on a personal Creator?

b) How might a necessary and eternal Being originate a contingent world, continuously open to change and unpredictability?

c) Finally, since the relation between God and Nature involves the debate between creation and cosmic evolution, could the observation of natural phenomena reveal the presence of any final causality, and so yeld the existence of a global, purposive plan?

The Aristotelian-Thomistic concept of nature, framed in the wider context of the Christian theology of creation, contains some useful insights to shed light on the questions raised above. It seems to entail, in fact, two major implications for the debate between science and theology: it makes clear that the way in which the world depends on God does not fall into the domain of science, and it introduces the notion of finality in a way that does not interfere with the empirical analysis of science.[71]

If creation puts in act a relation by which God brings things into being and causes the existence of their specific nature (through the metaphysical determination of their essence), then the role of a Creator does not hinder the description of the physical universe in its being and becoming. The action of God is as intimate as the act of being, and it is so transcendent as to continuously sustain what each creature performs on the empirical level.[72] This ontological perspective holds no matter how deep or varied the analysis of science may be, because they concern a different formal object. The philosophical concept of nature, as well as the metaphysical notion of essence, stands for science as a source of intelligibility, something which anticipates and gives foundation to any description or observation made on the experimental level. In this way, the question about God is better disentangled

from the debate between realism and idealism: we are not obliged to associate those views with a mechanistic or a non-mechanistic relation between God and the world; they rather represent two different and irreducible philosophical *Weltanschauungen*.

Concerning the second question, it must be said that the adjective *necessary* has a different meaning when we refer to God or to creatures. But the main reason why the ontological necessity and the immutability of God (theology would prefer to speak of God's allegiance to His own promises) does not imply a necessary and unchanging created world, lies in the metaphysics of *creatio ex nihilo*. God is other than things. Things partake of the being of God without being a part of God: the Christian doctrine of the *transcendental participation* of being differs completely from pantheism. Aquinas finds no problem in relating the rich and dynamical content of the concept of nature to the causal action of a necessary and eternal Creator. The link between each creature and its Creator is not a channel that carries into creatures the same properties of God's essence and life. The core of that link is to allow a creature to exist as a subject of formal, potential or active properties; something contingent, it is true, but emerging above the anonymous flux of absolute indeterminism. Something possessing a nature, that is, an ultimate principle which account for its being and becoming and upon which the intelligibility of its physical behavior can firmly rest.

Passing on to the third question posed above, it is well known that many books of popularized science often endorse the commonplace view that finality should be regarded as the action of a "Cosmic Artisan" which controls and steers *from outside* the phenomena of the physical world. Accordingly, the notion of finality is usually seen with a feeling of suspicion by the majority of people trained in scientific work. Aquinas' perspective could easily help to rescue finality from the darkness and to introduce it in a way more suitable for the world of science. As we have seen in Section II, scientists are better prepared to understand the action of a formal causality, because they easily recognize the objective character of givenness shown by natural laws. Now, final causality is nothing but the explanation of the operating aspect of formal causality, as codified in the regular nature of each entity. An historical example of how the relation between nature and finality can work is the one provided by Copernicus in the XVI century. It is surprising to compare what the Polish astronomer said a century before Newton's discovery of the law of gravitation, with a passage already quoted in Section I from Aquinas' Commentary to the *Physics*:

«I myself think that gravity or heaviness is nothing except a certain natural appetency implanted in the parts of the universe by the divine providence of the universal artisan, in order that they should unite in their oneness and wholeness, coming together in the form of a globe.»[73]

«Nature is nothing but a certain kind of art, i.e. the divine art, impressed upon things, by which these things are moved to a determinate end. It is as if the ship-builder were able to give to timbers that by which they would move themselves to take the form of a ship»
(*In II Physicorum*, lectio 14, n. 268).

Once understood in this way, finality is more accessible to the intellectual abstraction of scientists, who know that «the *substance* of the universe is not only mass-energy, but also information. A certain amount of information is coded within the structure of nature; science deals with its decoding. Each discovered law of nature is information which we have been able to read.»[74] If the world is seen to have a purpose, it is simply because this information exists, and it exists as something given by nature, not made by man. This is nothing but to state that *the reason* for such information, like finality, has a transcendental character. The presence of finality does not imply any constraint on the level of experimental analysis, because it remains inaccesible to physico-mathematical formalism. Finality is then the last door which allows to have access to *that ultimate reason* which explains why nature is the way it is. A door which someone has suggested to open with the keys of physics.[75] but whose entrance is probably reserved to those who are prepared to accept that this ultimate reason lies in the loving free will of God.

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[1] Among these essays, we must mention some works, which have greatly influenced, more than others, the interdisciplinary debate: A. EINSTEIN, *The World as I See It* (London: Lane, 1935); IDEM, *Ideas and Opinions* (New York: Crown, 1954); D. BOHM, *Causality and Chance in Modern Physics* (London: Routledge, 1957); W. HEISENBERG, *Physics and Beyond* (New York: Harper & Row, 1962); R. FEYNMAN, *The Character of Physical Law* (Cambridge: The MIT Press, 1965); J. MONOD, *Le hasard et la nécessité* (Paris: Seuil, 1970); F. CAPRA, *The Tao of Physics* (New York: Bantam, 1977); I. PRIGOGINE, I. STENGERS, *Order out of Chaos* (London: Heinemann, 1984).

[2] A. EINSTEIN, *Letter to M. Solovine*, 30.3.1952, English translation quoted by S. JAKI, *The Road of Science and the Ways to God* (Chicago: University of Chicago Press, 1978), pp. 192-193.

[3] J.D. BARROW, *Theories of Everything* (Oxford: Clarendon Press, 1991), p. 197.

[4] P. DAVIES, "The New Physics: a synthesis", in *The New Physics* (Cambridge: Cambridge University Press, 1989), p. 4. The italics is ours.

[5] These *philosophical* questions are tackled in many scientists' recent essays, now become also *classical* in the field of science popularization. Among the others, cf.: R. FEYNMAN, *QED: The Strange Theory of Light and Matter* (Princeton: Princeton Univ. Press, 1985); J. BARROW, F. TIPLER, *The Anthropic Cosmological Principle* (Oxford: Clarendon Press, 1986); S. HAWKING, *A Brief History of Time* (New York Bantam, 1988); J. BARROW, *The World within the World* (Oxford: Clarendon Press, 1988); IDEM, *Theories of Everything*, *o.c.*; R. PENROSE, *The Emperor's New Mind* (Oxford: Oxford Univ. Press, 1989); P. DAVIES, *The Cosmic Blueprint* (London: Heinemann, 1987); IDEM, *The Mind of God* (New York: Simon & Schuster, 1992); S.A. KAUFFMANN, *The Origins of Order* (New York: Oxford Univ. Press, 1993).

[6] On the concept of nature in Aristotle's and Aquinas' natural philosophy, see also the following works: J.A. WEISHEIPL, "The Concept of Nature", in *Nature and Motion in the Middle Age*, W.E. Carroll ed. (Washington :The Catholic University of America Press, 1985), pp. 1-23 (reprinted from *The New Scholasticism* 28 (1954), pp. 377-408); S. O'FLYNN BRENNAN, "Physis. The Meaning of Nature in the Aristotelian Philosophy of Nature", *The Thomist* 24 (1961), pp. 247-265; A. GHISALBERTI, "La concezione della natura nel Commento di Tommaso d'Aquino alla Metafisica di Aristotele", *Rivista di Filosofia Neoscolastica* 66 (1974), pp. 533-540; M.J. NICOLAS, *L'idée de nature dans la pensée de St. Thomas d'Aquin* (Paris: Téqui, 1979); J.J. SANGUINETI, "La naturaleza como principio de racionalidad", *Sapientia* 41 (1986), pp. 55-66.

[7] «Hic distinguit hoc nomen natura: cuius quidem consideratio, licet non videatur ad primum philosophum, sed magis ad naturalem pertinere, ideo tamen hic hoc nomen natura distinguitur, quia natura secundum sui quandam acceptionem de omni substantia dicitur.» *In V liber Metaphysicorum*, lectio 5, n. 808.

[8] Cf. ARISTOTLE, *Metaphysics*, Book V, Ch. IV, 1014b-1015a. Cf. J.A. WEISHEIPL, "The Concept of Nature", *o.c.*, pp. 5-7; S. O'FLYNN BRENNAN, "Physis. The Meaning of Nature in the Aristotelian Philosophy of Nature", *o.c.*, pp. 248-251.

[9] ARISTOTLE, *Physics*, Book II, Ch. I, 192b.

[10] On this point see also *Summa Theologiae* I, q. 115, a. 2, resp.

[11] Cf. *Summa Theologiae*, I, qq. 44-47.

[12] «Deus est in omnibus rebus, non quidem sicut pars essentiae, vel sicut accidens, sed sicut agens adest ei in quod agit. (...) Cum autem Deus sit ipsum esse per suam essentiam, oportet quod esse creatum sit proprius effectus eius; sicut ignire est proprius effectus ignis. Hunc autem effectum causat Deus in rebus, non solum quando primo esse incipiunt, sed quandiu in esse conservantur; sicut lumen causat in aere a sole quandiu aer illuminatus manet. Quandiu igitur res habet esse, tandiu oportet quod Deus adsit ei, secundum modum quo esse habet. Esse autem est illud quod est magis intimum cuiuslibet, et quod profundius omnibus inest: cum sit formale respectu omnium quae in re sunt, ut ex supra dictis patet. Unde oportet Deus sit in omnibus rebus, et intime.» *Summa Theologiae*, I, q. 8, a. 1.

[13] «In operatione qua Deus operatur movendo naturam, non operatur natura; sed ipsa natura operatio est etiam operatio virtutis divinae; sicut operatio instrumentis est per virtutem agentis principalis. Nec impeditur quin natura et Deus ad idem operentur, propter ordinem qui est inter Deum ed naturam.» *De Potentia*, q. 3, a. 7, ad 3^{um}. «Quidquid est causatum secundum aliquam naturam, non potest esse prima causa illius naturae, sed secunda et instrumentalis.» *Contra Gentes*, II, c. 21.

[14] Cf. Wisdom 8:1.

[15] *Summa Theologiae*, I-II, q. 94, a. 5, ad 2^{um}.

[16] *In II liber Physicorum*, lectio 1, n. 142.

[17] «Natura nihil aliud est quam principium motus et quietis in eo in quo est primo et per se et non secundum accidens.» *In II liber Physicorum*, lectio 1, n. 145.

[18] «Dicendum quod de unaquaque re corruptibili dupliciter loqui possumus: uno modo secundum naturam universalem; alio modo secundum naturam particularem. Natura quidem particularis est propria virtus activa et conservativa uniuscuiusque rei.» *Summa Theologiae*, I-II, q. 85, a. 6, resp.

[19] «Haec enim dicuntur esse secundum naturam, quaecumque ab aliquo principio intrinseco moventur continue, quousque perveniant ad aliquem finem; non in quodcumque contingens, neque a quocumque principio in quemcumque finem, sed a determinato principio in determinatum finem: semper enim ab eodem principio proceditur in eundem finem, nisi aliquid impediat.» *In II liber Physicorum*, lectio 14, n. 267.

[20] «Ridiculus est quod aliquis tentet demonstrare quod natura sit, cum manifestum sit secundum sensum quod multa sunt a natura, quae habent principium sui motus in se. (...) Natura autem esse est per se notum, inquantum naturalia sunt manifesta sensui. Sed quid sit uniuscuiusque rei natura, vel quod principium motus, hoc non est manifestum.» *In II liber Physicorum*, lectio 1, n. 148.

[21] Cf. *In II liber Physicorum*, lectio 13, n. 256; *Summa Theologiae*, I, q. 63, a. 9. «Causae naturales deficiunt a suis effectibus propter superveniens impedimentum.» *Summa Theologiae*, I-II, q. 114, a. 7, ad 3^{um}.

[22] «Et dicit quod habentia naturam sunt illa quae habent in seipsis principium sui motus. Et talia sunt omnia subiecta naturae: quia natura est subiectum, secundum quod natura dicitur materia; et est in subiecto, secundum quod natura dicitur forma.» *In II liber Physicorum*, lectio 1, n. 146.

[23] «Naturale dicitur quod est secundum inclinationem naturae (...). Dicitur autem aliquid naturale dupliciter. Uno modo, quia est a natura sicut a principio activo: sicut calefacere est naturale igni. Alio modo, secundum principium passivum, quia scilicet est in natura inclinatio ad recipiendum actionem a principio extrinseco.» *Summa Theologiae*, I-II, q. 6, a. 5, ad 2^{um}.

[24] «(...) et hoc est educi formam de potentia materiae absque additione alicuius extrinseci.» *De Spiritualibus creaturis*, a. 2, ad 8^{um}. Cf. also *Summa Theologiae* I, q. 45, a. 8, ad 1^{um}; *De Potentia* q. 3, a. 8, ad 11^{um}.

[25] Some authors have suggested that, in such a way, even the notion of biologic evolution could be interpreted from a thomistic point of view; cf. on this theme M.J. NICOLAS, *Evolution et Christianisme* (Paris: Arthème Fayard, 1973), Chapts 1 and 2.

[26] «Unumquodque magis dicitur secundum quod est in actu, quam secundum quod est in potentia. Unde forma, secundum quam aliquid est naturale in actu, est magis natura quam materia, secundum quam aliquid est naturale in potentia.» *In II liber Physicorum*, lectio 2, n. 153.

A similar consideration is offered in Aquinas' Commentary on *Metaphysics*: «Unde patet ex dictis, quod "primo et proprie natura dicitur substantia", idest forma rerum habentium in se principium motus inquantum huiusmodi. Materia enim dicitur esse natura, quia est formae susceptibilis.» *In V liber Metaphysicorum*, lectio 5, n. 826.

[27] «Unde manifestum est quod in natura est alterum propter alterum, scilicet priora propter posteriora, sicut et in arte.» *In II liber Physicorum*, lectio 13, n. 257.

[28] «Ponitur autem in definitione naturae *principium*, quasi genus, et non aliquid absolutum, quia nomen naturae importat habitudinem principii. Quia enim *nasci* dicuntur ea quae generantur coniuncta generanti.» *In II liber Physicorum*, lectio 1, n. 145.

[29] Cf. R. ALVIRA, *La noción de finalidad* (Pamplona: EUNSA, 1978), pp. 117-148; J.-H. NICOLAS, "L'univers ordonné à Dieu pour Dieu", *Revue Thomiste* 91 (1991), pp. 357-376.

[30] «Omnia quae fiunt, aut fiunt a casu, aut fiunt propter finem; quae enim accidunt praeter intentionem finis, dicuntur accidere casualiter: sed impossibile est ea quae fiunt semper vel frequenter, accidere a casu: ergo ea quae fiunt semper vel frequenter, fiunt propter aliquid. Sed omnia quae fiunt secundum naturam, fiunt vel semper vel frequenter, sicut etiam ipsi confitebantur: ergo omnia quae fiunt a natura, fiunt propter aliquid.» *In II liber Physicorum*, lectio 13, n. 256.

[31] «Non enim dicimus quod necessarium sit esse talem finem, quia materia talis est; sed potius e converso, quia finis et forma talis futura est, necesse est materia talem esse. Et sic necessitas ponitur ad materiam, sed ratio necessitatis ad finem.

(...) Et naturalis quidem assignare debet utramque causam, scilicet materialem et finalem, sed magis finalem, quia finis est causa materiae, sed non e converso. Non enim finis est talis quia materia est talis: sed potius materia est talis quia finis est talis, ut dictum est.» *In II liber Physicorum*, lectio 15, nn. 272-273.

[32] «Sed ea quae fiunt naturaliter, sic aguntur quod inducuntur ad finem; ergo sic apta nata sunt agi, ut sint propter finem: et hoc est naturam appetere finem, scilicet habere aptitudinem naturalem ad finem. Unde manifestum est quod natura agit propter finem.» *In II liber Physicorum*, lectio 13, n. 257.

[33] «Unde patet quod natura nihil est aliud quam ratio cuiusdam artis, scilicet divinae, indita rebus, quae ipsae res moventur ad finem determinatum: sicut si artifex factor navis posset lignis tribuere, quod ex se ipsi moverentur ad navis formam inducendam. (...) Manifestum esse quod natura sit causa, et quod agat propter aliquid.» *In II liber Physicorum*, lectio 14, n. 268.

[34] «Nec artifex deliberat inquantum habet artem, sed inquantum deficit a certitudine artis: unde artes certissimae non deliberant, sicut scriptor non deliberat quomodo debeat formare litteras. (...) Ex quo patet quod non deliberare contingit alicui agenti, non quia non agit propter finem, sed quia habet determinata media per quae agit. Unde et natura, quia habet determinata media per quae agit, popter quod non deliberat. In nullo enim alio natura ab arte videtur differre, nisi quia natura est principium intrinsecum, et ars est principium extrinsecum.» *ibid*.

[35] «Et ipsa natura uniuscuiusque est quaedam inclinatio indita ei a primo movente, ordinans in debitum finem. Et hoc patet quod res naturales agunt propter finem, licet finem non cognoscant, quia a primo intelligente assequuntur inclinationem in finem.» *In XII Metaphys.*, lectio 12, n. 2634.

[36] Cf. *Summa Theologiae*, I, q. 2, a. 3.

[37] «Nam tota irrationalis natura comparatur ad Deum sicut instrumentum ad agens principale.» *Summa Theologiae*, I-II, q. 1, a. 2.

[38] See on this point J.A. WEISHEIPL, "The Concept of Nature", *o.c.*, p. 5.

[39] Thales' conclusion was reported by Aristotle himself: cf. *On the Soul*, Book I, Ch. 5, 411a.

[40] Cf. J.A. WEISHEIPL, "The Concept of Nature", *o.c.*, pp. 15-17.

[41] Cf. *ibid.*, p. 23.

[42] For an introductory review on this subject, cf. C. WASSERMANN, "Individuality and Flux," *Studies in Science and Theology*, Labor and Fides, 1 (1993), pp. 141-158.

[43] For a review on these changes of perspective in science, see D. BOHM, "Postmodern Science in a Postmodern World," *The Reenchantment of Science*, D. Griffin ed. (New York, 1988), pp. 57-68.

[44] «It is matter of experience that each physical reality in the universe steadfastly insists on being itself; it behaves in a characteristic way and, in a sense, refuses to behave in any other way. In other words, any physical reality manifests determined properties and behavior; and it is through such

characteristics that different realities can be recognized. This is the very foundation of physical science.» J.A. WEISHEIPL, "The Concept of Nature", *o.c.*, p. 16).

[45] The possibility of a *bridge* between these two different, but converging physical and philosophical approaches to the notion of nature has been pointed out by various authors: cf. R.J. CONNELL, *Matter and Becoming* (Chicago: The Priory Press, 1966), espec. pp. 152-157; P. DURBIN, *Philosophy of Science: an Introduction* (New York: McGraw Hill, 1968), espec. pp. 207-214; W.A. WALLACE, "The Measurements and Definition of Sensible Qualities," *New Scholasticism* 39 (1965), pp. 1-25.

«If an electron is an elementary body, then its particular characteristics have their ground in the substantial form (whose *particular* nature is unknown) which, along with primary matter, constitutes the electron's substance... Indeed the physicist comes very close to saying what form truly is. Certainly, the physicist with a theoretical (rather than mechanical) attitude toward his science (a man like Heisenberg, for example) is considerably closer in his philosophical understanding of the fundamental principles of natural things than the larger part of the philosophers. The reason for this superiority is the greater tie the scientist has to the facts. His procedures are stringently measured by them, whereas philosophers find it easy to remove themselves from reality, and many consider their philosophical activities not as an attempt to explain what is given but as an effort to construct an image of it. For this reason, too, the somewhat artificial separation of philosophical problems from those of science, has worked to the detriment of philosophy. And the separation also has, I think, disadvantages for the scientist; for, it leaves his understanding of his science incomplete» (R.J. CONNELL, *Matter and becoming*, *o.c.*, pp. 152-153).

[46] Cf. B. CARR, M. REES, "The Anthropic Principle and the Structure of the Physical World," *Nature* 278 (1979), pp. 605-612; J. BARROW, F. TIPLER, *The Anthropic Cosmological Principle*, *o.c.*.

[47] Words by M. Planck, quoted by S. JAKI, *The Roads of Science and the Ways to God*, *o.c.*, p. 170.

[48] Words by Niels Bohr in W. HEISENBERG, *Der Teil und das Ganze* (Munich, 1969), translated and quoted by E. CANTORE, *Scientific Man. The Humanistic Significance of Science* (New York: ISH Publications, 1977), p. 97. The italics is ours.

[49] Cf. A. TUBBS, A. WOLFE, "Evidence for Large-Scale Uniformity of Physical Laws," *The Astrophysical Journal Letters*, 236 (1980), pp. 105-108.

[50] J.D. BARROW, *Theories of Everything*, *o.c.*, p. 197.

[51] J. POLKINGHORNE, "The Quantum World," in *Physics, Philosophy and Theology. A Common Quest for Understanding*, R. Russell, W.R. Stoeger, G.V. Coyne, eds. (Città del Vaticano, 1988), p. 341.

[52] On the epistemological legitimacy of building satisfactory views of quantum reality or quantum ontologies see also S. BERGIA, V. FANO, "The Search for a Quantum Reality," *The Foundations of Quantum Mechanics,* (Dordrecht: Kluwer, 1995), pp. 43-58.

[53] Cf. D. BOHM, "A Suggested Interpretation of Quantum Theory in Terms of "Hidden" Variables," *Physical Review* 85 (1952), pp. 166-193.

[54] For a recent review on Cramer's suggestion, cf. J. GRIBBIN, *Schrödinger's Kittens and the Search for Reality* (Boston-New York: Little, Brown & Co., 1995).

[55] Cf. on this theme: R. FEYNMAN, *The Character of Physical Law*, *o.c.*; D.M. ARMSTRONG, *What is a Law of Nature*, (Cambridge: Cambridge University Press, 1985); J. BARROW, *The World within the World*, *o.c.*, Chapts. V and VI; IDEM, *Theories of Everything*, *o.c.*, Chapts. II, V and VII; P. DAVIES, *The Mind of God*, *o.c.*, ch. III; *Quantum Cosmology and the Laws of Nature*, R. Russell, N. Murphy, C. Isham eds., Città del Vaticano 1993, (espec. the contributions by W.R. Stoeger, P. Davies and J. Polkinghorne).

[56] For more information on this point see the volume S. HAWKING, G. ELLIS, *The Large Scale Structure of Space-Time* (Cambridge: Cambridge University Press, 1973).

[57] I. NEWTON, *Opticks*, Query no. 31.

[58] Consider, for example, Heisenberg's words: «One is almost scared by the simplicity and harmony of those connections which nature suddenly spreads out in front of you and for which you were not really prepared... However, when one stumbles upon these very simple, great connections which are finally fixed into an axiomatic system the whole thing appears in a different light. Then our inner eye is suddenly opened to a connection which has always been there--also without us--and which is quite obviously not created by man.» W. HEISENBERG, *Der Teil und das Ganze*, *o.c.*, translated and quoted by O. PEDERSEN, "Christian Belief and the Fascination of Science," in *Physics, Philosophy and Theology*, *o.c.*, pp. 132-133.

[59] P. DAVIES, *The Mind of God*, *o.c.*, p. 81.

[60] Cf. R. FEYNMAN, *The Character of Physical Law*, *o.c.*

[61] This is the thesis maintained by Prigogine and Stengers in their well-known essay *Order out of Chaos*; a thesis that would provide the basis, in the authors' view, for a new reenchantment of nature. «One of the main sources of fascination in modern science was precisely the feeling that it had discovered eternal laws at the core of nature's transformations and thus had exorcised time and becoming... This feeling of confidence in the *reason* of nature has been shattered... A new unity is emerging: irreversibility is a source of order at all levels.» (London: Flamingo, 1988[3)], pp. 291-292.

[62] I. PRIGOGINE, I. STENGERS, *Order out of Chaos*, *o.c.*, p. 176.

[63] Cf. D. BOHM, *Causality and Chance in Modern Physics*, *o.c.*, pp. 130-170.

[64] Cf. *Ibid*, p. 134.

[65] *Ibid*, p. 159. «There is, however, one general statement that can be made at this point about the inexhaustible diversity of things that may exist in the universe; namely that they must have some

degree of autonomy and stability of their modes of being. Now, thus far, we have always found that such autonomy exists. Indeed, if it did not exist, then we would not be able to apply the concept of a "thing" and there would then be no way even to formulate any laws of nature.» *ibid.*, pp. 139-140.

[66] *Ibid*, p. 165.

[67] «Even though the existence and the characteristic defining the mode of being of any given thing can, and indeed must, be contingent on other things, that of the infinite totality of matter in the process of becoming cannot, because whatever it might be contingent on is also by definition contained in this totality» i*bid*, pp. 168-169.

[68] Cf. M. POLANYI, *Personal Knowledge* (London: Routledge, 1958), pp. 5, 15, 37, 43, 64.

[69] For a review on the origin of natural laws in a cosmological context, cf. G. ELLIS, "Majot Themes in the Relation between Philosophy and Cosmology", Venice Conference on Cosmology and Philosophy, 15.12.1989, published in *Memorie della Società Astronomica Italiana* 62 (1991), pp. 553-605.

[70] Cf. M. HELLER, "Singularities, Quantum Creation, History and Existence of the Universe," *Philosophy in Science*, Pachart, 5 (1993), pp. 33-49.

[71] Additional analysis on this same theme can be found in my articles: "A Comment on the Relation between Christian Theology of Creation and Contemporary Cosmology," *Studies in Science and Theology*, Labor et Fides, 2 (1994), pp. 26-36; "Nature as Creation," *Philosophy in Science*, Pachart, 6 (1995), pp. 77-95; "The Relevance of the Aristotelian-Thomistic Concept of Nature to the Contemporary Debate between Science and Theology," *Annales theologici* 9 (1995), pp. 107-125.

[72] Cf. *Summa Theologiae*, I, q. 8, a. 1; q. 83, a. 1; q. 104, a. 1.

[73] «Equidem existimo gravitatem non aliud esse, quam appetentiam quandam naturalem partibus inditam a divina providentia opificis universorum, ut in unitatem integritatemque suam sese conferant in formam globi coëuntes.» N. COPERNICUS, *De Revolutionibus Orbium Coelestium* (Norimbergae, 1543), Book I, Ch. IX; English translation in *The Philosophers of Science*, R. Linscott ed. (New York, 1947), p. 62.

Kant, who rejected the significance of teleology within the frame of his *Critique of the Pure Reason* (1781), offered a reflection similar to Copernicus' in one of his earlier works, a treatise about the origin of the solar system (1755): «God put a secret art into the forces of nature so as to enable it to fashion itself out of chaos into a perfect world system.» *Universal Natural History and Theory of the Heavens* (Ann Arbor: Univ. of Michigan Press, 1969), p. 27.

[74] M. HELLER, *The World and the Word* (Tucson: Pachart, 1986), p. 45.

[75] «If we find the answer to that, it would be the ultimate triumph of human reason--for then we would know the mind of God.» S. HAWKING, *A Brief History of Time*, *o.c.*, p. 175.