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Ruđer Bošković and the Structure of the Experience of Scientific Discovery

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Abstract

Ruđer Josip Bošković (1711-1787) was a Jesuit priest and a scientist from the former Republic of Dubrovnik in today's Croatia. He published many works in such fields as mathematics, physics, astronomy and geodesy. According to Werner Heisenberg, Bošković's "main work, Theoria Philosophiae Naturalis, contains numerous ideas which have reached full expression only in modern physics of the past fifty years." The question that this paper seeks to elucidate is what enabled Bošković to anticipate the discoveries of modern physics. Because Bošković could not avail himself of the resources and instruments by which modern theories are validated, it is assumed that there exists a mechanism of subjective validation that allowed him to accept the truthfulness of his ideas. It will be argued that this mechanism of internal validation is very similar to the process of spiritual transformation. More specifically, using Polanyi's notion of twofold awareness (subsidiary and focal), it will be shown that this mechanism is best explained by the fact that when an idea has been fully internalized by a person so that it has become an instrument by which that person makes sense of the world and interacts with it, it acquires by this process an enormous credibility.

> *"To some extent, Bošković was able to identify many of the realities that constitute the conceptual framework of modern physics and chemistry."*

Ruđer Josip Bošković (1711-1787) was a Jesuit priest and a scientist from the former Republic of Dubrovnik in today's Croatia. He published many works in such fields as mathematics, physics, astronomy, geodesy and even archeology.* He is also known as being the first natural philosopher to have formulated a unified theory of forces that tried to explain all the phenomena of the observable universe. Bošković's theory is based on the concept of field, thus anticipating Faraday and Maxwell in their speculations about the substratum of phenomenal world. He also proposed an atomic model similar to that of Niels Bohr, that is, a model that accounts for the notion of discrete and stable orbits. His theory of forces foresaw

* See in the Bibliography a sample of the works published by Bošković in those fields. Although he mainly published in Latin, some of his works were translated into French and, more recently, into Croatian. As far as the author knows, only his main work, *Theoria Philosophiae Naturalis*, has been translated into English.

as well the existence of what came to be known in physics as quantum confinement. To some extent, Bošković was able to identify many of the realities that constitute the conceptual framework of modern physics and chemistry. Corroborating this affirmation, Werner Heisenberg said in 1958: "The remarkable concept that forces are repulsive at small distances, and have to be attractive at greater ones, has played a decisive role in modern atomic physics: In chemistry, in the constitution of matter out of atoms, Bohr's quantum theory of atomic structure can be related precisely to this concept, and the study of the atomic nucleus over the past thirty years has taught us that the particles which make up the atomic nucleus, protons and neutrons, are held together precisely by such a force."* And to highlight Bošković's power of anticipation, he added: "His main work, *Theoria Philosophiae Naturalis*, contains numerous ideas which have reached full expression only in modern physics of the past fifty years, and which show how correct were the philosophical views which guided Bošković in his studies in the natural science."† Finally, his theory of forces, which is represented by a simple curve identifying points of cohesion and non-cohesion, can account for the stability of material structures as well as their points of highest volatility. In other words, his theory easily accommodates the notion of attractor and that of point of bifurcation, notions that are important constituents of any modern theory of chaos.‡ One may ask at this point what exactly enabled Bošković to have these intuitions into the nature of reality.§

"Ideas are not isolated islands spread out over a vast ocean, but are rather part of a few continents in which continuity between their various features is to be found at a deeper level."

One possible approach for answering that question is to look, as just hinted, into the philosophical views underlying Bošković's theory. This approach assumes that our ways of looking at reality are expressions of a deep-rooted cognitive structure, a conceptual system, to use William Byers' expression that, once it becomes more explicit, allows us to see the interrelations between what appeared to be at first sight unconnected if not contradictory. To use an analogy, ideas are not isolated islands spread out over a vast ocean, but are rather part of a few continents in which continuity between their various features is to be found

* Cited in Dadić, *Ruđer Bošković*, p. 126.

† Idem, p. 127.

‡ In this regard, note the following passage from the *Theoria* (§468): "Suppose that from the sea there rises a mountain of considerable height, and that along the sides of it there lie immense masses of huge stones, and the higher one goes, the smaller the stones are; until towards the top the stones are quite small, and at the very summit they are mere grains of sand. Also suppose that all of these are just in equilibrium, so that they can be rolled down by a very slight force compared with their whole volume. If, now, a little bird on the top of the mountain moves with his foot just one grain of the sand, this will fall, and bring down with it the small stones; these as they fall, will drag with them the larger stones, and these in their turn will move the huge boulders. There will be an immense collapse and a huge motion; and as all these stones fall into the sea, the motion will communicate itself to the sea and cause in it a huge agitation and immense waves, and this vigorous motion of the water will last for a very considerable time. The little bird disturbed the equilibrium of the grain of sand with a very slight force; gravity produced the remaining motions, and it obtained its opportunity for acting through the slight motion of the little bird." [Child, p. 329]

§ In addition to one's understanding of the basic structure of reality, Stipe Kutleša, in his book *Ruđer Josip Bošković*, argues that Bošković "was able to formulate the continuum of real numbers, thus becoming a forerunner for German mathematicians Julius Wilhelm Richard Dedekind (1831-1916) and Georg Cantor (1845-1918). He predicted the problem of "geometry of nature", by giving instructions for the building of two fractal structures, i.e. curves which do not have tangents in any of the points (snow flake of Koch's curve—which is named after the Swedish mathematician Helge von Koch, 1904). The mathematical fractal theory, which was discovered in the 20th century, is based on this very thought." (Kutleša, p. 107).

at a deeper level, for instance, at the stratum of the tectonic plates. As examples of such continents, we have the notion of non-divisible material objects as the basis of all atomic theories of reality, theories that have triggered a search for the ultimate building blocks of our observable world. New speculations in modern physics, for instance those incorporating the notion of dimensionless quarks or the idea of string as fundamental elements of reality, seem to have frustrated this several centuries long aspiration. If these speculations have not completely led us to abandon such a search, at least they have forced us to consider the concept of a particle as nothing more than a useful device to make sense of our mathematical equations knowing perfectly well that this concept has no ontological pretensions whatsoever.

Another way to illustrate this first approach is to talk about, as Lee Smolin does in his books *Three Roads to Quantum Gravity* (2001) and *The Trouble with Physics* (2006), specific roads that have been followed by important scientists throughout history. These roads are distinguished by fundamental features like the nature of space and time, that is, whether it is absolute or relative. In this regard, Smolin says that a scientist like Newton always assumed a background dependent reality, namely, that "there exists a fixed, unchanging background that provides the ultimate answer to all questions about where and when."* In contrast to this fundamental assumption, we have Leibniz and Einstein who advocated the concept of background independence where there is no fixed framework of reference and consequently, that a reality is defined in terms of its relation to another reality. Smolin further argues that the progression of modern physics along these two roads has led it to a state of crisis and that a third road has to be opened for further progress, especially at the theoretical level. It is interesting to note that Smolin believes that this third road has already been opened by Faraday and Maxwell with their fundamental concept of field, the very idea that is, as mentioned earlier, on the basis of Bošković's theory.

It is up to the historians of science to determine how genuine is Bošković's intuition as one can always be fooled by false similarities occurring at the level of the language used to express views about reality. However, this first approach as a way to answer our initial question is valid only if we enjoy the benefit of a retrospective view of the evolution of scientific thoughts. Without this retrospective view, all intuitions and original ideas are more or less the same. There was a time when it was impossible to decide, empirically speaking, between a Copernican explanation of the solar system or a Ptolemaic one. For an external observer, an intuition is just a hypothesis, a figment of someone's imagination. Even for the person who generates a far-reaching intuition, it remains that there is almost no way to confirm its validity. Moreover, the reason why we say that an idea is far-reaching is because it presents itself as a solution to problems that were not yet formulated at the moment it was imagined. How then was it possible for Bošković, knowing the state of the intellectual environment in which he evolved, to have so much confidence in his intuitions to a point where he was ready to elaborate from them an entire system of thought? He was even willing to stake his own reputation as a scientist on such ideas that verged, at least for his 18th century colleagues, on lunacy, for example the claim that there is no such thing as hard matter, that it is possible to walk through walls or that we may consider the existence of multiple and parallel universes.

* Smolin: 2001, p. 25.

Thus, our initial question is not only related to determining the origin of an intuition, but also to understanding the reasons why those who generated such intuitions, and those who accepted them as true, are sometimes passionately committed to defending them even when the means to offer a clear objective proof for their validation are not available. In this regard, we may think of Galileo who had the courage to face the Roman Inquisition in order to defend heliocentrism or Einstein who knew about the validity of his theory of general relativity before Arthur Eddington confirmed it by his observations of the solar eclipse of May 29, 1919.* Consequently, we have to assume that there exists a mechanism of subjective validation that enables one's intuitions to persist over time and, to use an evolutionary model, to survive in a hostile intellectual and social environment. What exactly is this mechanism? What are its epistemological (its objective dimension) and existential (its subjective dimension) implications? These are the main questions that constitute our second approach by which I would like, in this article, to explain Bošković's power of anticipation or the source of his intuitions. This second approach is not meant to invalidate such means of external validation as experimentation, observation and measurement. It rather seeks to explore the nature of the connection between a knower and that which that knower holds to be true.

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Details of Bošković's epistemological approach are scattered all over his works. He nevertheless offers a summary at the beginning of his *Theoria Philosophiae Naturalis,* where he expounded his unified law of forces. It goes as follows:

> I put on one side all prejudices, and started from fundamental principles that are incontestable, and indeed are those commonly accepted; I used perfectly sound arguments, and by a continuous chain of deduction I arrived at a single, simple, continuous law for the forces that exist in Nature. The application of this law explained to me the constitution of the elements of matter, the laws of Mechanics, the general properties of matter itself, and the chief characteristics of bodies, in such a manner that the same uniform method of action in all things disclosed itself at all points being deduced, not from arbitrary hypotheses and fictitious explanations, but from a single continuous chain of reasoning.†

In order to highlight the existential component of his approach, I would like to juxtapose with this quotation a second one which is also taken from his *Theoria.* It is to be found in the dedication of his work to the Count of Migazzi:

> Of a truth, that well-known old saying, "What you do, DO," which from your earliest youth [...] had already fixed itself deeply in your mind, has remained firmly implanted there during the whole of the remainder of a career in which duties of the highest importance have been committed to your care. Your strict observance of this maxim in particular, joined with those numerous talents

* In fact, Einstein was so convinced of the validity of his theory that, when asked by Ilse Rosenthal-Schneider whether he was worried about the possibility of having his theory refuted by Eddington's observations, he replied: "I would feel sorry for the good Lord; the theory is correct". (Rosenthal-Schneider, p. 523)

† Child, p. 25.

> so lavishly showered upon you by Nature, and those virtues which you have acquired for yourself by daily practice and unremitting toil, throughout your whole career, forensic, courtly, and sacerdotal, has so to speak heaped upon your shoulders those unusually rapid advances in dignity that have been your lot.*

On the basis of these two quotations, I believe that it is possible to establish the fact that there is in Bošković's mind a close connection between the process of scientific discovery and that of moral development. This fact should help us better understand some of the implications of his scientific method.

First of all, we may assume that Bošković's use of the word *continuous,* in both the phrases *by a continuous chain of deduction* and *from a single continuous chain of reasoning*, indicates some form of sustained commitment. In this regard, Dubravko Tadić is also of the opinion that this continuous chain of deduction involved some degree of mental discipline. While discussing what could have been different in Bošković's approach from the modern scientific methodology, he says: "In the 'fundamental and incontestable' principles used by modern science there are some, at least minor ones, which resulted from Bošković's relentlessly thinking sustained by tremendously disciplined mental effort."† Such sustained efforts are, as it is well-known, an important requirement for any subjective transformation.

Secondly, Bošković's continuous chain of deduction has its starting point in the acceptance of fundamental principles that are incontestable as well as commonly accepted. Here, there is no indication that these fundamental principles were experimentally proven so that we have to presuppose, like the Count of Migazzi did with his maxim, that Bošković accepted them on trust.

Finally, the entire process led him to the realization of an idea whose plausibility was subsequently enhanced by observation of the phenomenal world. This realization is an objective event, as it can be communicated, evaluated, etc., like the Count's moral transformation which was witnessed, I assume, by many people.

The similarity between these two passages is therefore based on the fact that they share the same presuppositions with regard to the process of creation, be it the acquisition of a virtue or the emergence of a new idea. Indeed, it requires the acceptance *a priori* of an idea followed by some form of commitment to that idea. These would be some of the ingredients necessary to bring about an experience of creation. Here, it may be interesting to note that, from the point of view of the modern scientific discourse, especially the one supported by the positivist presuppositions, these ingredients are not acceptable as this discourse exclusively advocates the cultivation of an attitude of doubt toward all affirmations and the use of experimentation and quantitative measurement as the only means of validation.

Another important evidence that shows that there exists a connection between scientific creativity and the cultivation of virtues may be given by looking at the cognitive aspect of

* Idem, p. 24.

† Tadić, p. 121.

what is meant by the term *continuous*. If previous evidence suggested that this term refers to a sustained act of commitment, that is, as an expression of one's motivation, the present one is related to the type of mental activity that is being sustained and nurtured by this act of commitment.

In addition to the summary of his epistemological approach given above, Bošković often refers to the practice of *reflexio* as an instrument that guides him into his exploration of reality. According to Peter Henrici, *reflexio* is not to be understood in terms of the "psychologically reflective ability with which the consciousness (the mind) can perceive its own operation," but rather in the sense of "active thinking: "meditatio quaevis" or "rectae rationis usus"".[*] In this meaning, *reflexio* has above all the function of a critical examination and correction of ideas. It is also the ability to realize "the limits of our sensitive knowledge and thus also to think beyond these limits."[†] It is precisely this last function that makes *reflexio,* still according to Henrici, "the most important faculty of cognition"[‡] for Bošković, since it sets into place, as I am going to show, the conditions for the emergence of a new idea.

This practice of *reflexio* has its equivalent in Indian religions, especially within the various mystical schools of Hinduism and Buddhism. As a matter of fact, many terms are used to describe this practice depending on the intensity of the cognitive process involved. For example, there is *vicâra* (pondering over), *manana* (meditation), *nididhyâsana* (contemplation). They are sometimes regrouped under the term *tarka,* which, according to one of the mystical schools of Hinduism (Advaita Vedânta), "is needed (i) to ascertain the purport of scriptural passages, (ii) to remove doubts and contrary beliefs, and (iii) to convince us of the probability of the existence of what is to be known."[§] In other words, *tarka* is a cognitive operation that continuously questions the validity of the primary ideas derived from the senses, ideas that are tying us to a fundamental but deficient or limited way of looking at things. It also prepares the ground for the emergence of a new vision or 'conceptual system', to use Byers' terminology once again. It does so on the basis of accepting *a priori* a fundamental principle. A famous example of such a principle is the idea that the entire universe is Brahman, the ultimate reality, and consequently, that the phenomenal world, as we experience it, is just an illusion.

The comparison between *reflexio* and *tarka,* a cognitive function essential to the process of spiritual transformation, thus indicates that Bošković's approach to the investigation of the phenomenal world shares some features with the practice of mystical contemplation. What all mystical contemplations have in common, no matter the religious traditions they are issued from, is a relativization of sense experiences as means of knowledge. However, this relativization is not the product of following some kind of methodological diktat, but rather the fruit of a specific cognitive operation. Indeed, one can say that the purpose of *reflexio*, as well as that of *tarka*, is to add another organ of perception, this time, a mental one, by which the world is to be seen and investigated. In other words, prejudices resulting from an

* Henrici, p. 30.

† Idem, p. 36.

‡ Idem, p. 31

§ Satchidananda Murty, pp. 149-150.

experience of reality through the five senses are questioned or regulated, not on the basis of *a priori* doubt, but by adding another sense.

This way of relativizing sense experience is not different from what we usually do when we do not accept an idea produced by an experience derived from one type of sensation on the basis of another impression resulting from an experience caused by a second type of sensation. Similarly, today, when we look at a sunrise in the East or a sunset in the West, we "see" that it is the earth that is moving and not the sun. This impression is possible because we have internalized the idea that the earth moves around the sun. Thus, by accepting an idea as true and by cultivating an awareness of its implications by the process of intense contemplative reflection, it becomes part of one's cognitive apparatus with which we look at the world.

It might be worthwhile to consider more thoroughly this process of internalization by which an idea is transformed into an instrument of perception. Similar to using instruments like microscopes and telescopes, the validity of ideas accepted *a priori* is established by the quality of one's observation of the world. If, for example, it allows us to see phenomena in a way unnoticed before or simply to discover entirely new ones, we come to have more trust in them. Inversely, the impossibility of understanding a phenomenon by observing it through one's instrument, be it a physical device or an idea, forces us to question its quality and even its usefulness. From this point of view, one can say that there is no substantial difference between an idea that has become part of one's cognitive apparatus and a device like a telescope as both are instruments through which we look at reality.

We could go further in the analysis of this process by defining what is meant, cognitively speaking, by *quality of one's observations*. As mentioned above, this is the validating experience that confirms the trustworthiness of one's instruments of observation or *a priori* accepted ideas. Firstly, one may ask, what do we see when we observe the world? We see all kinds of things, but what essentially attract our attention are asymmetries. What are these asymmetries? There are discrepancies between our observation of the world and a tacit vision that accounts for our subjective or existential sense of order or harmony. It is tacit because, either it has been acquired from infancy in a more or less unconscious way on account of our interaction with the world—Bošković would even argue that parts of this vision were acquired while we were in the womb—or, if it has once been the object of a conscious and explicit realization, it has been pushed back at the level of implicit assumption by the process of internalization just mentioned. What the *a priori* acceptance of an idea is going to accomplish is to force us to refocus or redirect our attention so that we become more aware of the cause of the discrepancies and, by the same token, are able to formulate a question by which we are going to prepare the ground for the emergence of an answer. That answer will be accepted as valid if it brings about a new vision of reality—this is its cognitive component—and, as the existential component, an experience of reconciliation in the ways we interact with the world. Perhaps, another detour to the Asian spiritual traditions, more precisely the Zen tradition of Japan, might help us better understand the role of a question, issued from an idea accepted *a priori*, in bringing about a new reconciliatory view of reality.

The purpose of Zen meditation, especially in the Rinzai school, is to generate an experience of Satori or awakening through the resolution of a kôan. A kôan is like a riddle such as "Two hands clap and there is a sound. What is the sound of one hand clapping?" Victor Sogen Hori described the experience of Satori as follows:

> At the extremity of his great doubt, there will come an interesting moment. This moment is hard to describe but on reflection afterward we might say that there comes a point when the monk realizes that he himself and the way he is reacting to his inability to penetrate the kôan are themselves the activity of the kôan working within him. The kôan no longer appears as an inert object in the spotlight of consciousness but has become part of the searching movement of the illuminating spotlight itself. His seeking to penetrate the kôan, he realizes, is itself the action of the kôan that has invaded his consciousness. It has become part of the very consciousness that seeks to penetrate itself. He himself is the kôan. Realization of this is the response to the kôan.*

Thus, the idea which has been *a priori* accepted, that is, the fact that there is no essential distinction between an observer and the observed world, has crystalized itself into a specific question, which is here the kôan, to serve as a kind of pike that shatters the deficient dualistic vision of reality. This transformation is made possible not when an idea has been rearranged to fit with other ideas, in a way similar to what we do when we try to assemble the pieces of a puzzle—this would be an example of analytical thinking—but rather when the unique piece that seems to upset the previous vision of reality has become so to speak fully transparent. What does it mean to become transparent and why is this essential to the process of subjective validation? This is the last point that remains to be explained so that we have a complete picture of what this process consists of.

The experience of transformation that allows us to see a new order in the world does not imply that the elements that constitute that world are going to be revoked or occulted. On the contrary, as a result of a reorganization of their relations, they are seen with a renewed sharpness. To use an analogy, it would be like first seeing a triangle and then, by adding an inverted triangle within the first one, we come to see that it is in fact made of four smaller triangles. However, as we focus our attention on the four triangles, we somewhat forget about the first one. In reality, this latter triangle is still seen, but in a different way.

In this regard, Michael Polanyi suggested that the seeing of the four triangles is an experience of focal awareness, while the initial triangle is now being seen subsidiarily. It is important to note that without the subsidiary awareness of the initial triangle, the focal awareness of the four triangles is not possible. To explain what appears to be a causal relationship between two different ways of experiencing the world, he gives as an analogy of the impression of depth seen in a picture by using a stereoscope. A stereoscope is a device by which two photographs of the same object taken at slightly different overlooking positions are viewed as one picture. This new picture is qualitatively different as it is seen as

* Hori, p. 30.

possessing three dimensions. In this context, we can say that the two photographs function as instruments or are *subsidiaries* to our seeing the *joint* picture.

With practice, however, it is possible to experience the impression of depth without a stereoscope. To achieve this, one will have to undergo a training similar to that of the Zen kôan meditation where the possibility of seeing a three-dimensional picture is accepted *a priori* and the idea is used to bring about a distance from the sense experience that ties us to either one of the two pictures. In other words, we do not commit ourselves to the primary two-dimensional impressions derived by the senses while looking at the photographs individually. Like a mantra we keep repeating in our mind, we may try to cultivate that sense of distance by constantly telling ourselves that these two photographs can be seen in a different way. Eventually, if we sustain our effort, the joint three dimensional picture reveals itself and the cognitive experience of discovery is accompanied by an experience of emotional soothing.

Now that we have a model providing a general explanation of the mechanism of subjective validation, I would like to apply it to Bošković's continuous chain of deduction. This will enable us to see the cognitive structure of his theory of forces as a whole as well as the specific steps of its emergence. This will be accomplished by looking again at this chain, this time, not as a whole, but at its particulars.

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Since the formulation of the law of gravity by Newton, action at a distance was more or less accepted as a possibility to explain the cause of the interaction between objects. However, it still met with strong resistance especially by those who advocated that the cause of all movements had to be reduced to a physical contact. Which type of cause is real, which one is an illusion? Does nature offer two types of cause, one for the cosmological objects and one for the sub-lunar world? These were the questions that were generated by accepting the validity of Newton's discovery and which greatly preoccupied Bošković. In short, his solution will be to say that objects never touch each other and that their movements are regulated by one single force that can be attractive or repulsive depending on the distance between them. Let's see how he arrived at his solution.

According to Ivica Martinović, the deductive chain, or the line of reasoning that led Bošković to his original concept of forces acting between particles of matter, consists of four distinct elements: (1) analogy and simplicity in nature; (2) a critical approach to the results of experiments and to the capacities of the senses; (3) the distinction between mathematical and physical contact; and (4) the principle of continuity in nature.*

Superposing the model of subjective validation suggested above, we could say that the acceptance of the principle of simplicity as an *a priori* challenges the idea that there are two ways of creating movement in nature. Since that idea is the result of sense experiences, the acceptance of the notion of simplicity forces us to take a distance toward what is given from our observation of certain phenomena. This experience of detachment translates itself in the

* Martinović, p. 67.

present context into an explicit cognition, namely, that mathematical contact as a negation of distance between objects has to be a prejudice. This implies that even if we have an impression of contact between objects, they never touch each other or there is always a distance between them. As such, this explicit cognition is a negative statement, as it denies the possibility of having two types of contact, and it is at the same time a question in the sense that it forces us to imagine one single principle by which the fact of always having a distance between objects will be expressed. For Bošković, that principle was that of continuity, a principle that was already formulated by Leibniz, but is now the result of an experience of resolution brought about by an intensive investigation or *reflexio*. In other words, the notion of contact, as an expression of the idea of discontinuity, having been refuted, has now given room to that of continuity. Although it is for us impossible to verify, that realization must have been validated by an experience of cognitive and affective transformation as there is no obvious connection between absence of contact and continuity or, to use Polanyi's expression, a logical gap had to be crossed to bring about that realization.

It is to be noted that the principle of continuity is now a reality available to be tested, to be used as a new cognitive tool for probing the phenomenal world. As a matter of fact, Bošković is going to use it as the starting point of another cycle of investigation that will finally lead him to formulate his famous law of forces. Indeed, the principle of continuity is going to cause its own experience of detachment that will force the realization of a new prejudice, namely, the idea that sudden change of movement due to collision between objects is a mental construction. If we negate the existence of sudden change, then we have to ask, what exactly accounts for the changes of trajectories? The answer that came to Bošković was that there must be, in addition to Newton's notion of attractive force, a repulsive force acting between objects. It is the principle of simplicity again that forces Bošković to assume that we are not talking about two forces, but a single one. And it is the principle of continuity that brings him to accept that the changes in the distances between objects take place in a continuous manner, that is, without jumps.

Thus, similar to a blind man's cane that becomes an extension of his arm, the principle of simplicity was first used as a cognitive instrument *through* which the principle of continuity has been realized. To use Polanyi's model, the principle of simplicity is now seen *subsidiarily* while the principle of continuity is the *focus* image. Then, it is the principle of continuity that has been transformed into an instrument by which the notion of single force acting in the universe has been realized. This means that, Bošković's deductive chain is a kind of succession of cycles, where one moves from grasping an idea as an object of the mind to having it transformed into the content of a subsidiary awareness through which it will be possible to see or discover a new idea. The latter can in turn be seized to start a new cycle leading to another realization. As previously discussed in relation to the experience of validation of one's instruments of observation, each cycle of realization validates the finding of the previous ones. It is like constructing a building where each additional floor confirms the solidity of its foundations. By this process of validation, each floor in the structure, except the first and the last, has a double nature: it is a product of the preceding one as well as an instrument of the subsequent one. This process of successive validation is, I believe, that

which accounted for Bošković's confidence in his theory of the continuous curve of forces. Whether his theory has some validity for the progression of modern physics, this will be ascertained only by using external means of validation. However, one may wonder whether the process of subjective validation can occur if it were not corresponding to something real in the external world as both types of reality have to reconcile themselves in one way or the other.

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