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# The formation of modern science: intertheoretical context

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**Abstract**

The model of scientific revolution genesis and structure, extracted from Einstein's revolution and considered in my previous publications, is applied to the Copernican one. According to the model, Einstein's revolution origins can be understood due to occurrence and partial resolution of the contradictions between main rival classical physics research programmes: Newtonian mechanics, Maxwellian electrodynamics, thermodynamics and Boltzmann's statistical mechanics. In general the growth of knowledge consists in interaction, interpenetration and even unification of different scientific research programmes. It is argued that the Copernican revolution also happened due to realization of a certain dualism – now between mathematical astronomy and Aristotelian qualitative physics in Ptolemy's cosmology and the corresponding efforts to eliminate it. The works of Copernicus, Galileo, Kepler and Newton all were the stages of the mathematics descendance from skies to earth and reciprocal extrapolation of earth physics on divine phenomena.Yet the very realization of the gap between physics and astronomy appeared to be possible because at least at its first stages modern science was a result of Christian Weltanschaugung development with its aspiration for elimination of pagan components.

**Keywords**

Modern science, Copernican revolution, mathematical astronomy, qualitative physics.

## Introduction

What prompted mathematicians, astronomers and physicists of the Modern Age to make a dizzying pirouette from the Ptolemaic and Aristotelian *geocentric* cosmology, that was a convention for centuries and whose astronomy component was excellently developed mathematically and physical one was perfectly confirmed by experience, to a highly questionable, especially at first time, scientific *heliocentric* picture of the world? And thus to initiate the process which led to the first scientific revolution? What deep "internal" impulses and powerful "external" social movements should have contributed to the genesis, formation and victory of the classical European science?

Obviously, the first that comes in the head and recurs to us is a "schoolish" explanation – an appeal to the "*solid facts*" provided by the creators of the new open natural science. But it is quite unconvincing. In common sense, it's difficult to believe that hundreds of generations of brave, practical, energetic and smart people, creators of world empires and builders of the pyramids and cathedrals, people of no less intellectual honesty and observation than Frombork's canon Nicolas Copernicus, the court astrologer Johannes Kepler, guard officer Rene Descartes, the court philosopher Galileo Galilei and the director of the mint, Sir Isaac Newton, from century to century stubbornly did not notice "solid facts" known to every schoolchild today.

How did these textbook facts suddenly fall on the heads of the new natural sciences' creators in order to lay a solid foundation of modern science?

In the literature, there are many such moralizing stories moving from one textbook to another, but an appeal to the *real* history of science, original documents of the era allows us to put at least some of these myths into question.

So, the patriarch of the modern-age science Nicolaus Copernicus himself was somehow far from blaming his rival Claudius Ptolemy in the fallibility of predictions. He considered the Ptolemaic astronomy being quite "*relevant to numerical data*". Indeed, the planetary theory of the geocentric research program at the time, long before Copernicus, more than once experienced considerable difficulties in the description of astronomical data. But it was precisely for consecutively (and successfully) overcoming these difficulties why the *"epicycle"* and the *"deferent"*[1] and then the so called

1 Epicycle – a circle which center moves along another circle – the deferent.

*"equant"*[2] were first invented. However, in the end it turned out that the planets move with equal speed not according to their deferents and not with respect to a real center, as the Aristotelian science would think. As Copernicus himself noted "having realized these shortcomings, I have often reflected on the fact whether it is possible to find some *more reasonable* combination of circles, from which one could deduce every apparent deviation and by which every object would move uniformly around its own center, in accordance with the rule of perfect motion"[3].

But that's what astronomy historians say: "theory of Ptolemy was not very accurate. It described the position of the planet Mars in the sky, for example, with an accuracy of about 5 degrees. But ... predictions of planetary positions in the Copernican theory ... were in the same way bad ..."[4].

Further, textbooks usually read a cautionary tale about the chandelier at Pisa Cathedral, by contemplating its vibrations during ***mandatory*** Catholic Masses a medical student Galileo had discovered the law to relate the period of pendulum's oscillations to its length[5]. Alas, as shown by the French historian of science Alexander Koyré, this chandelier was suspended from the ceiling of the cathedral many years after Galileo had left his hometown.

The same holds true for the textbook history of the "critical experiment" that abolished physics of Aristotle. It consisted in Galileo's throwing wooden and iron balls from the Leaning Tower. But none of the protocol papers with specific dates and the experimental results were found. Moreover, in his numerous writings Galileo (1564-1642) never mentioned these experiments. They were, however, referred to by his pupil Vincenzo Viviani in his sketch about the life of Galileo, written after the death of the teacher in 1654 (and published only in 1717). According to Viviani, Galileo lowered from the Leaning Tower of Pisa, "which excellently suited for this kind

2 In the Ptolemaic system epicycle of each planet moves not evenly from the deferent center, but from another point, dubbed the "equant".

3 Copernicus, Nicholas (2009), *On the revolutions of the heavenly bodies* [*O vrashcheniyakh nebesnykh sfer*], Amfora, St. Petersburg, p. 462.

4 Gingerich, A. (1973), "The Copernican Celebration", *Science Year*, p. 266.

5 Dannemann, F. (2011), *Die Naturwissenschaften in Ihrer Entwicklung Und in IhremZusammenhangen* [*Istoriya estestvoznaniya. Estestvennye nauki v ikh razvitii i vzaimodeistvii: Ot epokhi Galileya do serediny XVIII veka*], LIBROKOM, Moscow, p. 29.

of experience," a half-pound ball and a hundred-pound bomb. It turned out that the bomb was ahead of the ball only a few inches[6].

Such a result can hardly be considered as the "critical experiment, "taking into account that this kind of experiments (with similar results) was made already by a commentator of Aristotle, who was called Philoponus of Alexandria, a thousand years before Galileo.

It is clear that in his studies of motion, Galileo, due to the current state of science, neglected such factors as air resistance. The law on the resistance of liquids and gases to moving bodies was firstly discovered only by Newton. The latter came to the conclusion that for a body resistance of the medium is proportional to the square of the body's velocity. However, experiments made by Newton to test this law, have shown that it is valid only for small and medium speeds.

When the problem of determining the *actual* trajectory, which is traced out by a moving body under the influence of air, was took up by another founder of mathematical physics – Johann Bernoulli (1667-1748) – it turned out that the mathematical analysis was not able to cope with this task. Approximate solution of ballistic problems could only be expected from a combination of experience and calculations. The largest contribution to this problem was made by Benjamin Robbins (1707-1751) in his work "New principles of artillery" (1742)[7], which showed that Newton's law is valid only for small velocities, and that at high speeds air resistance increases significantly stronger.

It is important that, in order to determine the *actual* velocity of the projectile at any point of its trajectory, Robbins had to construct a special "ballistic pendulum": a very heavy body was suspended so that it could swing. Only after shooting at the body with the core from a gun, it was possible to calculate the core's speed by weight, size and deviation of pendulum based on the law of momentum conservation. It is not surprising

6 Ibid. P. 48. Scientific historian E. Wohlwill commenting upon the biography of Galileo written by Viviani advices to treat biographies compiled by students with caution, because in the recent "the objectivity of presentation is sacrificed to a reverent mood of the biographer". In particular, Wohlwill came to the result that if Viviani's information is not confirmed by other evidence, then they should not be treated with complete confidence.

7 Robins, B. (1805), *New Principles of Gunnery: containing the determination of the force of gun-powder, and an investigation of the difference in the resisting power of the air to swift and slow motions, with several other tracts on the improvement of practical gunnery*, F. Wingrave, London, 341 p.

that, in view of the extreme complexity of factors being taken into account *the issue is still not resolved definitively*. Apparently, the modern theoretical mechanics did not make great strides from Aristotle (384-322 BCE), who saw the cause of free fall in some properties hidden in body's "striving to its natural place". At the same time, anticipating Galileo Aristotle pointed out that such a movement should become more imminent, as an air by locking over the falling body continuously gives it more and more impulses.

Further, describing equally well-known experiments on the movement of balls on an inclined plane that served as the basis for another series of critical arguments against the Aristotelian mechanics Galileo does not give any other experimental results at all. He only casually remarks that his findings "give excellent agreement with experiment". But our intellectually honest contemporaries note that it is very doubtful since accurate clock mechanisms have not been invented yet, and Galileo had to measure time either on his pulse[8], or by using a water clock[9]. Despite the rhetorical appeals to "study nature, not Aristotle", and sarcastic comments about the dissidents ("when I wanted to show the satellites of Jupiter to professors of the Florentine gymnasium through my tube, they refused to look at them and at the tube as well, these people think that the truth should be sought not in nature but in the collation of texts"[10]), in his writings, Galileo describes experiments that he never did.

And astronomical discoveries (by using a telescope he had invented) of surface irregularities on the moon, sunspots, the phases of Venus and Jupiter's moons made by Galileo lose their credibility by being inscribed in the historical context of his time and analyzed from the standpoint of common sense.

Firstly, it would be strange if prior to the court philosopher of the Duke de Medici nobody noticed irregularities of the Moon's surface. And indeed, even Plutarch, for example, in the Middle Ages – Nikola Orezm wrote a lot about this. The latter justified the fact of the lunar surface roughness in the same way as

8 Kline, M. (2007), *Mathematics and the Search for Knowledge* [*Matematika. Poisk istiny*], RIMIS, Moscow, p. 153.

9 Mach, E. (2012), *Popular scientific lectures* [*Populyarno-nauchnye ocherki*], KomKniga, Moscow, p. 172.

10 Dannemann, F. (2011), *Die Naturwissenschaften in Ihrer Entwicklung Und in Ihrem Zusammenhangen* [*Istoriya estestvoznaniya. Estestvennye nauki v ikh razvitii i vzaimodeistvii: Ot epokhi Galileya do serediny XVIII veka*], LIBROKOM, Moscow, p. 31.

Galileo, but contemporaries did not pay attention to his arguments. Why?

Further, as the French historian Lucien Febvre noted, telescopes were used in mass starting from the XIII century, and loupe (magnifying glass) has been known since antiquity. Why did no one but Professor of Mathematics University of Pisa think to direct a telescope at the sky and make a number of outstanding discoveries?

Is it not the case that they could not guess, of course, many of them, but no one simply *dared* to identify them and tell the whole world about what he saw there. Why?

Is it not because the chromatic aberration was really a big hindrance, and absence of the diaphragm did not allow reducing spherical aberration? – Distrust specific for scientists of the first half of the XVII century is quite understandable that: "*Nature must be observed without an intermediary*". It was caused by fears to get a distorted and misleading picture[11]. And is it not because one of the discoverers of sunspots, along with Galileo and Fabrizio – German Jesuit Scheiner – thought initially that he was dealing with an *optical illusion* or some shortcoming of the tool?

After all, according to supporters of Aristotle, the heavenly and earthly objects are formed from a variety of substances and therefore are subject to *deferent* laws. It is reasonable to conclude that the result of the interaction of light (which links the heavenly world with the earthly world) cannot be extrapolated to the world of earthly objects[12].

It is no coincidence that in April 1610 Galileo brought his telescope into the house of his opponent – Aristotelians Maggini – to demonstrate it to 24 professors of different specialties. Horky, a disciple of Kepler who sympathized Galileo left about the incident the following frank testimony: "I have not fell asleep on April 24 and 25, but checked the Galileo's tool in many different ways and both on terrestrial objects and on celestial bodies. Directing the tool on the terrestrial objects it works perfectly, with the direction of the celestial bodies being cheating: some fixed stars appear double. The most outstanding scientists and noble people can attest that ... all of them confirmed that the tool was cheating ... Galileo had nothing more to say , and in the early morning of the 26th he was sad to leave ... even without thanking Maggini for his luxurious treat"[13].

11 Chaunu, P. (2008), *La Civilisation de l'Europe Classique* [*Tsivilizatsiya klassicheskoi Evropy*], AST, Moscow, p. 324.

12 Feyerabend, P. (2007), *Against Method* [*Protiv metoda*], AST, Moscow, p. 131.

13 Ibid. P. 132.

And is it not this circumstance that explains the reasonable position of the Catholic Church, which, in the person of Pope Paul III, enthusiastically supported the initiatives of Copernicus at first – but as a useful mathematical hypothesis, not as a description of what *actually* happens (see "preface of Osiandera" to the book of Copernicus)? The Catholic Church has not been a stronghold of slow-witted and aggressive fundamentalists: it tried to rely on the opinions of scientific experts! Indeed, the "position of the Church was not as dogmatic as one often claimed. Interpreting passages of the Bible has been changed in light of previous results. Everyone considered the Earth spherical and free-floating in space, despite the fact that the Bible tells a completely different thing"[14].

Therefore, having rationally reconstructed the Copernican revolution much more plausible seem to be explanations appealing either directly to changes in the "spirit of the times" (zeitgeist), for example, to the 'spirit of the Renaissance", to development of scientific (in the modern sense of the word) methodology, or to their reasons whether it was "the great geographical discoveries", "fall of Constantinople having forced thousands Byzantine scholars to emigrate to Italy", or even "the ascent of this new class to more progressive ideology". Such explanations are well known, elaborated and received a well-deserved reputation, having "highlighted" many important circumstances and interesting scientific facts[15]. Therefore proposing another, finally the only correct explanation which dismisses all other ones as sad delusions would be ridiculous.

As Paul Feyerabend, who devoted to these studies more than a dozen years, melancholy concluded "not one reason and one method, but *different* reasons, evaluated from *different* positions – that is what created the "Copernican revolution". These reasons and positions intertwined, but this process was of *random* nature, so one shall not try to explain the *whole* process only by the influence of simplified methodological rules"[16].

In this article on the Copernican revolution, which led to the formation of modern science, the concept of genesis and structure of scientific revolutions

14 Feyerabend, P. (2010), *Science in a Free Society* [*Nauka v svobodnom obshchestve*], AST, Moscow, p. 70.

15 Hellyer, M. (2003) *The Scientific Revolution. The Essential Readings*, Blackwell Publishing, 288 p.

16 Feyerabend, P. (2010), *Science in a Free Society* [*Nauka v svobodnom obshchestve*], AST, Moscow, p. 97.
Hereinafter goes my italics.

was applied being established by generalizing the experience of Einstein's revolution and described in previous publications of the author[17]. According to this theory, the Einstein's revolution arose from attempts to cognize and to resolve a number of the so-called "Contradictions of meeting" between basic research programs of classical physics – Newtonian mechanics, Maxwell's electrodynamics, statistical mechanics and thermodynamics. On the basis of the material related to the science of the late XIX – early XX centuries, the author has developed a model for the growth of knowledge in the processes of scientific revolutions, according to which the growth of knowledge consists of the interaction, interpenetration and the synthesis of a variety of research programs.

Therefore, I believe that the Copernican revolution can also be considered as a result of cognition and resolution of a certain dualism – between mathematical astronomy and a qualitative physics of Aristotle in the Ptolemaic cosmology. Works of Copernicus, Galileo, Kepler and Newton were stages both of the mathematics' descent from sky to earth and reverse accession of terrestrial physics in the sky.

*The purpose of this article – to reveal the intertheoretical context of the Copernican revolution, by showing the influence of the evolution processes and interaction of the "old" research traditions specific for mathematical astronomy and a qualitative physics of Aristotle on the formation of modern science.*

## Genesis of Copernicus program

According to Lakatos and Zahar[18], both Ptolemy and Copernicus worked on research programs, i.e. they did not just put forward and test assumptions, try to arrange the experimental data or associate themselves with "paradigms popular in the Community". Both programs separated from the Pythagorean – Platonic SRP. Its original principle was that, since the heavenly bodies are perfect, all the astronomical phenomena must be "saved" by the combination of the smallest number of uniform circular motions. This principle has remained the foundation of heuristics specific for

17 Nugayev, R.M. (1999), *Reconstruction of Mature Theory Change: A Theory-Change Model*, Peter Lang, Frankfurt am Main, 199 p.; Nugayev, R. M. (2010), *Einstein's Revolution of 1898-1915: Interdisciplinary context* [*Einshteinovskaya revolyutsiya 1898-1915 gg.: interteoreticheskii kontekst*], Kazan, 302 p.

18 Lakatos, I., Zahar, E. (1974), "Why did Copernicus's Research Program Supersede Ptolemy's?", *The Copernican Achievement*, Los Angeles, pp. 354-383.

both programs. This "protoprogram" contained no indication where the center of the universe was located. In this case, the heuristic was "primary", and a solid core – "secondary". Geocentric hypothesis evolved, "crystallized" into a solid core of Ptolemy programs only through connection with *Aristotelian physics* with its natural and forced movements, as well as division into sublunary and superlunary worlds.

Just because "the Aristotelian science" was thoroughly empirical, it was much more consistent with the usual "life experience" than Galilean science. Heavy bodies, as everyone knows, "naturally" fall down, and the fire really shoots up[19].

Inertial motion is not an experimental fact: the everyday experience contradicts it. Spatial infinity, which formed the basis of the Newtonian universe, is not an object of experience as well. Besides, everyone knows that "there is no emptiness as something separate"[20]. The Sun and moon are rising and setting and the bodies thrown horizontally do not keep endlessly the straightness of their motion.

According to our everyday experience, recorded in visual categories of Aristotelian metaphysics, our everyday's reality in which we live and act, is neither mathematical nor mathematisized. This is the area of the fluid, the changeable, the inaccurate, the area, where there are primarily notions "more or less", "almost", "like that", "estimated", "sort of", etc. In nature there are no circles or ellipses or parabolas or hyperbolas, no direct light or asphalted and well-swept streets.

That is why ancient thought did not admit the possibility that there was accuracy in the "sublunary world", and that "the matter of our sublunary world could imagine math's beings in the flesh"[21]. As Stagirite himself proclaimed, "accuracy, namely mathematical accuracy, is not necessary in all cases, but only for objects that do not have the matter. Thus, this method is not suitable for the science of nature, for nature in all, we can say, cases is connected with the matter"[22].

But in heaven, argued Aristotelian physics, everything is diametrically opposite. There are absolutely perfect and

19 Aristotle (1936), *Physics* [*Fizika*], Moscow, p. 58.

20 Ibid. P. 69.

21 Koyre, A. (1985), *Essays on the history of philosophical thought. Influence of philosophical concepts in the development of scientific theories* [*Ocherki istorii filosofskoi mysli. O vliyanii filosofskikh kontseptsii na razvitie nauchnykh teorii*], Progress, Moscow, p. 110.

22 Aristotle (2006), *Metaphysics* [*Metafizika*], Eksmo, Moscow, p. 45.

orderly movements of stars in full compliance with strict and immutable laws of geometry. "This is a circular movement that connects the end with the beginning, and it is the only thing being complete ... no change is infinite and continuous, except for a circular movement"[23].

Therefore, according to Aristotle, *mathematical astronomy is possible and mathematical physics is not*. It is no coincidence that the Greek astronomy not only successfully applied mathematics, but with remarkable patience and precision watched the sky, using measuring instruments. But it did not even try to mathematize earth movement or use measuring tools on the Earth.

The ancient cosmology reached its zenith thanks to the mathematician Claudius Ptolemy (87-150 AD), who was also known as a geographer and optician, astrologer and poet. His work "Almagest" has been occupying a dominant place in the European astronomy for 14 centuries. He completed construction of a scientific paradigm being the first in the history of mankind. Ptolemy was skeptical about the heliocentric hypothesis of Aristarchus the Samos – for perfectly rational reasons connected with the principles of Aristotle's physics. "The movement of the heavenly bodies should be the least forced and easiest. Among plane figures circle is the path of least resistance to movement, and the sphere – among the volume bodies"[24].

According to Ptolemy the sun moves around a certain center, located not far from the Earth. And it is typical of all his mathematical constructions. Carefully calibrating combinations of epicycles and deferents, Ptolemy, in the spirit of eastern instrumentalist tradition, was guided by considerations of "economy of thought", not bothering himself with reflections on the "nature of things".

He chose a quite rational way of further complications for created ideal models and corresponding improvement of calculating technology, having added to the positive heuristic the notion of "equant". According to him, an epicycle of each planet moves evenly not relative to the deferent's center, but to another point, which was dubbed "equant". However, in case of the Mercury, even this very artificial scheme had to be complicated. The deferent's center of the Mercury traces itself a small circle, so that the epicycle of this planet is periodically approaching the Earth, then it is moving away from it.

23 Aristotle (1936), *Physics* [*Fizika*], Moscow, p. 166.

24 Kline, M. (2007), *Mathematics and the Search for Knowledge* [*Matematika. Poisk istiny*], RIMIS, Moscow, p. 95.

From a modern point of view the equant of Ptolemy is the forerunner of future Keplerian ellipses. But in terms of biased critics of Ptolemy, as Copernicus, the introduction of the equant was a typical "hypothesis adhoc", which broke the "spirit of the program Ptolemy – Aristotle", i.e. uniform motion relative to the center of the universe.

In the program of Ptolemy mathematical precision requiring the introduction of non-circular orbits of celestial bodies and centers of rotation that do not coincide with the Earth, began to diverge increasingly from the principles of Aristotelian physics, which were well-founded on the experience. So, ultimately, *the cosmology of Ptolemy can be evaluated as a dualistic theoretical scheme unifying principles of "Platonic mathematics" and Aristotelian physics in terms of mechanics*. These principles were demonstrably in conflict with each other in the "theory of the planets" – objects to describe the motion of which one had to be tolerant towards particularly significant violations of the principles of Aristotelian physics.

After discarding the model of Eudocks *each new change in geocentric program contradicted to Plato heuristics*. "The eccentric shifted the Earth away from the center of the circle; epicycles of Apollo and Hipparchus meant that the actual trajectory of planets' motion around the earth was not circular, and finally, the Ptolemaic equants meant that even the movement of the epicycle's empty center was not simultaneously uniform and circular. It was uniform, but not circular in terms of an equant; it was circular, but not uniform in terms of defferent; uniform rotation was replaced by a quasi-uniform pseudo-circular one"[25].

The introduction of the equant administered a significant blow to the Plato heuristics: it was tantamount to its complete abolition. The author of the "Almagest" trying to describe the motion of some planets already created several alternative theoretical models, then, being honest, preferred the simpler one in terms of math. Ptolemy, taking skeptical position repeatedly stressed and declared that in astronomy one should always strive for the simplest mathematical model. But later the middle Ages with the barbarous immediacy perceived Ptolemaic cosmology as the ultimate truth.

Contradictions, with their identification (cognition) and resolution being the intertheoretical context of Copernican revolution, long ago, somewhere

25 Lakatos, I., Zahar, E. (1974), "Why did Copernicus's Research Program Supersede Ptolemy's?", *The Copernican Achievement*, Los Angeles, p. 371.

in the 50s of the last century, have been identified by the French historian and philosopher of science Alexander Koyre[26]. These contradictions are the "*glaring gap*" (the term A. Koyre) between mathematical astronomy and qualitative physics of Aristotle in terms of the Ptolemaic cosmology. Therefore, the main motive of creating one's own – heliocentric – program was not in an effort to resolve differences of certain Ptolemaic cosmology provisions with experience, but rather in considerations of aesthetic and metaphysical order associated with the Copernicus' realizing the abovementioned dualism.

Nevertheless, the A. Koyre's point of view on the genesis of the Copernican program does not seem entirely convincing to us. In fact, on the one hand, Koyre rightly argues that the primary motivation for the creation of heliocentrism were aesthetic and metaphysical considerations. But – on the other hand – he explains the Copernican heliocentrism by referring to the fact that the great astronomer considered the Sun to be the mind ruling the world and at the same time creating it. Indeed, we have an excerpt from the book of Copernicus, with the reference to Hermes Trismegistus. It itself really allows such an interpretation. But if we compare this single quote, which looks more like a demonstration of knowledge, with the whole multipage book of Copernicus, if we also analyze its numerous arguments against the system of Ptolemy, we would have somewhat different picture. Moreover, the fact of pagan inclinations, "the fire-worship" by the prominent figure in the Catholic Church, canon of the Fromborsk cathedral, nephew and secretary of the bishop, friend of bishops and the Pope trustee is rather strange ... – Is it not easier to assume that the solid Christian faith in the world created by the single Creator in terms of clear and simple mathematical laws, common to all its areas, inevitably conflicted with really pagan Greek ideas of Aristotle and the Egyptian Ptolemy?

But let us turn to the work of Copernicus. From our point of view, it itself suggests that it was deep religiousness of Copernicus to be the main motive for the development of the heliocentric theory. He valued his work primarily for the fact that it offered "*true harmony, symmetry and the divine plan of the universe*." Let us give the floor to the author.

26 Koyre, A. (1985), *Essays on the history of philosophical thought. Influence of philosophical concepts in the development of scientific theories* [*Ocherki istorii filosofskoi mysli. O vliyanii filosofskikh kontseptsii na razvitie nauchnykh teorii*], Progress, Moscow, 288 p.

"After thinking for a long time about the unreliability of mathematical traditions regarding the establishment of the movement specific for the celestial spheres, I started vexing that philosophers do not have any reliable theory for the motion of the global mechanism *created for us by the magnificent and skilled creator*[27]". After all, it is not accidental, "that many philosophers called it ***the visible God*** due to the extraordinary perfection of the sky. Therefore, if we evaluate the merits of sciences depending on the matter they study, the most prominent one would be, of course, astronomy"[28].

Copernicus saw convincing evidence of divine providence in his heliocentric system. In fact, in the preface to his main work, dedicated to "the holy lord, the great Pontiff Paul III", Copernicus wrote that "it is the fact *mathematicians themselves do not have anything relatively well established on studies of global spheres* that prompted me to think about another method of calculating these movements. First of all, they are so unsure of the movement specific for the Sun and the moon that they cannot ascertain by means of observations and calculations the value of the tropical year at all times. Further, by determining the motions of these bodies as well as other five wandering stars, *they do not use the same principles and the same premises or the same ways for the presentation of visual rotations and movements*; indeed, some use only homocentric circles, others – eccentric and epicycles, and nevertheless one could not achieve the desired to the full extent..."[29].

So what? Why different parts of the universe cannot be described in different ways? – And because *they are created by the same Creator in terms of a single plan*. "Thus, the same thing happened with them[30] as if someone got from various places hands, feet, a head and other members though being drawn fine, but not on the scale of the same body; due to their complete mismatch, of course, one would create rather a monster, not a man"[31].

Secondly, in full accordance with Aristotle, Copernicus was convinced that the circular motion was "the most natural one". Therefore, movements of celestial bodies shall be either directly circular, or

27 Copernicus, Nicholas (2009), *On the revolutions of the heavenly bodies* [*O vrashcheniyakh nebesnykh sfer*], Amfora, St. Petersburg, p. 17.
Hereinafter texts of Copernicus includes my italics.

28 Ibid. P. 20.

29 Ibid. P. 17.

30 With pagan mathematicians.

31 Ibid.

represent different combinations of circular motions. Each planet has to move on its epicycle at a constant speed. At the same time, the center of each epicycle must necessarily move at a constant speed along its main circumference. But "people who forged eccentric circles, although they obtained thanks to these circles numerical results being largely similar to the observed movements, but they had to admit some of them, apparently *contradicting the basic principles of movement's uniformity*"[32]. Indeed, "in their circumrotation they do not seem to be moving uniformly. It turns out that the Sun and Moon are moving faster or slower, and the remaining 5 planets, as we see, are sometimes observed in retrograde motion, stopping here and there. And then as the Sun goes straight on its way, these luminaries are wandering in different ways, deviating to the north, then to the south, that is why they were called planets , i.e. those who are wandering"[33].

The etymology of the word "wandering", being derivative of the word "fornication", "fornicate" is typical for sincerely believing Catholic, so it is not surprising that "because *both are conflicting with our mind and it is unworthy to assume something like that in terms of the object arranged in the best order*, then we must agree that the uniform motion of these luminaries appear to us uneven ... due to the fact that the Earth is not in the center of the circles in which they rotate"[34].

Copernican worldview and especially his skeptical attitude towards the arguments by the pagan Aristotle characterize the fact that he was not limited only by the reference to this authority to justify the inadmissibility of non-uniform motion. Instead, he introduces his own metaphysical argument: the reason of variable velocity can only be variable force. God being the root cause of all movements is always constant.

Copernicus actually constructed a hybrid theory (similar to the first semi-classical theory of Planck), which marked the beginning for the interpenetration of the Sky Mathematics and the Earth Physics. In the words of modern French historian, "Copernicus softly, perhaps being not aware of this introduces in the Aristotle stronghold two small assumptions through which Kepler, Galileo, Descartes exploded the stronghold"[35].

32 Ibid.

33 Ibid. P. 27.

34 Ibid.

35 Chaunu, P. (2008), *La Civilisation de l'Europe Classique* [*Tsivilizatsiya klassicheskoi Evropy*], AST, Moscow, p. 430.

In fact, Copernicus, having found an appreciative audience in the person of the Pope Paul III (to whom he dedicated his book), the Pope Clement VII (who not only approved the work, but also demanded the author to release it), his uncle the bishop, his friend Bishop Tiedemann Giese and others, blames Ptolemy for paganism. He criticizes the Egyptian Ptolemy that there was however no *single God* in his subtly developed system and the different elements of his cosmology reflect ideas of deferent creators.

Thus, Copernicus maybe without his own will paved the way for Galileo: if the Earth is an ordinary planet, the laws of mathematics should be applicable both to its motion around its own axis and around the sun, and the movement of bodies on its surface. Later in the work of Galileo the Aristotelian "natural movements" will turn into "inertial" movements.

## Evolution of Copernicus program

For a more complete and systematic rational reconstruction of the "hard core", "heuristics" and "protective belt" of Copernican program and strengthening of the modern-age science one needs to apply to the work of one of the greatest theologians and philosophers of the XV century – Cardinal Nicholaus Cusanus[36]. In his works metaphysical intuitions which formed the "spirit of the times" and fueled the creativity of Copernicus, Kepler, Galileo, Descartes and Newton, were of well thought, systematic and consistent nature. Monotheistic creationism of Cardinal Cusanus was directed against the Ptolemaic – Aristotelian cosmos: as a "creaturely one" The sky was not different from the Earth. The very reality of the created contains a divine infinity that cannot be described by any concepts. As a result Cusanus even formulates a quasi-galeelien "principle of relativity".

"*We've already understand that our Earth actually moves, although we do not notice*, for we perceive motion only in relation to something fixed. In fact, if someone standing on the ship, on water would not know that the water is flowing, and would not see the coast, how could he notice movements of a ship? In connection with this, as to everyone, whether he is on the Earth, the Sun or another star, it will always seem that he is in a fixed center, and everything else is moving, he will every time set for himself

36 Akhutin, A.V. (2005), *The turning times* [*Povorotnye vremena*], Nauka, St. Petersburg, 640 p.

different poles, ones – being in the Sun, the other ones – being on the ground, and the others – on the Moon, the Mars etc. It turns out that the machine of the world will have kind of a center everywhere and nowhere – a circle ..."[37].

On the other hand, the Renaissance interpretation of a man as a "second God", skillful creator of ideal (mathematical) thinking "entities", laid the theoretical and methodological foundations of mathematical science (Martin Heidegger)[38].

Inspired by the ideas of Copernicus and Plato (especially by the dialogue "Timaeus"), as well as by his own astronomical observations made with the help of the newly invented telescope, Galileo reduces mathematics from heaven. *If the Earth is just one of the planets, the laws of mathematics, previously used to describe the motion of everything that happens in the superlunary world are applied now to its movement as a whole, and to what is happening on its surface*.

As the Copernicans Salviati noted in the "Dialogue" in his dispute with the Aristotelians Simplicio, "and as far as the Earth is concerned – we try to refine it and make it more perfect, trying to assimilate it to heavenly bodies, and in a certain sense to put it at the sky, where it was exiled from by your philosophers"[39].

Or, as more accurately and definitely said the other party of the "Dialogue" – Venetian Sagredo – summing up the first day of discussions, "the main theme of yesterday's discussion was to investigate two opinions , and which of them is more likely and justified: whether the first one that considers substance of the heavenly bodies being non-occurring, indestructible , unchanging , enduring, in a word, free from any change, except for a change of location, and therefore recognizes the existence of the fifth element, quite different from our elements and which forms the bodies of the earth, emerging bodies, destroyed bodies, choppy bodies, etc. or the opinion, which denies such a difference for parts of the universe and assumes that the earth is endowed with the same perfection as the other bodies that make up the universe, i.e. it is a moving and wandering ball, like the Moon, Jupiter, Venus and other planets ... in the end we

37 Cusanus, N. (1979), *Works in 2 volumes. Vol. 1* [*Sochineniya v 2 tomakh. T. 1*], Mysl', Moscow, pp. 133-134.

38 Heidegger, M. (2007), *Being and Time* [*Vremya i bytie*], Nauka, St. Petersburg, 621 p.

39 Galilei, Galileo (1948), *Dialogue Concerning the Two Chief Systems – Ptolemaic and Copernican* [*Dialog o dvukh glavneishikh sistemakh mira – ptolemeevoi i kopernikovoi*], Moscow, p. 44.

came to the conclusion that this second opinion is more likely than first"[40].

But, from the point of view of Aristotle's physics, the Copernican system is meaningless because, in accordance with the concept of natural movement, the movement of the earth (does not matter – around its own axis and around the sun) is physically impossible. The natural movement of earthly bodies (rocks and water) is based on rectilinear motion towards the center of the universe.

Each simple body can participate in one and only one natural motion. The Copernicus doctrine seeks to attribute at least three natural movements to the Earth: rotation of the Earth as a whole in its orbit around the Sun, the Earth's rotation around its axis and participation of terrestrial bodies in their free fall toward the center of the Earth. As Salviati noted in the "Dialogue", "all the respective properties, which according to Aristotle differ the heavenly bodies from elementary ones, are derived from differences in the natural movements between the first and second ones. Thus, if we deny that the circular motion is characteristic only of the heavenly bodies, and assert that it is typical of all naturally moving bodies as well, then necessarily we have to admit that such attributes as occurring or non-occurring, mutability or immutability, divisibility or indivisibility and others equally belong to all world's bodies, i.e. both celestial and elementary, which is wrong and mistakenly Aristotle deduced from circular motion those attributes which he attributed to the heavenly bodies"[41].

Thus, in the struggle to implement the Copernican program it was necessary to *undermine the physics of Aristotle*. And in the program essay "Assay – maker" (1623) Galileo proclaims: "*The philosophy of nature is written in the great book, which is always open before our eyes – I mean the universe*, but it would be understood only by those who first learn the language and the writing, in which it is inscribed. And *this book is written in mathematical language*, and its writing consists of triangles, circles and other geometric figures, and it is impossible to understand humanly its words without them – vain whirling in a dark labyrinth"[42].

And for the readers had no doubts about who wrote this book, later, in the introduction to the "Dialogue", Galileo stresses: "the surest means to direct one's

40 Ibid. P. 91.

41 Ibid. P. 43.

42 Kline, M. (1984), Mathematics: *The Loss of Certainty* [*Matematika: utrata opredelennosti*], Mir, Moscow, p. 58.

gaze upwards – is to study the great book of nature, which is the real subject of philosophy. However *all that you can read in this book is a creation of the almighty artist* and located in the most perfect way, the most worthy of study are things that show us in the first place the creation and the creator from the higher side"[43].

Apparently, the Galilean interpretation of Christian theology was inspired and guided by Plato, in particular, by the myth about the creation of the world, set out in his famous dialogue "Timaeus" (favorite dialogue of one of the quantum theory founders, Werner Heisenberg as well, who used it as a regulative principle in physics for elementary particles). The character of this Plato's work – Demiurge (the supreme god) – having cut small triangles in space, made of them elementary bodies, and from these bodies, in turn, the real bodies, plants, animals, human beings... Moreover, it is thanks to the "Timaeus" the concept of God-creator was enriched by notion of a plan being eternally preset by him.

Thus, the nature is simple and highly ordered precisely because by creating the world God has put in it a mathematical necessity. Therefore mathematical knowledge is not just true, but sacred – and even more than the Bible. If by interpreting the Scripture there are many differences, the truths of mathematics are undeniable.

On the other hand, when, at this time in the "Dialogues", the Venetian Sagredo expresses feigned surprise why the Copernican system, if it is so consistent with the facts, has not been common so far, to say the least, the Florentine Salviati with dignity retorts: "are you surprised that the Pythagorean doctrine has so few followers, I'm amazed that there are people who learn this teaching and are surprised of it, and I can not wonder at the elevated thoughts of those who accepted it and taken for the truth: through liveliness of their mind they made *such an abuse of their feelings* that they could choose something dictated to them by reason which clearly contradicts the testimony of their sensory experience"[44].

Aiming at consistent mathematization Galileo radically transforms the methodology of the natural sciences, having lifted idealization and thought experiment on the pedestal of the leading methods for scientific knowledge.

43 Galilei, Galileo (1948), *Dialogue Concerning the Two Chief Systems – Ptolemaic and Copernican* [*Dialog o dvukh glavneishikh sistemakh mira – ptolemeevoi i kopernikovoi*], Moscow, p. 21.

44 Galilei, Galileo (1964), *Selected works in 2 volumes. Vol. 1* [*Izbrannye trudy v 2 tomakh. T. 1*], Nauka, Moscow, p. 423.

All this allowed Galileo, apart from anything else, both to formulate the "principle of inertia" and come close to Newton's second law.

Similar Platonic (and Neoplatonic) provisions, and especially – "amazing match between the Cosmos and the Divine Trinity" led Kepler to search for mathematical laws that govern the movement of the planets. Between the views of Copernicus and Kepler there was one fundamentally important difference. For Copernicus the planetary motion was circular, as for Ptolemy, so it did not require any reason and happened in terms of inertia. Therefore, the Sun was not for him the "center of power" and its position was not required to coincide with the center of the Earth's orbit. Only Kepler, wondering about the source of force driving planets, revealed the role of the Sun, and this idea helped him to reveal the mechanics of planetary motion[45]. Kepler made a second step towards unity of mathematical astronomy and physics. He revealed laws significantly violating Aristotelian – Ptolemaic principle of uniform rotation specific for celestial bodies. Kepler 's three laws were the first scientific laws formulated in mathematical form. The "Heaven" started demolishing the qualitative physics. Harmonious union of the heavenly and the sublunary pushed aside the physics of Aristotle.

The main task of the entire work by Isaac Newton was to discover uniform laws governing the movement of bodies, both in heaven and on the Earth. In fact, according to Galilean "principle of inertia", bodies must move "naturally" – uniformly and straight – as long as they are not influenced by any force. But the planets of the solar system, in accordance with the laws of Kepler, revolve around the orbit of the Sun in form of ellipses. Consequently, there must be some force that *constantly makes* the planet deviate from the state of rectilinear uniform motion. Apparently, the force of the Sun influences on the planets.

On the other hand, it is well known that the Earth somehow attracts bodies located on it. Therefore Descartes already had the task to combine both theories of gravity in the unified theory. The first thing that Newton guided by positive heuristics of Copernicus and Galileo had to do on this way was to demonstrate that the same force that attracts all objects to the Earth, makes the Moon orbit around the Earth as well. That is what was done in the "Mathematical Principles of Natural Philosophy" (1687). As its publisher summed up in the preface to this book, "Thus, it is established

45 Danilov, Yu.A.,Smorodinsky, J.A. (1973), "Johannes Kepler: from "Misterium" to "Harmony" [Iogann Kepler: ot "Misterii" do "Garmonii"], *Uspekhi fizicheskikh nauk*, No. 1(109), pp. 175-209.

that the centripetal force due to which the moon constantly deviates from the tangent to its orbit, is the Earth's force of gravity that extends to the Moon"[46].

In solving the main problem of his life Newton, of course, in his own words, "*was standing on the shoulders of giants*"; above all, he was guided by heuristics of Galileo Galilei, and for whom he had the greatest respect. It is no coincidence that in the preface to the first edition of "Mathematical Principles of Natural Philosophy" its author notes: "Since ancient, according to Pappus, attached great importance to the study of the nature mechanics, the newer authors, having rejected substances and hidden properties, tried *to subdue the phenomena of nature to the laws of mathematics*. In this work we have in mind the thorough development of an application of mathematics to physics ... and so we offer this essay as *mathematical foundations of physics*"[47].

In Newton's methodology the typical Galilean requirement "*to subdue the phenomena of nature* to the laws of mathematics" seems to be the basic one: one needs to "rape" in the Galileo manner feelings arising in the contemplation of nature, to dissect them, present them in dried and dissected form to such an extent that the results of their actions allowed an analytic treatment. This applies primarily to the basic concepts for the basic ideal model of classical mechanics – the concepts of "power", "space" and "time" that gain a character of mathematical *idealizations*[48].

Having created a "hard core" of his program due to the synthesis of hybrid theoretical schemes of Copernicus, Kepler, Galileo and Hooke in form of conjunction of the three laws of dynamics with the law of universal gravitation, Newton finally secured a permanent empirical progressive growth for the Copernican program.

## Conclusion

Thus, another – intertheoretical – context of Copernican revolution and formation of modern age science is presented. The perspective of delivery chosen by the author allows evaluating the interaction

46 Newton, I. (1989), *Mathematical Principles of Natural Philosophy* [*Matematicheskie nachala natural'noi filosofii*], Nauka, Moscow, p. 32.

47 Newton, I. (1936), *Mathematical Principles of Natural Philosophy: Collected Works of Academician A.N. Krylov, Vol. 7* [*Matematicheskie nachala natural'noi filosofii: Sobranie trudov akad. A.N. Krylova. T. 7*], Moscow, pp 1-3.

48 Husserl, E. (2004), *The crisis of European sciences and transcendental phenomenology* [*Krizis evropeiskikh nauk i transtsendental'naya fenomenologiya*], Vladimir Dal', St. Petersburg, 399 p.

of internal and external factors during the first scientific revolution from the other point of view. Self awareness and subsequent (partial) overcoming of the "glaring gap" between mathematics of Heaven and physics of Earth would be impossible without the development of the Christian, monocentric world with its intention to erase an insurmountable barrier between terrestrial and celestial processes.

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# Становление науки нового времени: интертеоретический контекст

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**Аннотация**

В статье анализируется интертеоретический контекст коперниканской революции, приведшей к становлению науки нового времени. Эта революция рассматривается через призму концепции генезиса и структуры научных революций, сложившейся в результате обобщения опыта революции эйнштейновской и изложенной в предыдущих публикациях автора. На основе этого материала автором была разработана модель роста знания в процессах научных революций, согласно которой рост знания состоит во взаимодействии, взаимопроникновении и синтезе разнообразных научно-исследовательских программ, выросших из различных предметных областей и сложившихся на основе разных культурных традиций.

В данной статье утверждается, что и коперниканская революция также может быть рассмотрена как результат осознания и разрешения определенного дуализма – между математической астрономией и квалитативной физикой Аристотеля в птолемеевской космологии. С этой точки зрения работы Коперника, Галилея, Кеплера и Ньютона были этапами как «нисхождения» математики с небес на Землю, так и обратного «воцарения» земной физики на небе. Но само осознание противоречия встречи между физикой и астрономией стало возможным потому,что на первых этапах европейская наука нового времени была закономерным результатом становления христианского мировоззрения с его стремлением «по капле выдавливать из себя» языческие компоненты.

**Ключевые слова**

Наука нового времени, коперниканская революция, математическая астрономия, квалитативная физика.

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