THE SECRET OF GENIALITY (II)

Robert DJIDJIAN[1]

djidjianrobert@aspu.am

INSTEAD OF ABSTRACT

We continue to publish, in series, the book THE SECRET OF GENIALITY (Yerevan, Armenia, Noyan Tapan Printing House, 2002) by our colleague Robert Djidjian, not only because we all must know the philosophical research and creation (in our domain of epistemology and philosophy of science and technology) from a wider area than that provided by the established fashion in virtue of both a yet obsolete manner to communicate and value the research, and extra-scientific reasons; but also because the book as such is living, challenging and very instructive.

The title of the book is suggestive enough to make us to focus on an old age question: the dialectic of the insight, of the discovery, its psychology moving between flashes of intuitions and cognizance stored in memory, and its logic of composition of knowledge from hypotheses to their demonstration and verification. The realm of science is most conducive to the understanding of this dialectic and the constitution of the ideas which are the proofs of what is the most certain for humans: the "world 3", as Popper called the kingdom of human results of their intellection, and though transient and perishable in both their uniqueness and cosmic fate, the only certain proof of the reason to be of homo sapiens in the frame of multiversal existence. Therefore, creation is the secret of the human geniality, and how to create science is a main part of this secret.

(Ana Bazac)

Step 4. THERE WERE NO ONE-LEAP REVOLUTIONS

"*Heaven is not reached at a single bound.*"
J. G. Holland

Knowledge is acquired by *inconspicuous* steps. Even the great insights of geniuses of science are supported and prepared by hard work and intensive thinking. "While individually we contribute little or nothing to the truth, by the union of all a considerable amount is amassed," noticed Aristotle. Studying the history of formation of the theory of evolution, Loren Eiseley concluded, "Great acts of scientific synthesis are not performed in vacuum." The *step by step character of scientific progress* is supported by the history of all great theoretical discoveries without any single exception.

To go into this problem in more detail, let us begin with the Copernican revolution. If we consider only the *idea* of the heliocentric world, this conception was well known from the day of Aristarchus of Samos. On the other hand, if by the term Copernican revolution we understand the *theory* of the heliocentric system it had only begun with Copernicus' work *On the Revolutions of the Heavenly Orbs*, the final step being accomplished in Newton's *Mathematical Principles of Natural Philosophy*.

The system of Copernicus was much simpler by its structure than Ptolemy's geocentric model. Copernicus did not need any epicycles to explain the most startling feature of the motion in the Heaven – the retrograde motion of the planets. But to explain all the peculiarities of astronomical observations, Copernicus was forced to introduce in his planetary model 46 spheres, which, compared to 90 spheres of the Ptolemaic system, could still look more advantageous. Anyhow, Copernicus did not succeed in producing more accurate astronomical computations. This

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[1] Graduated in Physics, later in Philosophy; Ph.D., Professor of Epistemology at the Department of Philosophy and Logic named after Academician Georg Brutian at the Armenian State Pedagogical University after Khachatur Abovian.

was one of the reasons that European astronomers and scholars did not hurry to accept the new conception. Only successive efforts of generations of astronomers, among which the most distinct position belongs to Tycho Brahe, Kepler, and Newton, eventually proved the advantages of the heliocentric system of the world.

Another obstacle arose from the well-known arguments against the idea of the moving Earth.

When I first met the ancient objections to the conception of the Earth’s space travel, it appeared to me quite clear that they could be dismissed only after Newton’s discovery of the law of universal gravitation.

The simplest of these arguments puts the matter as follows. If the Earth were moving we should feel a strong head wind, as it is the case when one is riding with sufficient speed.

The second argument is of the same line, but a little more sophisticated. If the Earth were moving, it would lose its atmosphere long ago. Really, light gasses of the atmosphere were not supposed to have an ability to cling to the Earth travelling on its space orbit.

There was another closely related argument, first suggested by Aristotle in *De Coelum*. Suppose we throw upwards a stone. If the Earth were moving, the stone would not come back to the same place. The higher goes the stone, the longer will be its flight and further away it would come down.

I was really startled to learn how easily Nicolas of Oresme, a prominent mediaeval scholar, neutralized all these three fundamental objections to a moving Earth. Oresme just suggested that the atmosphere of the Earth and bodies on its surface should be sharing the motion of the Earth.

This simple assumption overcomes all three above-mentioned objections. If the atmosphere shared the rotation of the Earth, there should be neither a head wind nor dissipation of the atmosphere caused by that motion. And a stone thrown vertically upwards had to come back to the same place, for in its flight through air it did not lose the speed that it acquired moving with the Earth.

The last classical objection to heliocentric ideology was astronomical. If the Earth were orbiting around the Sun, the picture of constellations should change when viewed from the opposite points of the Earth’s space orbit. *Star parallax* or change of the picture of constellations was never observed by a human naked eye. Yet this strong objection was neutralized already by Aristarchus who suggested a very natural possibility. The dimension of the orbit of the Earth is so negligible compared to the huge distance to the fixed stars that the star parallax can never be observed. In fact, even the first telescopes were unable to find out a star parallax. Astronomers succeeded to fix a star parallax only in 1838 though many attempts had been made previously since the first telescopic observations of the sky.

The intellectual climate radically changed in favor of the Copernican theory when Galileo made his first observations of the Moon and the planets through the telescope he built himself. Observing through a telescope mountains and valleys on the Moon people could see with their own eyes that there was no cardinal difference between the heavenly eternal kingdom and the earthly world.

Galileo’s another discovery was even more significant in the struggle of the two systems of the universe. Observing Jupiter, Galileo, to his own great amazement, discovered that it had four satellites, and these little satellites revolved round the Jupiter just as the planets were supposed to revolve round the Sun.

The impact of Galileo’s fragile instrument on human vision of the universe was enormous. The incorruptible celestial spheres had disappeared once and for all.

The final proof of heliocentric theory was provided by the works of Isaac Newton. But he would hardly be so successful if Johannes Kepler had not made his important astronomical discoveries. Kepler proved that planets are moving on elliptic orbits and formulated the laws of planetary kinematics. Kepler himself would not be able to make his invaluable contribution to astronomy if he had not the advantage to use the results of systematic observations of the planets carried on by his friend and colleague Tycho Brahe. Even having at hand these unique astronomical records, Kepler had to carry out years long hard calculations to find out that Mars' orbit was an ellipse. The goal of Kepler's obsessive investigation was to reveal the mathematical harmony of the solar system. As a by-product of this laborious exploration, Kepler revealed his famous laws of planetary distances, periods, and speeds of orbital motion. And what is perhaps not less important, Kepler suggested that the planets were kept on their orbs by the force exerted by the central body of the solar system, the Sun.

To build the system of celestial mechanics, Isaac Newton had first to formulate his fundamental laws of dynamics and discover the law of universal gravitation.

The scientific revolution started by the publication of Newton's magnificent *Mathematical Principles of Natural Philosophy and The System of the World* is justly appreciated as one of the highest achievements of human thought. Yet these publications should not be a complete surprise to many thinkers of that time. Much earlier Huygens published *Horologium Oscillatorum* where he treated the problems of mechanics and physics in the same axiomatic-mathematical way. In 1676, a decade before the publication of *Principia*, Leibnitz sent a letter to secretary of the Royal Society of London where he outlined his great plan of developing the complete system of theoretical physics. A bit earlier Robert Hook wrote to his friend of his System of the World that should be built on three suppositions, two of them presenting actually the law of universal gravitation.[2]

As we see, the real process of formation of the heliocentric conception had nothing common with a one-leap revolution.

Now let us turn to the revolution in the scientific world picture brought about by the creation of quantum mechanics.

The popular opinion is that atomic physics was created in the years 1913 - 1926, beginning with the publication of Niels Bohr's paper on atomic radiation and finishing with the development of the matrix system of quantum mechanics and creation of wave mechanics. In actuality, the history of atomic physics began much earlier. In 1897, J. J. Thomson gave a convincing experimental proof of existence of the electron – the minimal portion of electric charge equal $3 \cdot 10^{-19}$ coulomb. A negligible amount, only three parts in 10^{19} parts of coulomb! A real messenger of the micro-world. Actually, it was J. J. Thomson who succeeded first to steal the first glimpse of the inner structure of the atom.

But atom is electrically neutral. So physicists should be compelled to think that an atom consisted of positively charged electric substance in which negatively charged electrons were incorporated, as first suggested Lord Kelvin in 1902. Eventually, J. J. Thomson and his colleagues

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[2] Robert Hooke was well aware of the greatness of his task too. In 1674, he wrote to his friend: "[At a future date] I will explain a System of the World differing in many particulars from any yet known, [and] answering in all things to the common rules of mechanical motion. This depends on three suppositions: first, that all celestial bodies whatsoever have an attraction or gravitating power towards their own centers, whereby they attract not only their own parts … but they also attract all the other celestial bodies… The second supposition is this: that all bodies whatsoever that are put into direct and simple motion, will so continue to move forward in a straight line, till they are by some other effectual powers deflected and bent into a motion describing a circle, ellipse, or some other more compounded curve line. The third supposition is: that these attractive powers are so much the more powerful in operating, by how much the nearer the body wrought upon is to their centers."

developed in detail the so-called “plum-pudding” model of atom. They assumed that tiny negative electrons were embedded in regular patterns inside the huge positive charge of the atom.

Though this model appears to contemporary educated reader quite awkward, it did not emerge like an idle abstraction. J. J. Thomson and his colleagues succeeded to explain with its help the most important chemical property of substances – the chemical valence.

J. J. Thomson’s “plum-pudding” model of atom was developed at the Cavendish Laboratory. But in 1911, experiments on the deflection of alpha particles carried on by Ernest Rutherford’s assistants at the Manchester University brought to the discovery of atomic nucleus. Then Rutherford immediately proposed the planetary model of the atom.

It is usually underlined that Rutherford’s planetary model meant a complete rejection of J. J. Thomson’s conception. But the planetary model can be evaluated also as a definite correction of Thomson’s model. Instead of supposing that the positively charged electric substance filled all the spherical volume of the atom, it should be just corrected, in the light of new experimental data, that the positive charge was concentrated in the small nucleus of the atom. Nevertheless, Rutherford’s model crucially changed the picture of the microworld. As writers on atomic physics like to emphasize, it appeared that matter consisted overwhelmingly of empty space.

Rutherford’s discovery of the nucleus of the atom should be a great relief for the supporters of Thomson’s model. There was little chance to explain in the framework of the old model how the electronic shells could exist in the positively charged substance. And how could such an atom be ionized? It should seem also impossible to think up a way in which electrons could be brought back into the electronic shell to recombine with the ionized atom.

In 1912, Niels Bohr went to England to study physics in Thomson’s laboratory. Then he made friends with Rutherford and worked for a while under his guidance. In 1913, Bohr presented his first paper on atomic physics. Taking for granted Rutherford’s planetary model, he suggested a convincing explanation of the linear spectra of atomic radiation.[3]

First of all, the young physicist examined the simplest case – the radiation of hydrogen atom. It was well known in spectroscopy that the hydrogen spectrum is perfectly presented by Balmer’s formula. So, one had to deduce Balmer’s formula using the planetary model of atom. But Balmer’s formula dealt with the series of discrete numbers. So the atomic theory must be the theory of discrete states of electrons. Such considerations could bring Niels Bohr to his conception of the set of discrete orbits of atomic electrons.

Elaborating his conception of atomic radiation, Bohr had to take into account also the photon conception of electromagnetic radiation developed by Max Planck and Albert Einstein.

In general, can you imagine quantum mechanics without the conception of quanta of energy? Of course, not. So one can begin the history of the quantum mechanical revolution also from the year 1900 when Max Plank first proved that the difficulties of the theory of electromagnetic radiation could be resolved using the idea of quanta of energy.

In 1905, Albert Einstein succeeded to explain the phenomenon of photo-electricity that appeared entirely incompatible with the classical theory of electromagnetic radiation. Einstein’s conception of photoelectric processes was extremely simple. An electron in the metal plate absorbs

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[3] Niels Bohr acknowledged the contribution of his predecessors as follows: “The discovery of the electron and elucidation of its properties was the result of the work of large number of investigators, among whom Lenard and J. J. Thomson may be particularly mentioned. The latter especially has made very important contributions to our subject by his ingenious attempts to develop ideas about atomic constitution on the basis of the electron theory. The present state of our knowledge of the elements of atomic structure was reached, however, by the discovery of the atomic nucleus, which we owe to Rutherford”. (Niels Bohr, *The Structure of Atom*. – In: *Nobel Lectures. Physics*, vol.2. Amsterdam, Elsevier Publishing Company, 1965, p.7.)

a quantum of radiation with the energy $E = h\nu$, loses some amount A of this energy to come out of the plate, and then moves further with kinetic energy $mv^2/2 = h\nu - A$. The higher is the frequency ν of absorbed photons, the bigger is the kinetic energy of emerging electrons. In case the frequency of the electromagnetic radiation is too low ($h\nu < A$), electrons cannot come out of the metal plate, and there would be no photoelectric effect. Einstein's discovery produced an enormous impact upon the physical science of his day. In particular, it offered the mechanism of energy consumption and radiation on the level of atoms and molecules.

Using the idea of quanta of energy, Niels Bohr supposed that electrons of atom move on discrete orbits, each one of them having its own level of energy.

But according to classical electrodynamics, electrons rotating round the nuclei should radiate uninterruptedly. So Bohr postulated that in the atom electrons do not radiate while moving on the stable orbits. Energy radiation takes place only when an atomic electron moves from a higher level orbit to some of the lower level one.

Physicists soon understood that Bohr made only the preliminary step to the theory of atomic phenomena. The first break-through came with Heisenberg's paper published in 1925. Young Werner Heisenberg was fascinated by the new science of atomic physics from the year 1922 when he heard Niels Bohr's lectures on his theory of atomic radiation. Discussing various aspects of his theory with the young student, Bohr was delighted to see Heisenberg's enormous enthusiasm in regard of the fundamental problems of modern physics. So Bohr helped him to get a grant for research work at the physics institute of the University of Copenhagen in the winter semester of 1924/1925. Heisenberg carried on his research under the guidance of Hans Kramers, Bohr's best assistant. To develop further Bohr's theory, Kramers began to investigate the process of dispersion of light. During the joint research with Kramers, Heisenberg came to very promising results using products of Furie series. In 1925, Heisenberg succeeded to show that the method of multiplication permits to describe the states of electrons in atoms and the spectra of atomic radiation. Soon Max Born and his assistant Pascual Jordan developed this approach into a first system of quantum mechanics, the so-called matrix system.[4]

In 1926, Erwin Schrödinger elaborated the alternative conception of atomic physics – the wave mechanics. To get a set of discrete states of electrons in atoms, Schrödinger presented electrons as standing waves. There remained no particle-electron in atom. Electron was supposed to be spread over its orbit in the form of a standing wave.

The unordinary wave approach was not a chance success. Schrödinger adopted the fundamental new principle proposed by Louis de Broglie in 1923. The principle of de Broglie asserted that matter has dual wave-corpuscular nature. By that time, Einstein had already proved that light, the specimen of continuity in classical physics, should be regarded composed of discrete particles, photons. In photoelectric phenomena, photons really behaved as particles though electromagnetic radiation was well known by its wave properties. But in the case of particles – electrons, protons, neutrons, and alpha particles – there was no single evidence of their wave properties.

De Broglie just considered a logical possibility to reach symmetry between photons and electrons. The only ground for this brave idea served Einstein's discovery of photons. Few scientists knew of de Broglie's doctoral dissertation and still fewer were ready to conceive the apparently crazy idea. To the French scientist's great luck, Albert Einstein not only approved the brave idea,

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[4] For his contribution to atomic physics, Niels Bohr was awarded Nobel Prize in 1922. Werner Heisenberg got Nobel Prize in 1932. By the irony of history, Max Born, who first proposed the term "quantum mechanics" and together with his assistant Pascual Jordan built the first system of quantum mechanics, got the Nobel Prize only in 1954. And Hans Kramers, whose works prepared the road for Heisenberg, had never been nominated for the high award.

but gave it strong support in one of his papers. In those days, Einstein's name was already sufficient to turn the attention of scientists to that new hypothesis. Just due to Einstein's remark Schrödinger had learned the idea of wave-particle duality.

It became a wide spread tradition to mention only Einstein's name in regard of the theory of relativity. As some romantic writers like to declare, the theory of relativity, "like Athena, sprang full-grown from Einstein's head". Undoubtedly, Einstein was extremely original in developing the new mechanics. But he was not alone in building the new theory.

That there was a necessity for an essential reconstruction of mechanics should have become evident already after Michelson-Morley experiments. Quite unexpectedly, the speed of light appeared to be the same being measured in the direction of the motion of the Earth and in the perpendicular direction. It was in evident contradiction with the Galilean relativity principle based on the assumption of the existence of absolute space. Lorentz suggested that in the case of electromagnetic radiation Galilean transformation should be substituted by new transformation rule, which assumed that the speed of light was the maximal speed of motion in nature.

In 1902, French prominent mathematician Henry Poincaré published a collection of his papers *Science and Methodology* where he discussed a number of fundamental problems of scientific knowledge. Beside various original ideas, Poincaré came forward with a general conception of new mechanics. This general intention he brought to realization in 1905, a few months later of Einstein's famous paper.[5]

It is completely clear today that the special theory of relativity was built chiefly due to Albert Einstein's famous 1905 paper. Soon Hermann Minkowski, Einstein's former professor of Mathematics at the Zurich Polytechnic Institute, gave the relativistic mechanics a classical formulation using the idea of four-dimensional space-time continuum.[6]

In 1913, extending the principle of relativity to all reference systems, inertial as well as non-inertial, Einstein formulated the General Theory of Relativity. Soon it was recognized also as the new theory of gravitation. Abolishing in the Special Theory of Relativity the concept of absolute space, in his new theory Einstein proposed a new basis of the entire universe – the entity of space, energy and gravitational field.

Einstein's cosmological model based upon the General Theory of Relativity was a real sensation for the wide public as well as for the physics community. According to Einstein, the universe most probably was finite though having no boundary. And no one could help the astonished people to imagine a finite universe without boundaries. The necessary conclusion following from Einstein's cosmological model that beyond the finite universe there could be no physical object, even no empty space sounded even more incredible.

I would like to underline that "step by step revolutions" took place not only in the history of exact sciences. Consider for instance Darwinism. The idea of the evolution is almost as old as the idea of the heliocentric universe. In the Introduction to *The Origin of Species* Darwin mentioned how far Aristotle went in his anticipation of the mechanism of evolution. Due to works of Comte de Buffon, Erasmus Darwin (Charles Darwin's grandfather), Jean Lamarck and others, the idea of

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[5] Sir Edmund Whittaker, *History of the Theories of the Aether and Electricity*, vol.2. London, 1953.
In his speech at the 1904 Congress of Arts and Sciences at the Universal Exposition, Poincare questioned in a general form, "Perhaps, we should construct a whole new mechanics, of which we only succeed in catching a glimpse, where inertia increasing with the velocity, the velocity of light would become an impassable limit." (Quoted Ronald W. Clark, *Einstein. The Life and Times*. New York, The World Publishing Company, 1971.)

[6] Hermann Minkowski was sure of the cardinal significance of his contribution. In his paper *Space and Time* he emphasized this point as follows, "Henceforth space by itself, and time by itself, are doomed to fade into mere shadows, and only a kind of union of the two will preserve an independent reality." (*Problems of Space and Time*. Ed. J. J. Smart. New York, The Macmillan Company, 1964, p. 297.)

evolution of organic life was widely known by the end of the eighteenth century. All the necessary components of the theory of evolution through natural selection were known already to the beginning of the nineteenth century though diffused in the works of different authors. Both the founders of the evolutionary theory, Charles Darwin and Alfred Russell Wallace admitted how much they had been influenced by Malthus' idea of the struggle for existence. Darwin's scientific consultant and senior friend Charles Lyell was so close to the formulation of the theory of evolution that he could later on mention righteously, "I had certainly prepared the way". Darwin's biographers revealed that young Charles Darwin had been grown up in the air hovered with the idea of evolution. Darwin acknowledged that without Lyell's *Principles of_Geology,* where also the problems of biology had been discussed, his *Origin of Species* would not be written.[7]

Apart from this general evolutionist background, there was a particular powerful factor influencing Darwin's thoughts. It was the competition with Alfred Wallace. Anyhow, it took Darwin almost twenty years to work out his theory, and that, in fact, came to completion only in 1859, just after he got in 1858 a letter from Alfred Wallace informing about his discovery of the mechanism of evolution – the natural selection.

In his turn, Wallace was much stimulated by Darwin's publications concerning biological discoveries during his round the world voyage as well as by the personal correspondence with Darwin. Loren Eiseley characterized the complex interrelations between two great founders of the theory of evolution as follows: "without the stimulus of Darwin, there might have been no Wallace, just as, without the stimulus of Wallace, Darwin might never have got around to formal publication [of his theory of evolution]". [8]

The continuity of successive steps, which eventually bring to the formation of a new revolutionary theory, unavoidably raises the question of priority. For instance, some authors still discuss who is the creator of the special theory of relativity: though the history of science itself has resolved the question definitely in favor of Albert Einstein.

In support of this factual state of things, I would like to mention the following. First, one must draw strict *distinction between the philosophical conception of relativity and that of the system of relativistic mechanics*. The conception of relativity, undoubtedly, got wide acceptance due to the name of Albert Einstein. But even Einstein cannot be awarded laurels of sole creator of the philosophical conception of relativity. The general understanding of the principle of relativity and its philosophical-methodological conclusions were achieved in a *collective* quest started by Einstein**,** Lorentz, and Poincaré and continued by many others, Minkowski and Eddington keeping a notable position among them.

On the other hand, Einstein's contribution is really exceptional in regard of relativistic mechanics. Yet, one should bear in mind that the principles of relativistic mechanics could be formulated through appropriate corrections of the principles of classical mechanics. Einstein himself once pointed out, "We have here no revolutionary act but the natural continuation of a line that can be traced through centuries".[9] As separate ideas, Einstein's forerunners suggested many

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[7] "One can scarcely resist the observation," mentioned Loren Eiseley, "that the *Origin* could almost literally have been written out of Lyell's book, once the guiding motif of natural selection had been conceived. Lyell circled again and again about the leading idea that eluded him, but perhaps the fact that he was older than Darwin by more than a decade produced in him, both by background and temperament, a greater aversion toward the last inevitable step." (Loren Eiseley**.** *Darwin's Century***.** *Evolution and the men who discovered it.* New York, Anchor Books, 1961, p.100.)

[8] Loren Eiseley, *Darwin's Century*, p.157.

[9] Albert Einstein, *On the Theory of Relativity*. – In: Albert Einstein, *Ideas and Opinions*. New York, Crown Publishers, 1954, p.246.

significant corrections. But only Albert Einstein was daring enough to suggest the *system* of new relativistic mechanics.[10]

Step 5. UNINTENDED REVOLUTIONS

"*Years of hard research produce great discoverers almost against their will.*"
Anonymous

Of course, it is rather unusual and even strange that scientific revolutions have happened step by step. But this fact does not diminish the historic significance of these great discoveries. The important and essential moment is the *radical change of the world outlook*. And if this radical reconstruction of the scientific world picture came to life not in one great effort, it does not change the essence of the happening. Human understanding of the world did change. This is the goal and final result of a scientific revolution. It is only a matter of historical and methodological inquiry to reveal the way the revolution factually took place. The value and significance of a basic revolution is determined by its *final results*. If a given revolutionary theory was not born in a momentarily flight of thought of a genius, but rather was produced by laborious evolution of some initial concept, this circumstance cannot lessen its historic value.

Yet there is a striking fact concerning the revolutionaries of science. They are included in two unequal groups. A few of them admitted that they did not intend the revolution brought to life by their discovery. The rest of them concealed this fact. I am quite categorical. *Revolutionaries of science did not intend the revolutions they made.*

I have discussed above the question why is it so difficult to make a fundamental theoretical discovery? A great discovery requires *radical reconstruction of the foundations* of the given branch of science. Such a task is the most difficult problem for a scientist since he comprehends the world and the knowledge about the world through the same fundamental concepts that need revision and reconstruction. In this sense, making scientific revolution requires to solve a super-difficult problem.

Quite surprisingly, famous scientists succeeded to become founders of revolutionary conceptions without being forced to solve a supper-difficult problem. And that simply because they did not place themselves in opposition to basic paradigms of their day and did not intend to make the revolution brought to life by their ideas.

Let us review the history of revolutionary discoveries from this point of view. Eudoxos-Aristotle-Ptolemy theory of the Heavens presumed that the uniform rotation is the ideal type of motion for heavenly bodies and that the uniform rotation of celestial spheres is the only possible basis for the explanation of the eternal motion of heavenly bodies.

Copernicus did not reject this main principle of the fabric of the Heavens. Moreover, in his own heliocentric system he made use of almost fifty uniformly rotating spheres to calculate the motion of the planets. The main goal of Copernicus was to build a more simple system for astronomical calculations. He was sure there could little be done to improve significantly the astronomical system of Ptolemy. On the other hand, it was clear that the heliocentric system would have an essential advantage since there was no need to build epicycles for the retrograde motion of

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[10] It is a historic fact that Einstein's revolutionary papers on relativity caught the interest of all scientific community, while the ideas of Poincaré and Lorentz were known only to the limited circle of physicists. It could not be other way. Poincare's general remarks on relativity were very occasional. Lorentz could never interest wide public since his main task was to improve and keep working Maxwell's electromagnetic theory. By contrast to them, Albert Einstein launched a strong offensive on the principles and fundamental notions of classical science.

the planets. Though this main advantage did not provide more precise astronomical calculations, it is very probable that the idea of simplicity of the proposed heliocentric system was the most attractive moment for Copernicus.

If Copernicus' intention were a revolution in human understanding of the universe, which should eventually bring to the denial of the geocentric world picture sanctified by the Holy Scriptures, it would be unthinkable for him to dedicate his historic *De Revolutionibus* to the reigning Pope Paul III.

There is an additional argument supporting the opinion that Copernicus did not intend a revolutionary change in the worldview of his day. I mean the content of the second Preface of the *De Revolutionibus*. This additional Preface asserted that Copernicus' system was just a device designed for astronomical calculations and has nothing to do with the true motion of the Earth and the planets. It is nowadays widely accepted that the editor of the *De Revolutionibus* Andrew Osiander wrote this Preface almost against the will of ailing Copernicus. But in fact, Copernicus himself had asked an advice from his colleague and friend Osiander, and there is no direct evidence that Copernicus rejected the position expressed in the Preface.

Some authors believe that the main motif was Copernicus' deep dissatisfaction with the fact that Ptolemy put no physical sense in his model of the Heavens. To explain each separate feature of planetary motion, Ptolemy introduced special spherical constructions and assigned them a set of uniform rotations. Anyhow, no planet was provided a geometrical construction capable of accounting for all features of its motion. Ptolemy succeeded to provide uniform rotation to the planets, but that only in relation of the specially designed points – the "equants". The cost of such approach came out to be too big if one wanted to understand the *physics* of the fabric of the Heavens. The motion of the planets on their deferent circles and round the centers of their epicycles became non-uniform. For Copernicus, as for anyone else interested in the physics of the Heavens, a non-uniform motion of the heavenly spheres was completely unacceptable.

In a definite sense, the heliocentric system of Copernicus was a premature enterprise. Until Newton's discovery of the law of universal gravitation, Aristotle's argument against the hypothesis of heliocentric world could not be answered properly. On the other hand, only after Kepler's proof that the orbits of the planets are ellipses the new heliocentric system could provide more precise astronomical calculations than it had been achieved on the basis of the geocentric system.

Even if so, this argument cannot diminish the historical significance of Copernicus' great work. Not being lead by heliocentric teaching, Kepler would never explore the orbit of Mars, and astronomy would lack Kepler's laws of planetary kinematics. And it would be a very hard task for Isaac Newton to prove the law of universal gravitation not having at hand Kepler's laws.

To evaluate objectively Copernicus' great work, one must be extremely careful, especially when formulating a general conclusion. Otherwise incorrect estimates are unavoidable. Unfortunately, even Thomas Kuhn gave place to such a conclusion in his fundamental investigation *The Copernican Revolution,* the best contemporary study in this field. Measuring Copernicus' creation in terms of its consequences, Thomas Kuhn came to the conclusion that it is "a relatively staid, sober, and *unrevolutionary* work".[11] One must be very cautious using such a characteristic of Copernicus' system. Of course, Copernicus views are sober and even old-fashioned compared to

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[11] Thomas Kuhn argued his position as follows: "Most of the essential elements by which we know the Copernican Revolution – easy and accurate computations of planetary position, the abolition of epicycles and eccentrics, the dissolution of the spheres, the sun as a star, the infinite expansion of the universe – these and many others are not to be found anywhere in Copernicus' work. In every respect except the earth's motion the *De Revolutionibus* seems more closely akin to the works of ancient and medieval astronomers and cosmologists than to writings of the succeeding generations who made explicit the radical consequences that even its author had not seen in his work". (Thomas S. Kuhn, *The Copernican Revolution*. Cambridge, Harvard University Press, 1957, p.134.)

Keplerian computations and Newtonian mechanics. These later achievements, though initiated by Copernicus' work, compose a new and more profound revolution in celestial mechanics. If such parallels were justified, one should conclude that Newton's *Principia* were sober and old-fashioned too if it were compared to Einstein's theory of relativity.

There can be no doubt that Newton's physics produced one of the most significant scientific revolutions. But it is not a big secret for the historians of physics that men of science knew well the laws of mechanics, and even the law of universal gravitation, several years before the publication of the *Principia*.

Then what was Newton's contribution?

Two things of exceptional importance made Newton, to which no other scientist was able in that time. First, he built a complete theoretical *system* from the separate ideas known to his contemporaries: a system so much powerful that it successfully built the foundations of the mechanical theory of all earthly phenomena as well as of the motion of heavenly bodies. Newton fully deserved the right to call his creation "the System of the World".

What is not less important, Newton gave physicists an effective mathematical instrument for an accurate description of physical phenomena. He created the differential calculus and showed with incomparable brilliance how it should be used in the field of theoretical physics. Fortunately for natural sciences, the Heavens endowed Newton equally with a brilliant mathematical talent and an exceptional intuition of a natural philosopher. "I have in this treatise cultivated mathematics as far as it relates to philosophy," pointed out Newton in *Principia*.

By the end of the nineteenth century, classical physics had so successfully explained the fundamental features of the physical world that few scientists would think of the necessity to rebuild its foundations. Max Planck least of all had the intention to revolutionize the physical science. In James Franck's words, Planck was a revolutionary "against his own will". His main concern was to reach a deeper understanding of the principles of thermodynamics. The young scientist got especially interested in the conception of entropy, the law of increasing disorder in the structure of material world. One could hardly avoid also the wide spread interest to the problem of so called "ultraviolet catastrophe". Experiments on the density of the energy of radiation showed that in the range of short waves there was a huge gap between the theory of electromagnetic radiation and the experimental data of the "black-body" radiation. Physicists were forced to use two separate formulas, one of them describing the long wave radiation spectra, and the other one precisely presenting the short wave part of the spectra. Max Planck succeeded to unite these two formulas into a single one, which formally resolved the "ultraviolet catastrophe". But what was hidden behind this formula?

Max Planck, as all the physicists of his days, had no doubt that energy radiated through electromagnetic waves was a specimen of continuity. According to classical conception, energy was a non-discreet characteristic of the physical world. Yet Planck succeeded to prove that his formula, which resolved the ultraviolet catastrophe of the classical conception, could be derived only from the opposite assumption of the discreet structure of electromagnetic radiation.

It is well known that introducing the idea of quanta of energy Planck had no intention to rebuild the classical physics. The concept of quanta of energy appeared a necessary means for correct theoretical calculations. "It is difficult to say," wrote later on James Franck, "whether the joy of the discovery prevailed in Planck or the regret that the classical approach to physics so cherished by him, had failed dismally. He was by his very nature a classical and by no means a romantic revolutionary."[12]

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[12] James Franck, *Introduction*. – In: Max Planck, *The New Science*. Greenwhich Edition published by Meridian Books, 1959, p. XIX.

Such an understanding of Planck's position is confirmed by the following startling fact. In years 1911-1917, over a decade after the discovery of quanta of action, Planck published a number of papers in which he tried to prove that though energy is radiated in discrete quanta its absorption is a continuous process. Max Born who had been close to Planck for long years noted that the famous physicist was not a revolutionary by his personal character. To Born's opinion, Planck was rather conservative by his nature. "He had nothing of a revolutionary, and, in general, he was very skeptical in regard of speculative suggestions," concluded Max Born.

Max Planck directly admitted his classical convictions in his autobiography. "My futile attempts," recalled Planck, "to fit the elementary quantum of action somehow into the classical theory continued for a number of years, and they cost me a great deal of effort. Many of my colleagues saw in this something bordering on a tragedy. But I feel differently about it. For the thorough enlightenment I thus received was all the more valuable. I now knew for a fact that the elementary quantum of action played a far more significant part in physics than I had originally inclined to suspect."[13]

Planck's hypothesis became an essential part of the revolutionary process that succeeded to build atomic physics. J. J. Thomson's strange model of atom with negatively charged electrons floating inside the sphere of positive charge was forced on him by empiric data. The most decisive fact was J. J. Thomson's own discovery of electron. Since the mass of electron appeared to be negligibly small compared to that of the atom, there was no other way but to assume that the body of the atom is a sphere of positively charged substance. The new fact – the discovery of the existence of atomic nucleus – brought to an essential correction of Thomson's model. Rutherford suggested the planetary model of atom where the positive charge and practically all the mass of the atom were concentrated in its nucleus.

So J. J. Thomson and Rutherford opened the gate into the mysterious kingdom of atoms. It was a real revolution in the scientific vision of the world. Yet it was a revolution of factual knowledge, but not of basic principles.

Developing Rutherford's conception, Niels Bohr suggested a really "crazy" idea. He postulated that electrons in atom revolve only on a definite set of orbits. Judging strictly, even Niels Bohr's postulate was not a new theoretical principle. It was a factual fixation of the state of affairs. Accepting Rutherford's model of atom and trying to explain on its bases the discrete spectra of atomic radiation one should eventually realize that, due to some unknown factor, electrons could rotate inside the atom only along discrete orbits. Young Niels Bohr did not intend a revolution. He was just forced to formulate his postulates trying to agree Rutherford's planetary model of atom with the discrete structure of the spectra of atomic radiation.[14]

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[13] Max Planck, *Scientific Autobiography and Other Papers*. New York, Philosophical Library, 1949, p.44.
In general, Planck was very proud of his discovery. In 1911, closing his lecture to a society of German scientists, he declared, "The hypothesis of quanta will never vanish from the world". (Quoted Martin J. Klein, *Thermodynamics and Quanta in Planck's Work* – In: *History of Physics,* Readings from *Physics Today*. New York, American Institute of Physics, 1985, p.302.)

[14] Bohr's postulates are understood today as a radical rejection of the classical electrodynamics according to which electrons rotating round the atomic nucleus should lose their energy through electromagnetic radiation. Niels Bohr supposed that electrons in atom are moving on the discrete stable orbits and, for some yet unknown reason they do not radiate energy while rotating on those orbits. Electrons could radiate only while descending from a higher stable orbit to a lower one. If the energy level of these two orbits were E_2 and E_1 respectively, then the radiated quanta of energy should had been $h\nu = E_2 - E_1$. But Bohr did not initially judge completely in line with his own conception of quantified states of electrons in the atom. At early stages, Bohr was not yet ready to deny the classical principle according to which the frequency of the radiation of electrons in atom depended upon the frequency of their rotation round the atomic nucleus. As Werner Heisenberg recalls, Bohr realized that such a semi-classical approach contained an "unbearable contradiction". But Bohr, according to Heisenberg's evidence, did not intend to build new mechanics. He believed that

Working on Bohr's model, Heisenberg used some special method for the calculation of radiation dispersion, which was soon generalized by Born and Jordan. It brought to the formation of the matrix system of quantum mechanics. Was Heisenberg guided by the intention to make a revolution in physics? The answer is definitely negative. The young physicist just examined a particular problem of dispersion in the theory of atomic radiation. Did Max Born intend to rebuild radically the fundamental principles of physics? The negative answer is clear in this case too. In the annotation to his 1924 paper where for the first time the term "quantum_mechanics" was introduced, Born directly mentioned that the goal of his research was to show that the main features of atomic physics can be naturally explained in line with the laws of classical physics.[15]

It was only later realized that these pioneer works resulted in a fundamental revolution of physical science.

Modern theoretical physics is predominantly a mathematical science. Apparently, de Broglie was not strong enough in mathematics. He did not succeed to build a particular physical theory using his hypothesis of wave-particle duality.

But already in 1926, Erwin Schrödinger created the alternative system of atomic physics – the wave mechanics – describing the motion of electrons in atoms with the help of de Broglie's idea. After Max Born had interpreted Schrödinger's wave function as a means to describe the probability of corresponding physical parameters, it became clear that wave function is the most effective instrument of atomic physics. But does it mean that Schrödinger was rejecting classical mechanics and wanted to build a new theory instead? No, he never had such an intention. On the contrary, Schrödinger was convinced that with the help of wave function he would be able to describe the atomic radiation classically, without Planck's quanta and Bohr's "jumps". His intention was to eliminate eventually the concept of quanta of energy from physics altogether. Even two weeks of uninterrupted debates with Niels Bohr in Copenhagen in September 1926 could not change Schrödinger's position.[16]

To finish with quantum mechanics, let us discuss two more discoveries. Firstly, Paul Dirac's relativistic quantum mechanical equations with the help of which he predicted the existence of anti-particles and suggested a very strange conception of physical vacuum full of uncountable particles with negative energy. Dirac's relativistic conception appeared to be so fundamental that it was extensively used not only in atomic physics but later on also in the theory of elementary particles.

Did we finally find a revolutionary of science who was strong enough to break off with paradigms of his scientific beliefs and conceive the world in the light of a radically new conception? Alas, things look quite different. For the 23 years old Paul Dirac, Einstein's conception of relativity was a basically proven fundamental theory. Dirac did not need big effort to adopt relativity. After 1919 observations of the sun eclipse, the theory of relativity not only was accepted as a fundamental conception of modern physics, but all of a sudden it became a subject of common interest and admiration.

Relativity was Dirac's basic paradigm. When he learned from Heisenberg's lectures the new quantum mechanical methodology, he should soon realize that the equations of quantum mechanics must be relativisticly invariant. The relativistic approach to quantum mechanics did not assume for Dirac any conflict with his basic paradigms. Adopting relativistic approach was not for him a super-difficult problem in any sense of the term. Dirac just applied a well-established principle of relativity to a new field of research – the quantum mechanics.

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the difficulty is caused by some limitations of electrodynamics and tried to get out of the trouble with the help of his principle of correspondence. (See Werner Heisenberg, *Tradition in der Wissenshaft.* Munchen, 1977, S.46.)

[15] Max Born, *Uber Quantenmechanik*. Zeitschrift fur Physik, 1924, Bd. 26, S.379.

[16] Werner Heisenberg, *Schritte uber Grenzen*. Munchen, 1973, S.62.

Now some short comments in regard of Wolfgang Pauli's "exclusion principle". Pauli's principle appeared to be so effective in the physics of the micro-world that some methodologists got convinced that the modern theory of elementary particles must be built not as a system of fundamental laws but rather as a system of rules of "prohibition". Pauli initially introduced his principle to solve a particular problem how many electrons could dwell in each electronic shell of the atom. It just stated that in atom there could be no two electrons in the same state, *i. e.* with identical quantum numbers. Pauli's initial conception neither meant a further extension to the field of elementary particles nor pretended to be a revolutionary fundamental principle of the micro-world physics.

Discussing my observation that revolutionaries of science did not intend the revolutions they made, it is worthy to consider also the case of Charles Darwin. As a young naturalist, Darwin went to a voyage to South America on the board of *Beagle* in 1832. He collected a huge amount of facts necessary and sufficient for the formulation of the theory of evolution. The first account of Darwin's voyage came in the *Journal of Researches* in 1839. Still another twenty years had passed before Darwin completed his theory of evolution in *The Origin of Species*. And this great work was accomplished only after receiving a letter from Alfred Wallace that told Darwin about new evolutionary conception based on the principle of natural selection.

Visiting the Galapagos Archipelagos, Darwin got a real chance of an empiric refutation of Lamarckian evolutionary conception. Animals, particularly the birds of the same species, were notably modified on different islands though these islands were only a few miles apart and had the same climatic and physical conditions. So Darwin had to face the central problem of the theory of evolution: if the physical conditions were not responsible for the variations, then what was the source of the variability of species?

Since in Darwin's days creationism was completely abandoned and the intellectual atmosphere was full of expectation of emergence of a convincing theory of evolution, the Galapagos experience of Darwin should force him to the only remaining alternative – the assumption of the spontaneous variations and natural selection. But apparently Darwin was not so much impressed by the Galapagos experience or, at least, he was not ready to realize the problem. Summing up his discussion of the possible impact of Darwin's Galapagos experience on his perception of the problem of evolution, Loren Eiseley wrote: "Darwin did not come to this problem by great flash of insight. It was not his way".[17]

Returning from the voyage, Darwin undertook intensive study of domestic selection. It made matters worth. Darwin began to think that in nature the organism varied in a lesser degree. That might strengthen his inclination to assume environmental rather than interior causes of change. In addition, Loren Eiseley mentions that Darwin often shared Lamarck's belief in reality of acquired characteristics and their inheritance.[18] All that taken together was a serious obstacle for Darwin to find out the real mechanism of evolution. In this situation, the letter from Alfred Wallace should give Darwin a decisive impetus to undertake his historic task and create a fundamental theory of evolution.

Another apparent case when the author of a fundamental scientific discovery never intended the revolution is that of Gregor Mendel. The new genetic theory of heredity revolutionized all the biological science and provided a solid basis to the theory of evolution. But the founder of genetics

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[17] Loren Eiseley. *Darwin's Century*. New York, Anchor Books, 1961, p.173. In fact, Loren Eiseley should be aware that by the days of his journey Darwin was unable to realize the real importance of Galapagos phenomenon. Just on the following page of his book Eiseley brings in a citation from the first edition of the *Origin* where Darwin clearly admitted that the correct comprehension of Galapagos data long appeared to him a great difficulty "in chief part from the deeply seated error of considering the physical conditions of a country as the most important for its inhabitants."

[18] *Ibidem*, p.p.200-201.

Gregor Mendel had only the intention to create the concise conception of plant hybridization. To do justice to the great explorer, it must be mentioned that Mendel realized the principle importance of his hybridization experiments. In his main paper *Experiments on Plant Hybrids* Mendel mentioned that among the numerous experiments not one has been carried out to an extent that would make it possible to determine the number of different forms and permit ascertain their numerical interrelations. But biologists could hardly miss the importance of such experiments. "It requires," wrote Mendel, "a good deal of courage indeed to undertake such a far-reaching task; however, this seems to be the one correct way of finally reaching the solution to a question whose significance for the evolutionary history of organic forms must not be overestimated." Yet, in Mendel's papers and letters there is no direct statement of the possibility of developing the genetic theory of inheritance on the bases of laws established by his experiments. [19]

Among all revolutionaries of science, *only Albert Einstein intended a radical reconstruction of fundamental theories*. Already in his early work on dimensions of atoms and molecules, young Einstein pursued the goal of rebuilding theoretical physics. He directly stated the necessity of a new revolutionary theory when he undertook the critical review of the classical electrodynamics. "I am more and more convinced that the electrodynamics of moving bodies, as presented today, is not correct," wrote Einstein already in 1899. Even Planck's quantum theory seemed to him far from being completely satisfactory. Suggesting his extraordinary conception of photons of light, Einstein clearly realized that only a revolutionary synthesis of wave and corpuscular theories might resolve the difficulties suggested by apparently incompatible phenomena of interference and diffraction of light, on the one hand, and photo-electricity, on the other. Moreover, Einstein declared unsatisfactory even his own great contribution to science – the special theory of relativity – and suggested instead the general theory of relativity with its grandiose model of the universe. The uncompromising revolutionary spirit forced him to the last days of his life in science to pursue the great goal of creating the unified field theory.

Step 6. GREAT DISCOVERIES AND SUPER-DIFFICULT PROBLEMS

"Most anomalies are resolved by normal means."
Thomas S. Kuhn

Intentions are subjective. So my interpretation of intentions of geniuses of science in regard of their great discoveries cannot avoid subjectivity either. But I can prove with a complete objectivity that geniuses of science making their great discoveries have not been forced to solve super-difficult problems.

I will start with great Aristotle. As it was agreed above, a problem is super-difficult when its solution requires using ideas and hypotheses incompatible with the paradigms of the epoch. Aristotle had the advantage that science was making its first steps. In his days, there were only a number of scientific paradigms, like the principle of causality, the ideal of uniform rotation, the teaching of four basic elements, etc. One could hardly question the validity of these principles since they were firmly supported by the entire experience of ancient society.

Aristotle never rejected the principles of physics provided by the everyday experience of his time. He effectively used these principles suggesting rational explanations of all known to his epoch phenomena including those of the heavenly world. The objective study of Aristotle's physics

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[19] Gregor Mendel, *Experiments on Plant Hybrids*. – In: *The Origin of Genetics. A Mendel Source Book*, Ed. Curt Stern and Eva R. Sherwood. San Francisco, W. H. Freeman and Company, 1966, p. 2.

reveals that the principles of his natural philosophy were closely related to the experience of the everyday life and least of all were products of hasty speculations, as Baconians were used to declare.[20]

The other advantage was the air of complete freedom of thought in ancient Greece. Any idea was worthy of consideration if there was logical possibility for this idea to be true. Two conditions seemed sufficient for this purpose. First, a rational conception had to avoid any form of self-contradiction. Second, suggesting a rational conception one had to be careful not to confront the well-established facts and go in line with widely accepted general principles that were based on the experience of those days too.

None of Aristotle's great discoveries confronted the paradigms of his epoch. For instance, his model of the universe was based on fundamental concepts of his time like those of eternal uniform circular rotation and four basic elements.

Of course, old paradigms were not sufficient to build the scientific picture of the entire universe. Aristotle developed some principles of his own. First must be mentioned the concept of the natural motion of elements to places of their destination. Heavy bodies composed of earth and water had to move to the center of the Earth, while light elements fire and air – upwards to the sphere of the Moon. In spite of the totally general nature of problems Aristotle dealt with in his *Physics,* the principles underlying its solutions appear closely tied to everyday experience.

The really extraordinary point of Aristotle's world picture was the concept of the First Mover – the ultimate source of the eternal motion in the whole universe. But the idea of this strange mover of all the earthly and heavenly bodies – who itself remained non-moving – necessarily followed from the main principle of Aristotle's mechanics. I mean first of all the central principle of the natural philosophy of those days that a body keeps moving only if there is a force acting on it. This principle appeared completely evident to ancient thinkers, and many people would agree with it even nowadays if they judge from their own everyday experience.

To prove the concept of the First Mover, Aristotle considers a chain of interactions that has put bodies into motion. Following this chain into the past, Aristotle mentions that there are two logical possibilities: the chain may have a beginning or it may have no beginning. The second assumption, proves Aristotle, is unacceptable since it is in contradiction with the conception of potential infinity. If the chain of events had no beginning, then observing the elements of this chain at the present time, we would witness infinity reaching us from the past. But it would mean an actual infinity. And that is unacceptable since the infinity can be only potential.[21]

For the epoch of Copernicus, Aristotelian principles and concepts were instances of ultimate truth. Copernicus himself never rejected them. Angus Armitage, who thoroughly studied the life and work of the great astronomer, was really surprised that Copernicus had "swallowed" many of Aristotle's ideas.[22]

In Copernicus' revolutionary work the fundamental problem of the heliocentric structure of the world is discussed only in its Preface. The remaining part of the *Revolutions* deals with various problems of astronomical calculations. And even discussing the central problem of his theory whether did the Earth move in space or not, Copernicus was rather on defensive.

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[20] Stephen Toulmin and June Goodfield, *The Fabric of the Heavens.* London, Hutchinson & Co., 1961, p.92-93.
To their credit, the authors of the book deny the fashion "to pour scorn on Aristotle's physics". Of course, the general principles of the *Physica* are unacceptable to modern science, but one should keep in mind that they are sound enough in the context of the empiric knowledge of their epoch. "Far from being a piece of armchair imagining, his theory of motion was if anything too close to the facts and not abstract enough," conclude categorically the authors.

[21] Aristotle, *Metaphysica,* IX, 10, 1051 b 4-10.

[22] Angus Armitage, *The World of Copernicus.* New York, Mentor Books, 1951, p.110.

Naturally, Copernicus should give some answers to Aristotle’s objections concerning the idea of the motion of the Earth. These answers were mainly hypothetical. Aristotle pointed out that people would feel a strong headwind if the Earth were moving. To explain the absence of the headwind, Copernicus suggested that the air surrounding the Earth was moving with it. The idea came out to be completely true. But in Copernicus’ days such an idea could not be evaluated as a scientific hypothesis because it confronted the general principles of the so-called natural motion. Air should have a natural tendency to move upwards.

The main astronomical objection to the hypothesis of the motion of the Earth was the fact that no astronomer could observe the parallax of stars. There was no shift in the positions of the stars depending on the supposed orbital motion of the Earth. To resolve the difficulty, Copernicus presumed that the stars were so far away that the shift in their positions was too small to be noticed. Copernicus was lucky enough not to live to the days when first telescopes appeared. Even much later, more than two hundred years after Galileo’s observations, astronomers had been unable to detect any stellar parallax with the help of their telescopes. Only in 1838, F. W. Bessel succeeded to detect for the first time the star parallax – a slight shift in the position of the star 61 Cygni.

Copernicus not only followed the principles of Aristotle’s physics, but also used them to back up his heliocentric conception. Like all educated men of his day, he was convinced that the only kind of motion that could explain the eternal movement of heavenly bodies was circular uniform rotation.

But the planets observed from the Earth did not appear moving at a steady rate. Moreover the retrograde motion of the planets was well known already to the astronomers of Babylon. That undoubtedly proved that the Earth was not fixed at the center of the planetary orbs. To Copernicus, this fact was sufficient to believe that the Earth was moving. But the motion of the Sun was so evident and arguments against the possibility of the Earth being in motion so strong that on those days few people could accept the heliocentric conception.

Newton too was not involved in solving super-difficult problems to find out the main ideas of his theory of mechanics and the law of universal gravitation. These ideas had been already suggested by his predecessors and contemporaries.

The idea of inertial motion entered physical science due to Galileo’s famous dialogues.[23] Christian Huygens suggested that the acceleration of a body is proportional to the acting force. He succeeded also to prove that the centrifugal acceleration of a body is proportional to the square of its velocity, and inverse proportional to the radius of the circle at which the body is kept by the centripetal force. Borelli applied Huygens’ formula to the motion of the planets and concluded that the Sun is the source of the centripetal force that keeps the planets on their orbs. Huygens himself demonstrated that the force of attraction of the Sun should be inverse proportional to the square of the distance, in order to account for Kepler’s Third Law. But Huygens could prove this important relation only for the case of circular orbits while it was well known that the orbits of planets were ellipses. Robert Hooke suggested so many ideas concerning celestial mechanics, including that of the law of universal gravitation that he was deeply hurt learning that Newton did not mention his name in his *Principia*. But Robert Hooke was in fact unable to elaborate the strict mathematical proof of the law of universal gravity, too.

Actually, Newton had not much to discover. Newton’s mission was to give strict proof to all mentioned ideas and to build the complete theory of mechanics. He built the basis of the modern

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[23] Though Galileo formulated the basic law of the new mechanics, he was not completely consistent and could not entirely abandon the ancient ideal of circular motion. He was convinced that the alternative ideal of straight motion “goes entirely out of the window and nature never makes any use of it.” (Galileo Galilei, *Dialogue Concerning the Two Chief World Systems.* Berkley, University of California Press, 1953, p.167)

science of physics and expanded the mechanical approach to the research of various fields of natural phenomena. Newton's great service to science is unprecedented in all modern history. His *Principia* determined the further advance of modern science just like Aristotle's *Physics* had done it for his epoch. Yet Newton's great performance was rather a triumph of proof than a revolution of ideas and principles.[24]

One of the most striking ideas in the history of physics was the principle of wave-particle duality suggested by Louis de Broglie. According to his argument, nature had to have dual properties in its very foundation. Waves demonstrated properties of particles (as Einstein proved it in regard of electromagnetic radiation). So particles of substance might demonstrate wave properties believed de Broglie. In a historically short period**,** atomic physics proved that the principle of wave-particle duality reveals one of the most fundamental features of the micro-world.

Yet to make his most original discovery, Louis de Broglie did not solve a super-difficult problem. There was not yet any problem to be solved with the help of his hypothesis. There was no single fact in favor of his assumption that electrons and other particles of substance had wave properties. The idea appeared belonging to the physical science of days to come. It made sense only as a logical possibility reminding ideas of Greek natural philosophers. The only basis for the hypothesis of wave-particle duality was Einstein's proof that electromagnetic radiation demonstrated corpuscular properties in photoelectric phenomena.[25]

The special theory of relativity confronted many puzzling questions. Why should the mass of a body, which always was considered the measure of the amount of the substance in it, increase along with the speed of its motion? Why should the length of a rod be different when measured at different speeds? How is it possible that the speed of light is absolutely independent of the speed of its source? By what reason can the mass of a body be equivalent to an amount of energy proportional to this mass while for the long centuries the mass of a body was a symbol of inertness? Why should the speed of light be chosen as the maximal speed of motion in nature?

Each one of these questions contained a great mystery. And the special theory of relativity provided strict answers to all of them. Is it not clear that such a tremendous theory could be born only as a solution of a super-difficult problem?

If great discoveries were born through formal logical reasoning, the answer could be only positive. But you *hardly meet formal logic on the ways leading to great discoveries*. And in the case of the special theory of relativity, *historical facts* are not speaking in favor of the assumption that its discovery demanded to solve super-difficult problems.

Michelson's first experiments, which proved that the speed of light was constant, were carried on already in 1881. Morley helped to improve significantly these experiments in 1896. In fact, Michelson-Morley experiments made it unavoidable to question the very existence of ether. Scientists should be psychologically prepared for developing a new theory of electrodynamics by postulating that the speed of light was a physical constant. George F. FitzGerald tried to explain

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[24] Stephen Toulmin and June Goodfield, *The Fabric of the Heavens*, p.239-243 - The authors point out also the integrative function of Newton's theory: "Newton's unique contribution lay in the imaginative integration of many ideas into a single picture. This quality of imaginative integration is shared by many of the greatest scientific theories. Starting with a comparatively simple step, but systematically carrying the analysis through an unexpectedly wide field, such theories have the power to present old problems in an entirely new light. Whole new fields of study are opened up to patient and industrious inquiry. As a result, what had seemed to be old, insoluble difficulties appear to us in retrospect, perhaps unfairly, as mere confusion of mind".

[25] The decisive role of Einstein's involvement in the formation of wave mechanics had never been questioned. Louis de Broglie himself had stressed this point: "The scientific world of the time hung on every one of Einstein's words, for he was then at the peak of his fame. By stressing the importance of wave mechanics, the illustrious scientist had done a great deal to hasten its development. Without his paper my thesis might not have been appreciated until very much later." (Louis de Broglie, *New Perspectives in Physics,* Edinburgh, 1962, p.140)

Michelson’s experiment supposing that moving bodies could contract in the direction of motion if their speeds approach the speed of light. These circumstances should have significantly helped Lorentz to suggest his transformation formulas – the core of relativistic mechanics.

In 1902, Lorentz was awarded the Nobel Prize for his discovery that the motion of electrons in atoms is the source of atomic radiation. Soon Lorentz published his paper on relativistic transformations. The paper of the Nobel Prize winner could influence Albert Einstein making his task much easier. Young Einstein could take advantage also of general remarks on the problems of space and ether by the prominent French theoretician Henri Poincaré who was first also in introducing the term *relativity*.

The principles of new mechanics presented in the famous 1905 paper were so convincing and impressive that soon only Albert Einstein’s name was to be recalled regarding the concept of relativity.

As if the shocking conclusions of the Special Theory of Relativity were not enough, Albert Einstein came forth with a more striking conception of space and gravitation in his Theory of the General Relativity. The new conception brought to the discovery of the last basis of the existing world – the entity of the gravitational field, gravitating masses, energy, and space.

Soon Einstein elaborated his cosmological model of the universe. To any other scientists to think up such a grandiose program would be a real super-difficult problem. But not for Einstein. In the Special Theory of Relativity, he put emphasis on the point that the laws of nature have one and the same form in all inertial reference systems. Investigating the essence of space and gravitation, Einstein could not avoid the question of relativity in the case of accelerated motion. The task of extending the frame of relativism was rather natural than forbidden for Albert Eistein.[26]

The intention to build a revolutionary theory is most apparent in Immanuel Kant’s cosmology. Already the title of his cosmological essay, *The General Natural History and Theory of Heavens,* declared its unprecedented goal. Kant was determined to develop the theory of the origin of the solar system, of the Sun and the Earth and the planets, as well as of the myriad of stars from the initial chaotic substance.[27]

The problem itself, the origin of the Earth and heavenly bodies, was very *strange and unusual for the way of thinking of his epoch*. From Plato and Aristotle up to Copernicus and Newton, science proved the eternity of the super-lunar world. The science of the seventeenth and even eighteenth centuries considered nature stable and unchanging.

Kant’s position was radically different. His cosmology explained the origin of the solar system and stars due to the action of natural forces, first of all, that of gravitational attraction. It is

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[26] “The *general* theory of relativity,” explained Einstein, “proceeds from the following principle: Natural laws are to be expressed by equations which are covariant under the group of continuous co-ordinate transformations. This group replaces the group of the Lorentz-transformations of the special theory of relativity, which forms a sub-group of the former.” (Albert Einstein, *Autobiographical Notes*. – In: *Albert Einstein: Philosopher-Scientist,* La Salle, Illinois, Open Court, 1970, p. 69.)

[27] Two features were characteristic to Kant’s conception. The great admirer of Newton’s mechanics believed that the ultimate sources of the forces of nature are determined by divinity. Kant emphasized that the essential properties of the elements that constituted the chaos were “a consequence of the eternal idea of the Divine Intelligence.”

Secondly, Kant boldly suggested that the observable dynamics of the Heavens should be supported by yet unknown forces of repulsion. “But nature has other forces in store, which are especially exerted when matter is decomposed into fine particles. They are those forces by which these particles repel each other, and which, by their conflict with attraction, bring forth that movement which is, as it were, the lasting life of nature.” (Immanuel Kant, *On the Origin of the World*. – In: *A Source Book in Astronomy*. Ed. by H. Shapley and H. E. Howarth. New York, McGrow Hill Book Company, 1929, p.118).

believed that Kant had declared proudly: “Give me the matter, and I will show you how the world originated from it”.

Anyhow, Kant never opposed the paradigms of the Newtonian theory of mechanical motion and gravitation. In actuality, Kant’s cosmological theory was an extension of Newton’s physics. Kant began with a chaotic state of matter in the universe. Under the action of the force of gravity, chaotically moving particles had to concentrate in huge masses of proto-stars. Particles with greater energy would escape the process of condensation and rotate in circular orbits round the central mass. The later condensation of orbiting particles could bring to the formation of the planets. So through condensation and rotation, according to Kant’s conception, originated the stars, the Sun, the Earth, the planets, and all the heavenly bodies.

Of course, Kant was far from being able to prove his grandiose conception more or less rigorously. But even a complete proof of his cosmological hypothesis would not require to oppose the paradigms of Newtonian physics. The line of argumentation of the new cosmogony went on fully in accordance with the principles of classical mechanics. Intended to build a revolutionary theory, Kant, nevertheless, was not compelled to solve a super-difficult problem.

Another striking example of coexistence of a revolutionary conception with the principles of classical science was Niels Bohr’s theory of atom. Many historians of science rightly evaluate Bohr’s theory as a revolutionary step on the way to quantum mechanics. Yet Bohr never attempted to dismiss the classical mechanics. On the contrary, Bohr calculated the main parameters of the motion of the electron in its atomic orbit just on the bases of the laws of Newtonian mechanics. But the radiation of atom appeared to have no direct connection to the orbital motion of the electron. Luckily for Bohr, it came out that the frequency of atomic radiation could be calculated with the help of the quantum conception of energy, a few years earlier developed by Planck and Einstein.

Bohr’s famous 1912 paper *Trilogy* pointed out that his conception of atomic radiation presumed two principle assumptions:

“(1) That the dynamical equilibrium of the systems in the stationary states can be discussed by the help of the *ordinary mechanics*, while the passing of the systems between different stationary states cannot be treated on that basis.

“(2) That the later process is followed by the emission of a homogenous radiation, for which the relation between the frequency and the amount of energy emitted is the one given by Planck’s theory.”[28]

Bohr believed that the second assumption was necessary in order to account for experimental facts. His paper suggested also a general principle in favor of this assumption: “…it is known that the ordinary mechanics cannot have an absolute validity, but will only hold in calculations of certain mean values of the motion of electrons”. This argument, apparently, was based on Albert Einstein’s famous paper on photons of light, in which Einstein suggested that classical electrodynamics deals with “time averages rather than interaction values”.

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[28] Niels Bohr, *On the Constitution of Atoms and Molecules* – In: Niels Bohr, *Collected Works*, vol.2, p.167.

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