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COPERNICUS AND THE CIVILIZATION OF THE 20TH CENTURY

"Only one thing was needed to assemble and polarize all the new components of the megamachine: the birth of the Sun God. And in the sixteenth century, with Kepler, Tycho Brahe, and Copernicus officiating as accoucheurs, the new Sun God was born" [1]. Indeed, "the return of the Sun God... was the great event of the 16th and 17th centuries" [2].

Fourty years ago Lewis Mumford, the author of these words, was predicting for the era, which he called neotechnical, a bright future brought about by the further development of technology: "When automatism becomes general and the benefits of mechanization are socialized, men will be back once more in the Eden-like state in which they have existed in regions of natural increment" [3]. Now, deeply disappointed by the modern effects of technological development, Mumford accuses Copernicus and his fellow scientists of a criminal conspiracy in creating the ideological climate in which the megamachine — an Egiptian invention of the pyramid epoch, or a system in which society is organized and subjected by technology in the name of the power and glory of the deified ruler or of the deified ideal incarnated in the Sun God — could be reinstated and flourish.

"Power, speed, motion, standardization, mass production, quantification, regimentation, precision, uniformity, astronomical regularity, control, above all control — these became the passwords of modern society in the new Western style" [4]. However, whereas in the times of Chefren and

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[1] L. Mumford, *The Myth of the Machine: Technics and Human Development*, New York, 1966, p. 294.

[2] L. Mumford, *The Myth of the Machine: The Pentagon of Power*, New York, 1970. As quoted by R. P. Multhauf in his review published in *Technology and Culture*, No. 2, 1972, p. 296.

[3] L. Mumford, *Technics and Civilization*, London, 1946, p. 279.

[4] L. Mumford, *The Myth of the Machine: Technics...*, p. 294.

Cheops the working elements of the megamachine were men, after four thousand years it was possible "to enlarge the scope of the megamachine by progressively replacing the recalcitrant and uncertain human components with specialized mechanisms of precision made of metal, glass, or plastics, designed as no human organism had over been designed, to perform their specialized functions with unswerving fidelity and accuracy" [5]. Mumford considers that these functions are more and more of a destructive nature, both directly in a military sense and indirectly as contributing to the degeneration of human environment.

These accusations could eventually be treated with forebearance as reflecting the bitterness of an old man and philosopher whose expectations did not materialize. However, this distorted image contains also — as we shall see — a basically sound evaluation of the historic role of Copernicanism in the creation and development not only of modern science but of our entire culture and civilization as well.

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The Universe which Copernicus came to know during his studies at several universities was the Aristotelian Universe, as adapted by the great scholastics, and in the first place by Thomas Aquinas, to the needs of the Christian philosophy.

The physical world appeared then, in principle, to men in the same forms as directly perceived. It was a finite world, limited by the sphere of the stars. In its centre there was the motionless ball-shaped Earth, with the celestial bodies moving around it. Beyond the outer layer of the sphere of the stars there was supposed to be the Heaven — with God, his suite and the blessed souls — the whole immaterial and immeasurable world deprived of both matter and dimension.

The Earth was made up of heterogenous matter composed of four elements arranged, in principle, in layers, namely of earth, water, air and fire. The elements of matter which have been displaced from their natural position in a given layer were trying to revert to their original place, either by falling down in the direction of the joint centre of the Universe and the Earth like a stone or a drop of water, or by rising up like a bubble of air in water or like fire.

Above the earthy layer of fire there was the space filled up tightly with ether i.e., with perfect, hence immutable, matter. This space was, in turn, divided into consecutive spheres in which condensed ether was creating celestial bodies — the Moon, the Sun, the planets, and stars. God, directly or through His servants, was setting in motion the sphere of stars, which was transferring the movement to the sphere of Saturn,

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[5] *Ibid.*, p. 293.

which was transferring it, in turn, to the sphere of Jupiter so that all the spheres up till the lowest sphere of the Moon were moving along perfect circular orbits around an axis passing through the middle of the Universe, and making a full revolution in 23 hours and 56 minutes. All spheres, with the exception of the sphere of stars, were making simultaneous revolutions around another axis also passing through the middle of the Universe, but oblique to the axis mentioned previously. The planets were also moving within their own spheres along additional circular orbits, called epicycles, and this created the complicated apparent movement of planets on the firmament that is, so to say, against the background of the sphere of stars. Celestial spheres were transferring through the intermediary of the sphere of the Moon in the course of motion impulses to the earthy layer of fire, and these impulses were carried further, affecting among other things human destinies and anabling to forecast them: the study of such influences and of their forecasting was the domain of astrology [6].

Thus, the Earth was occupying in the Universe of the Middle Ages a doubly specific position: it alone stayed immutable in the centre of the Universe, and it alone was composed of a specific mutable and hence imperfect, matter. These privileges had their counterpart in the status of men. Being in the centre of the Universe man enjoyed special divine protection, however he was placed on the border-line between the perfect celestial spheres adjacent to the Heaven itself and the seat of all Evil — the Inferno, situated, as described by Dante, in the depths of the heaviest and most imperfect terrestrial matter.

In this way scholastic philosophy established a link between the destiny of man and a coherent system of the Universe. Astronomers were, therefore, unable to modify anything of substance in their interpretation of the motions of celestial bodies "without overturning physics and religion as well" [7] and this in turn could not fail to affect the whole civilization and culture.

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The late Middle Ages and the early Renaissance period brought in their wake some new scientific ideas, such as the theory of motion by Buridan and Nicole Oresme and some philosophical and mystical theories

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[6] The motions of the celestial bodies have been presented here in a very simplified form, as they appeared at the end of the Middle Ages to some enlightened persons not familiar with the science of astronomy, for example Dante. (See H. Butterfield, *The Origins of Modern Science*, London, 1958, p. 17–24). For a more detailed study of the motion of celestial bodies in the geocentric system see T. S. Kuhn, *The Copernicus Revolution. Planetary Astronomy in the Development of Western Thought*, Cambridge (Mass.) 1957, Chapter 2.

[7] T. S. Kuhn, *op. cit.*, p. 76.

like the cosmology of Nicholas of Cusa. These theories were, however, treated at best as interesting intellectual exercises without great scientific or philosophic value, and were unable to shake the foundations of the splendid edifice of the Aristotelian-Scholastic science. Such humanistic ideas as for example those which Pico de Mirandola expressed in the words of the Creator addressed to man: "I have put Thee in the centre of the World for you to see better what surrounds you" [8], have only added a new facade to that edifice, better suited to the intellectual mood of the time.

The first great breach in the foundations of the edifice, instrumental in causing its final collapse, is due to Nicolaus Copernicus. Although, as may be assumed, he aimed only at modernizing and perfecting this structure through partial modifications, the gap he created could not be filled again. True enough such attempts were made half a century later by Tycho Brahe, but the effect was contrary to the intended one: the gap only widened and Giordano Bruno, Kepler and Galileo brought finally the whole outdated structure down, thus clearing the ground for a new more splendid edifice whose construction was attempted by Descartes and completed 150 years after the publication of *De revolutionibus* by Newton.

The essential change contained in the work of Copernicus which produced a revolution in both science and religion could be summarized in the popular Polish dictum that Copernicus "stopped the Sun and moved the Earth" [9]. Let us examine what is so essential in that change.

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First, if the Earth ceased to be the immovable centre of the Universe, it lost thereby its privileged position. At the same time the concept of two kinds of matter was shattered.

True enough, after having discussed the movements of planets Copernicus wrote poetically: "In the middle of all sits the Sun enthroned. In this most beautiful temple could we place this luminary in any better position from which he can illuminate the whole at once? He is rightly called the Lamp, the Mind, the Ruler of the Universe... So the Sun sits as upon a royal throne ruling his children, the planets, which circle round him" [10]. While placing the Sun "*in medio vero*" of the planets, Copernicus does not identify that point with the centre of the Universe. He states

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[8] From *De hominis dignitate*, as quoted by W. Voisé, *Mikołaj Kopernik — dzieje jednego odkrycia* (Copernicus — History of a Discovery), Toruń, 1970, p. 69.

[9] J. N. Kamiński, *Przekłady i ulotne wiersze* (Translations and Popular Verse), Lwów, 1828, p. 121.

[10] N. Copernicus, *De revolutionibus orbium caelestium*, as quoted by T. S. Kuhn, *op. cit.*, p. 179.

only that "near the Sun is the centre of the Universe" [11]. However, since the Sun was not the unique, like the Earth in the geocentric system, immovable celestial body, for immovable were also the stars, the privileged place of the Sun in the Copernican system was not so marked as the distinction enjoyed by the Earth in the Aristotelian-Scholastic world.

This was also due to the theory of gravitation adopted by Copernicus. With Aristotle gravitation concerned only terrestrial matter and was caused — as indicated above — by its tendency to rest in layers around the centre of the Universe. Other celestial bodies, perfect, immutable and immutably revolving along circular orbits together with their spheres were not subject to gravitation. Copernicus, however, wrote: "Now it seems to me gravity is but a natural inclination, bestowed on the parts of bodies by the Creator so as to combine the parts in the form of a sphere, and thus contribute to their unity and integrity. And we may believe this property is present even in the Sun, the Moon, and Planets, so that thereby they retain their spherical form notwithstanding their various paths" [12].

Thus for Copernicus gravitation is a general law ruling, at least, the celestial bodies of the Solar system. However, since by extrapolation it is easy to attribute gravitation to stars as well, it was possible to recognize it to be a general law of nature governing if not all matter than at least matter concentrated in celestial bodies.

On the other hand, Copernicus, considering that — as we would have put it today — there are as many gravitational fields as there are celestial bodies, treated these fields as internal qualities of these bodies, which can not affect their mutual behaviour and therefore can not be the cause of their motions. Copernicus is thus formulating another general law of nature related to the spherical celestial bodies, which he defines as simple: "That the motion of a simple body must be simple is true then primarily of circular motion, and only so long as the simple body rests in its own natural place and state. In that state no motion save circular is possible, for such motion is wholy self-contained and similar to being at rest" [13].

Thus, celestial bodies are not composed of perfect etherical matter, but have a perfect spherical shape or at least try to attain one, revolving in a natural way around their own axis and moving along circular orbits (or along a combination of such orbits). Hence there is no need for another explanation of the motion of celestial bodies.

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[11] *Ibid.*, p. 178. The displacement of the Sun in relation to the centre of the Universe, i.e., to the centre of the immobile sphere of stars was due to the concern over the most precise description of the movement of planets in conformity with observations.

[12] *Ibid.*, p. 153.

[13] *Ibid.*, p. 152.

This part of Copernicus theory still shaped by traditional thinking and representing a variation of Aristotelian thought was discarded in a natural way when Kepler introduced the elliptic orbits of the planets. The movements along such orbits could not be considered as natural, and no wonder that Kepler himself (and before him Gilbert) started the search for those forces which put the celestial bodies in motion and make them act one upon another. After Descartes has failed to produce an answer to that question Newton has formulated the general law of gravity which governs matter and explains both the attitude of bodies near the surface of the Earth and the motion of celestial bodies.

The importance of that event for the formulation of the concept of the law of nature can best be judged by the words of the eminent Polish astronomer Jan Śniadecki who said at the beginning of the 19th century: "Everything which moves and evoluates on the Earth and in the depths of Heaven is the work of eternal laws of nature's mechanics; the powder thrown into the air by human breath and agitating in the wind is subject to the same laws as the planets revolving around the Sun. These laws and the effects resulting from them make for the beauty and perfection of nature's creations and the study of these laws is the most important aim of the science of physics" [14].

Since Newton nobody over doubted the unity of Universe's matter, although it was only after William Herschel's observations of double stars at the turn of the 18th century that is has been proved that the laws of gravity apply also beyond the Solar System. Furthermore, the latest studies of lunar rocks crowned by the production of similar rocks from terrestrial matter have demonstrated with a degree of certitude meeting the most severe scientific criteria that terrestrial matter and lunar matter are identical, though organized in a somewhat different way.

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In the second place, the changes introduced by Copernicus in the Aristotelian system of the Universe affected so seriously its coherence and logic that it could be rejected entirely and without difficulty by those who followed him.

Copernicus kept in his model of the Universe celestial spheres and in particular "the Sphere of the Fixed Stars, containing all things and being therefore itself immovable" [15]. Thus, his Universe is as limited and finite as the Universe of Aristotle.

However, Copernicus has pushed back the limits of the Universe as

[14] Jan Śniadecki, *O Koperniku* (On Copernicus), Warszawa, 1953, p. 52.

[15] N. Copernicus, as quoted by T. S. Kuhn, *op. cit.*, p. 178.

to make it "*similem infinito*" [16]. Whereas in the Middle Ages its diameter was evaluated at about 20,000 diameters of the Earth, it resulted from the considerations arising from the fact that the revolution of the Earth around the Sun has no effect on the picture of the sky (the annual parallax of stars was not observed until the 19th century), that the diameter of the Universe is equal to at least 1.5 million diameters of the Earth [17]. Thus the followers of Aristotle were placed before a problem almost impossible to be solved — what can fill the immense space between the sphere of Saturn and the stars.

Moreover, the sphere of stars immobilized by Copernicus has ceased to play its role as an intermediary in transferring motion from God to the planetary spheres becoming solely as it were the wrapping of the Universe. The conviction concerning the influence of stars on man's destiny as well as the theological importance of the sphere of stars have been deprived of their foundation in the structure of the Universe and the way was now open for the development of astral astronomy.

Giordano Bruno had, therefore, no difficulty in reverting to the antique atomistic philosophy, known at that time primarily from Lucretius' *De rerum natura* and adopted in the 19th century by Nicholas of Cusa. Giordano demolished Copernicus' wrapping of the Universe claiming that "there exists an infinite number of particular worlds similar to our Earth, which... I consider to be a star in the same way as the Moon, the planets and all other innumerable stars. They are all worlds. Their multiplicity is unlimited. They constitute in the infinite space an infinite nature and this I call the infinite Universe in which infinite worlds are contained. Thus, there are two kinds of infinity — the infinite dimension of the Universe and the infinite multitude of worlds" [18].

At the same time Tycho Brahe stated that the existence of celestial spheres is incompatible with his compromising Solar System, for the spheres of Mercury and Venus revolving around the Sun would have to cut across the sphere of the Sun revolving around the Earth. The conclusion about the non-existence of celestial spheres was supported by Tycho Brahe on the basis of the observation of comets cutting across the orbits of succesive planets. The Aristotelian structure of the Universe fell into ruin and the mystical in its essence conception of Giordano Bruno became in its rationalized form part of the system of the infinite and unlimited Universe of Descartes and Newton.

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[16] From the introduction to the original second book *De revolutionibus*, as quoted by A. Birkenmajer, *Études d'histoire des sciences en Pologne*, Wrocław-Warszawa-Kraków-Gdańsk, 1972, p. 643.

[17] Compare, for instance, T. S. Kuhn, *op. cit.*, p. 159.

[18] *Giordano Bruno przed trybunałem inkwizycji. Akta procesu.* (Giordano Bruno before the Tribunal of the Inquisition. Records of Proceedings), Warszawa, 1953, p. 58.

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Third, in the infinite and unlimited Universe, unknown to Copernicus but studied by his followers who developed the ideas of the great master, there was no place for the seat of God and his suite, the reality of which or, as one may say, the spiritual materiality of which was an unchallengeable dogma of the scholastics. Furthermore, there was no reason to place the seat of Evil inside one of the planets moving about one of the countless suns.

At the same time the influence of God, and for that matter the influence of Satan, on the Universe and man ceased to be so obvious and almost tangible as it appeared to be in the Middle Ages when God and His servants were setting in motion celestial spheres or, at least, the sphere of stars nearest to the Heaven.

In the 17th and 18th century it was still generally believed that God created the world, although already Descartes claimed that only matter was created and that the world organized itself in accordance with the fundamental laws of motion; it is therefore Descartes who could have been the hero of the well known anecdote about Laplace, who asked by Napoleon about the function he is assigning to God in his system of the Universe, is said to have replied "*Sire, je n'avais pas besoin de cette hypothèse*" [19].

However, in the 17th century Descartes was rather isolated with his opinions. For Newton departed from the Cartesian interpretation of the laws of motion based on the direct, tactile interaction of elements of matter which, according to Descartes, were filling the Universe so completely and so tightly as the etheric matter the Universe of Aristotle. While stating that the forces of gravity are acting at a distance, through empty space, the author of *Philosophiae naturalis principia mathematica* could not explain such interactions otherwise but with the aid of the ever-present Providence. However, at the end of the 18th century the idea of distant action which shocked the scientists of the post-Cartesian generation became so obvious and understandable [20] that Laplace could discard the hipothesis of God directly intervening in the movements of the Universe.

Together with the secularization of the Universe one can witness a similar, albeit slower process of secularization of man. Copernicus while removing men from the centre of the Universe has opened the door to the calling in question of the rights of men to particular divine protec-

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[19] Compare, for instance, F. Lot, *Visages des grands savants*, Paris, 1963, p. 185.

[20] Einstein reverted later to that problem. He abandoned the concept of Lucretius and Newton of atoms moving in an empty space not linked with matter; he filled that space with electromagnetic and gravitational fields, identifying like Aristotle and Descartes extent with matter.

tion. Descartes has tried in vain one hundred years later to substantiate such a claim by formulating his dualistic conception of man. One hundred years later the progress of secularization enabled La Mettrie to advance his concept of the man-machine.

However, while undermining the belief in the direct divine protection enjoyed by the human race, Copernicus paved another way toward the privileged position of man in the Universe — a position based on the force of human intellect.

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The importance of *De revolutionibus* lies not only in the fact that with his work Copernicus "stopped the Sun and moved the Earth", that it was the first, since the times of Ptolemy, great synthesis of the science of astronomy based on the results of his own original observations as well as on the opinions gathered from many ancient and medieval sources, but also in the fact that it represented an important step in the development of the methodology of science.

The Aristotelian system owed its durability and force to its coherence and logic as well as to its common sense approach to "the primitive conception of the world", to "the evidence of unaided sense perception" [21].

Copernicus has challenged by his work two methodological principles which sustained the whole Aristotelian and scholastic systems of the Universe: the faith in the authority of both the ancient and scholastic philosophy and the Bible, and the conviction that the Universe is directly reflected in the image which man perceives through his senses. The contradiction between the heliocentric theory and the verse from Jeshua: "And the Sun stood still and the Moon stayed, until the people avenged themselves upon their enemies" [22] was a stumbling-block not only because the verse was taken out from the Book of Jeshua, but also because of the fact that the conviction concerning the movement of the Sun and the Moon corresponds to the data provided by our senses and to the criteria of common sense.

The objection raised against the theory of Copernicus as contrary to the letter of the Bible constituted if not the basis than at least the pretext for placing the *De revolutionibus* on the papal index of forbidden books and later for accusing Galileo of heresy. However the dispute led — as it is well known — to the weakening of the authority of the Church and, indirectly, to the secularization of the Universe and man.

From the point of view of science more important is the second aspect of Copernicus scientific method. This has been pointed out once by Goethe who wrote that "when we are confronted when dealing with natural phenomena with the necessity of verifying a certain idea, we

[21] T. S. Kuhn, *op. cit.*, p. 98.

[22] Joshua 10:13.

are most deceived by the fact that often if not always, as a rule, such an idea contradicts the perception of our senses". He quoted the example of the system of Copernicus which "is based on the idea so difficult to perceive and continuously contradicting our senses" [23].

While breaking with concepts imposed by common sense, based on sensual perception, Copernicus created with the force of his mind a splendid geometrical construction modelling the movements of celestial bodies which he later verified, using an essentially modern hipothetical-deductive method, by confronting the data arising from the model with the results of previous observations and original ones which he conducted in a planned and systematic way [24]. And when the confrontation did not produce satisfactory results, and when it appeared that the simple system conceived by Copernicus in which celestial bodies moved along straight circular orbits did not conform to observations, the scientist refused to disregard the fact, but changed his model, complicating it by introducing epicycles and ensuring thereby, at the expense of the simplicity and elegance of the model, its consistency with the observations.

One may accuse Copernicus of being conservative, of believing in the magic perfection of circles and spheres [25] which prevented him from introducing ellipsoidal orbits even before Kepler. However, it has to be remembered that Kepler, while replacing circles by ellipses — against his own conviction of the musical harmony of the Universe — based himself on an observation material gathered mainly by Tycho Brahe, a material much richer and more precise than that available to Copernicus. Breaking away from the Pitagorean and Platonic circular orbits, Kepler, has made a further important step toward modern science, ascertaining in this way the importance of the rational elaboration of material based on experiments and observations for the development of science.

From that time there was no lack in science of such ascertainments and violations of common sense, up till the modern theories of physics, so contrary to common sense and sensual perception like the concept of the finite non-Euclidean Universe or the corpuscular-undulatory interpretations of the nature of elementary particles. For all these theories "are not developing in the inductive way; they are not deriving from previous theories or experience because theoretical concepts cannot be deduced from either previous categories or experiences. The theoretician must therefore look for new ideas which could reflect the phenomena of nature" [26].

[23] As quoted by W. Voisé, *op. cit.*, p. 71.

[24] Compare, for instance, A. Birkenmajer, *op. cit.*, p. 638–639.

[25] Compare, for instance, H. Butterfield, *op. cit.*, in the chapter "The Conservatism of Copernicus", p. 31–32.

[26] Statement by the President of the USSR Academy of Sciences M. Keldysh before the general assembly of the Academy on June 18, 1968. *Vestnik Akademii Nauk SSSR*, No 9, 1968, p. 28.

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It is from Copernicus that the growing conviction about the potential of human mind discovering and interpreting the phenomena of nature can be derived. Only one more step was needed to convince men of their possibilities to master and use the forces of nature for their own benefit.

The man of the Middle Ages felt privileged by God, but it was God also who set the limits of those privileges. By depriving men of the very basis of their faith in the privileges they are entitled to, while at the same time demonstrating to them the potential of human mind, Copernicus prepared men for the removal of the successive barriers, for their interference with the functions of the natural environment, arising from the laws of nature. In this way men were acquiring privileges in the divine origin of which they ceased already to believe.

Several decades after the death of Copernicus Francis Bacon will write the following words: "*Scientia et potentia humana in idem coincidunt*" and show the way to the Kingdom of Man based on science [27]. Echoing the same ideas Descartes will state that "*il est possible de parvenir à des connaissances qui soient fort utiles à la vie*", which will enable us "*de nous rendre comme maitres et possesseurs de la nature*" [28]. As we can see at present, the Kingdom of Man is being created not only due to the mastering of the natural environment, but also due to the creation from materials provided by nature of a new world of new products and processes of technology. For such a Kingdom men are struggling by their own mind nad effort. Thus the replacement of geocentrism by heliocentrism led to the replacement of theocentrism by anthropocentrism.

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At the beginning of the 19th century Jan Śniadecki gave the following assessment of Copernicus' importance for the development of astronomy: "The entire flow of scientific enquiry had its origin in the science of Copernicus well interpreted and developed. Our century owes therefore to Copernicus a new direction of human thought in the study of celestial bodies, it owes to him ... the way of analogy in the study of phenomena and causes from which the greatest part of our present knowledge derives, it owes to him finally the entire plan and order of science" [29].

In our times the importance of Copernicus has found a broader definition in the words of Leopold Infeld, who having stated that modern

[27] F. Bacon, *Novum Organum, Book* 1, par. 3 and 68.

[28] R. Descartes, *Discours de la méthode pour bien conduire sa raison et chercher la vérité dans les sciences*, Chapter 6.

[29] J. Śniadecki, *op. cit.*, p. 66.

science of the Universe will never be exhausted, added the following words: "Copernicus was not only the greatest, but also the happiest among all astronomers, for the science of the Universe can only be inaugurated once. And this happiness was a privilege of Copernicus" [30].

However, the significance of Copernicus exceeds the limits of science. Thanks to the impact of his discoveries on modern civilization and culture, thanks to the awakening of human potential and to the shattering of the belief in man's submission to the protection and power of God, the significance of Copernicus extends over the whole field of human philosophy and determines the development of civilization of our century.

A negative assessment of the historic significance of Copernicus can only come from those who, like Mumford, view with a sense of gloom the dangers brought about by our civilization to man himself. However, it is much wiser, while not closing one's eyes on these dangers but emphasizing above all the immense possibilities of the development of human society which are within our grasp, to see in the person of Copernicus one of these geniuses whose thought and activities have led mankind in that direction.

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[30] L. Infeld, *Od Kopernika do Einsteina* (From Copernicus to Einstein), [in]: collective work: *Mikołaj Kopernik. Szkice monograficzne* (Copernicus. Monographic Essays), Warszawa, 1965, p. 187.