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JOSEF NOVÁK

Mathematics and Art: In Search of a Cultural History

Critical Study

LYNN GAMWELL, *Mathematics and Art: A Cultural History*, forward by Neil deGrasse Tyson, Princeton and Oxford 2016 , pp. 576.

Lynn Gamwell's book traces the quasi-simultaneous origin of mathematics and art featuring a cultural history, from prehistory to the present. The publication boldly asserts that mathematical branches, such as arithmetic, algebra, geometry, trigonometry, calculus, have – via their theories, symbols, diagrams, designs and patterns – inspired craftsmen and artists throughout history. With sumptuous illustrations of artwork and cogent math diagrams, the author offers a profound, wide-ranging, and carefully structured elaboration of her thinking on the interplay of mathematics and art. Drawing with equal facility on both the classics of mathematics and the works of philosophers, theologians, art historians, and artists, she skillfully weaves into the fabric of her argument most of the key issues that affect both mathematics and art; and therein lies what is fascinating about her work.

The extraordinary resonance that her writings achieve is no doubt partly due to the fact that Ms. Gamwell uses psychological and sociological approaches to explain "in plain English" the intricate spell of mathematics in various cultural settings. She reminds us that mathematics isn't just a matter of great theories. It's also bound up with a prodigious transformation of "human life for which art really matters". Mathematics is, in her opinion, an international language of exact thought which was readily absorbed by different historical contexts, particularly by pre-Greco civilizations, Greek antiquity, the Middle Ages and the Enlightenment.

Ms. Gamwell begins Part I of her book by describing mathematics from prehistory to the Enlightenment, including Greek, Islamic, and Asian mathematics. She briefly explores the Stone Age and mythic societies that formed an important transition from prehistory to history by lifting man's attention above the drudgery of life and fixing it beyond the world of things. Thus the purpose of works of art in Egypt and Mesopotamia was to impose a favorable order upon the universe under the inspiration of the creator who first had brought it into being out of chaos. In their rational and disciplined approach to life and art Egyptian and Sumer craftsmen of different trades, from sculptors, painters, bricklayers to stonemasons and lapidaries, usually worked under the direction of an educated supervisor, familiar with both mathematics and the techniques of several crafts. Hence the artworks there were often the result of collaboration between several different specialists.

The city-state in Greece also demanded risk-taking mathematicians who – along with the first philosophers – launched a quest to understand the world they saw before them and the abstract objects they knew by thought alone. In this context, Ms. Gamwell focuses on Plato highlighting an existence of abstract objects, such as numbers, lines and triangles, which are independent of human thought. She also outlines the development of the axiomatic method of proof by Euclid in his *Elements* (ca. 300 BC) and Plato's view that art is an imitation (MIMESIS) of nature. After reviewing their unification with Judeo-Christian theology in the fourth century AD, she then reminds the reader that knowledge of ancient Greek mathematics, such as Euclid and Ptolemy, was lost to the medieval West, but Islamic scholars preserved their writings in Arabic translations. Meanwhile, in search of theological implications, medieval theologians continued to study the ancient texts based on a curriculum that consisted of the seven liberal arts and sciences: geometry, arithmetic, astronomy, and music (the *quadrivium*), and grammar, rhetoric, and logic (the *trivium*). They are often now referred to as the seven liberal arts, but each one was originally called both an art (practical skill) and a science (a theoretical system). Indeed, they played an important role in regaining confidence in reason in the West where a shift in building churches and cathedrals occurred in the early twelfth century. Four centuries later, they also stimulated the study of eternal laws governing the natural world which were removed from the province of divine by Nicolaus Copernicus, Galileo Galilei and Johannes Kepler who introduced the heliocentric model of the universe. Galileo's study of the motion of projectiles presumably influenced Artemisia Gentileschi's painting, *Judith Slaying Holofernes* (ca. 1620). Indeed, Kepler's laws of planetary motion, Galileo's description of iron balls falling to the ground, and Newton's law of universal gravitation set the stage not only for a key distinction in science and mathematics that was blurred in antiquity, but also for their rapid development leading to their separation from religion in the nineteenth and twentieth centuries (p. 70).

In Parts II and III, Ms. Gamwell outlines the concepts of proportion and infinity. She finds the origin of the systems of proportion in the Pythagoreans and Plato. They were based, in part, on measurements of the human body, "whose harmonious parts were seen as an immutable embodiment of beauty in the image of its divine Creator" (p. 73). As Egyptologists point out, however, the concept of proportion had been known to ancient nations who, from earliest times, impressed a system of mensuration upon their environment and reduced it to a rational and finite pattern. Hence it is no wonder that they also devised a canon of proportion to which their works of art must conform. Anthropometry, theometry, and zoometry were their inventions.[1] Proportion was also related to the famous Golden Ratio that presumably was dominant in classical architecture and was taken up again during the Renaissance when Leon Battista Alberti, Giacomo Barozzi da Vignola, Andrea Palladio and Philibert Delorme published their treatises on architecture. As was suggested at that time, proportion was God's fingerprint reflected in the ideal human body. In this context Ms. Gamwell also considers the symmetrical plans and buildings of early Renaissance architects who favored the circle or polygon and who codified Filippo Brunelleschi's discovery of linear perspective. But she debunks "the widely held misconceptions that Euclid's mean and extreme ration (approximately 1.618) is the key to beautiful proportion (the so-called Golden Section) and that it was used in major monuments of art history […]" (p. XIII–XIV). In her eyes, these misunderstandings concerning proportion stand out particularly clearly after Darwin's presentation of evidence that the body evolves over time.

Historically, infinity, unlike the concepts of proportion and symmetry, required a still longer period to be brought fully to mind. It was discovered by the Greeks who feared "the absence of limits;" its notion was wholly alien to human experience in ordinary life. But after noticing that ordinary experiences have their limit, mathematics allowed them to reach and surpass that limit very quickly by, for example, extending the abscissa indefinitely. In such instances, the practice of abstract mathematics was understood as more truthful than ordinary life which became problematic, and at times, paradoxically, mysterious and impenetrable. In the early days of the Renaissance the cardinal Nicholas of Cusa wanted to make it less mysterious. Hence he made an actual infinity the centerpiece of his theology defining

[1] M. Verner, *Pyramidy: tajemství minulosti*, Praha 1997, pp. 90–95.

God as an actual infinity that was at every moment omnipotent, omniscient, and omnipresent. His conception of Absolute divinity influenced German Idealists, such as G.W.F. Hegel and Friedrich Schelling. Struggling between Enlightenment reason and Romantic imagination, Hegel wrote the first modern theory of art based on a cosmic spirit or "Absolute Spirit," which was for him "equivalent to the logical structure of the universe." In response to the rise of rationalistic science, Georg Cantor then applied his set theory to the organic universe and named the set "Absolute Infinity", thereby placing God in a realm that transcends all finite and infinite sets. His concepts were, according to Ms. Gamwell, readily accepted by Russian mathematicians, artists, and poets who would join in finding expression of the Absolute. Many abstract artists such as Kazimir Malevich felt a strong affinity with Cantor's Absolute Infinity precisely because of its abstractness. The end of the Absolute came in 1919 when the astronomer Arthur Eddington confirmed Albert Einstein's space-time universe. His validation caused a seismic reorientation not only in Russia where the Bolshevik Revolution brutally eliminated the last isles of artistic freedom, but also in Western culture in which a new spiritual creed for the secular era was formulated and where some disgruntled artists rather adopted Taoism or Buddhism because of their apparently seamless merge with the scientific worldview.

In the following Parts IV, V and VI, Ms. Gamwell describes the origins of formalism, logic, and intuitionism which developed in "Germanic communities, where modern mathematics and abstract art emerged" (p. XIV). Before Einstein published his 1916 *General Theory of Relativity*, in which he described space as deformed by the gravitational forces of massive bodies, a handful of mathematicians, such as Nikolai Lobachevsky, Carl Friedrich Gauss, Bernhard Riemann, and János Bolyai, had worked out the mathematics of non-Euclidian geometries. For these scholars the geometric objects exist in the mathematical world-out-there, independent of the human mind – a conviction in the Platonic tradition eagerly accepted by George Cantor and Gottlob Frege as well. Boolean algebra, Lewis Carroll's paradoxes, and of course the *Principia Mathematica* by Alfred North Whitehead and Bertrand Russell are also considered. The view that mathematics is based on logic (Frege) developed into British analytic philosophy, which, curiously enough, was in Ms. Gamwell's eyes expressed by the sculptures of Henry Moore and of Barbara Hepworth who reduced the human body to its essence. Meanwhile impressionist paintings were seen as a collection of elementary parts even though this may be the result of having many canvases left unfinished. Cantor's invention of a non-Euclidian arithmetic of infinite sums played an important role as well. His concepts were, according to Ms. Gamwell, readily accepted by Russian mathematicians and artists. But Cantor's invention precipitated a crisis in the foundations of mathematics in the late ninetieth century as it engendered sharp contradictions. The main response to this crisis was David Hilbert's formalist notion of mathematics as an axiomatic, internally consistent system with meaning-free and replaceable signs. His conception leading to formalist aesthetics and linguistics looks a lot like an artist's search for the essence of his craft, such as Aleksander Rodchenko's monochrome paintings. For Ms. Gamwell, Hilbert's views were largely embraced by Russian Constructivists who transformed them into aesthetics in their artworks composed of meaning-free colors and forms. But working in a nominally Marxist wasteland, many of them soon embraced Stalinism and its Communist ideology, others ended up in the Soviet gulag camps. In any event, their meaning-free experiments were a short-lived episode. In the West, by contrast, artists in the De Stijl circle continued adopting a mathematical vocabulary of horizontal and vertical lines; they learned that color, too, can be approached mathematically.

In Part VII Ms. Gamwell discusses the concept of symmetry. Originally, it referred to the property of a geometric object whose form can be equally divided by a line or plane. In three-dimensional space, the most symmetrical geometric form is a sphere. The twentieth-century scientists concluded that the universe began in perfect symmetry as a point that exploded into a sphere of plasma. In agreement with this discovery, they are "recreating samples of primordial spherical shapes to determine the degree to which the universe retains traces of its original symmetry" (p. 249). As the writings of Jakob Burckhardt, Heinrich Wölfflin, Alois Riegl, Ernst Cassirer, and Erwin Panofsky have shown, the concept of symmetry has played a key role in the history of the decorative and abstract arts. Here Ms. Gamwell particularly outlines artifacts with symmetrical patterns in Concrete Art in the 1930s and 1940s shaped by the aesthetics of De Stijl and Russian Constructivism.

Yet, while her interpretation may adequately account for the success of mathematics in other areas of human activity, Ms. Gamwell cautions that there was, after World War I, a powerful backlash against exact sciences that has dramatically impacted art. She notes that formalism, logicism, and intuitionism have been remarkably successful philosophically, but have nonetheless given way to Kurt Gödel's proof of the incompleteness of mathematics. His introspection points to questions about the nature of mathematics in the language of mathematics and about the inherent vocabulary limits of art. Here another kind of explanation is called for, and Ms. Gamwell finds it in the interpretation of Ludwig Wittgenstein, who established a parallel result for natural, spoken language by demonstrating its limits in *Tractatus Logico-Philosophicus*. But to support the common claim that M.C. Escher and René Margritte were inspired by Gödel and Wittgenstein leads to volatile grounds. Ms. Gamwell herself does not assert this to be true: "After the proofs of Gödel and Wittgenstein were popularized in the mid-twentieth century, their writings did, however, inspire many artists, such as the American Jasper Johns and the Chinese Gu Wenda." As mentioned earlier, this section also contains some fascinating reflections on topics like intuitionism, symbolism and De Stijl aesthetics. With respect to the latter, the author examines "Mondrian's shift from a Symbolist to a mathematical vocabulary […] away from an overtly Eastern Buddhist philosophy […] towards the mysteries of Western science […] De Stijl expressed a cosmic spirit (the Absolute, the Tao, the Brahma) as well as the scientific world view in which mathematics describes the natural forces that hold the cosmos together" (p. 241).

Pondering these historical patterns in art, Ms. Gamwell devotes Parts VIII and IX of her publication to examining some of the transitional problems that confront exact sciences. Here she speaks of "utopian visions after World War I" and of a "Romantic backlash" against the exact sciences. Not only these visions were felt in more and more European countries, but the protectors of exact sciences were increasingly unable to offer a coherent alternative. Take, for instance, the logical positivists who established the Vienna Circle and whose "greatest foes were metaphysics and psychology, which they found plagued with wooly-minded vagueness" (p. 285). By pushing rationality to an extreme, they could not imagine living in a world with metaphysics and psychology. In fact, their overweening rationalism had dissolved human responsibility into neutral and indifferent forces illustrated cogently by emotionless, atomized and detached characters that populated the literature. James Joyce and Virginia Woolf captured such characters superbly. The latter constructed her fictional world from the viewpoint of individuals "who report their subjective experiences as objective facts, given their private feelings a cold, clinical quality" (p. 216). Nonetheless, Ms. Gamwell, unlike Husserl, sees formalist mathematics, logic, and logical positivism as a proper remedy, not as a symptom of Europe's problems.[2]

The discussion in Parts VIII and IX is the most difficult and in some ways least satisfying section of Gamwell's book. Studded with references to David Hilbert, Kurt Gödel, L.E.J. Brouwer, Albert Einstein, Niels Bohr,

[2] Cf. E. Husserl, *Die Krisis der europäischen Wissenschaften und die transzendentale Phänomenologie. Eine Einleitung in die phänomenologische Philosophie,* Haag 1954.

Werner Heisenberg, Louis de Broglie, Rudolph Carnap, Ludwig Wittgenstein, Edmund Husserl, and Martin Heidegger, it will doubtless strike careful readers as somewhat glib, while art historians may find it rather abstruse. Painting with a broad brush indeed, Ms. Gamwell tries to show that even artists who do not always have scientific interests or are unaware of the latest mathematical advances have used twentieth-century-mathematical concepts in their abstract (non-representational) artworks. For the practice of both modern mathematics and modern art is similar: not only does it push the exactness in the direction of increasing perfection but it also manifests itself in reflections concerning their essence. Despite her effort, nevertheless, Ms. Gamwell does not disentangle the esoteric mathematical notions and constructs in art from other influences, such as religion, mythology, ideology, and mysticism. As a result, her argument that mathematical discoveries often provoke new art remains unconvincing.

After the disaster of World War II, an overall pessimism emerged in Europe, an understandable product of the global wars, genocidal atrocities, and totalitarianism of the twentieth century. The experience of these evils seemingly shattered not only the naïve nineteenth-century faith in the progress of sciences, but any notion of a projected happy-ending of European civilization. At the same time, however "[…] the widespread dread of an imminent nuclear catastrophe let to renewed efforts towards improving East-West relations […]. Searching for eternal truths in the spirit of internationalism, intellectuals and artists reached across cultural boundaries and borrowed traditional symbols, some of which were mathematical" (p. 355). Here Ms. Gamwell makes no distinction between Western and Eastern Europe. But in the East the concerns were, in part, justified by the authoritarian rule of communist parties which at times brutally suppressed any attempt to reach "across cultural boundaries." On the other side, in the West, the prospects of sciences were seen differently and perhaps in too rosy a light. One could add that computability led to the discovery of "mindless" computers by resolving Hilbert's old "decision problem" while "artists continued to express confidence in the Enlightenment ideals – albeit in a somewhat tattered state – by creating abstract art that was geometric and orderly […]" (p. 385–386). In this context Ms. Gamwell speaks of axiomatic approaches to music, of Concrete Art in Switzerland, of the French group called Bourbaki whose members presumably embraced Hilbert's formalism and applied it to the social sciences while post-war artists expressed a belief in order and rationality by creating abstract and optical art.

The artworks of Max Bill, Camille Graeser, Karl Gerstner, Verena Loewensberg and Richard Paul Lohse are presented in Part XI entitled

"Geometric abstraction after World War II." Here Ms. Gamwell observes that Constructivism and Concrete Art were exported to South America, and North American artists imported abstract and algorithmic processes to produce their *objets d'art*. The idea of reducing the essence in mathematics to a set of axioms was apparently reflected in American Minimal Art. If this were true then the author would have to grapple with the argument that the reductive aspects in minimalism (such as monochrome paintings) were often oversimplifications applied as a reaction against abstract expressionism. Be it as it may, Ms. Gamwell is right in saying that since the 1950s computers have been widely used to generate proofs in mathematics (the four color theorem), whereas computer graphics were capable of visualizing space in more than four dimensions. In the early 1980s, for instance, Tony Robbin created *Fourfield* (oil on canvas) whose objective was to evoke the appearance of four-dimensional cubes for a beholder who exists in three-dimensional space (p. 459). In the 1970s, the creation of fractal geometry opened wide applications to art – via graphics of fractals, photographs of fractal patterns in nature and computer animation – and offered deep insights into the natural world. Knots, graph theory, network analysis, and recursive algorithms appeared in science, technology, and the arts. The computer espoused by mathematicians, scientists, and artists has given them powerful new tools.

In the last Part, Ms. Gamwell reflects on the Platonism of our post-industrial era in which European civilization faces the political, social and cultural consequences of globalization and of the loss of a unified worldview. She frames her discussion of this section in terms of Enlightenment reason, "which had propelled such phenomenal advances in mathematics and science, [and which] had contributed to the overwhelming assertions of power at Auschwitz and Hiroshima" (p. 499). In her eyes, two German scholars, Theodor Adorno and Max Horkheimer, analyzed in the late 1940s and early 1950s the Enlightenment ideals and came particularly to grips with logical positivists whose narrow focus on "just the facts" disconnected the language of the exact sciences from society. For them, Enlightenment reason was intoxicated leading to disaster. Seen from Central Europe, however, these disenchanted Marxists missed the bus. They didn't offer anything groundbreaking after millions of humans were driven by the Nazis into a fiery furnace of global conflagration and aften the Communist fanatics of doctrinal perfection joined the killing contest in Central and Eastern Europe – though Ms. Gamwell has little to say about them, likely feeling that the failures of defunct ideologies like Communism and fascism require little comment. She is nevertheless convinced that, although a unified mathematical description of nature is impossible, mathematics has been not only the best vehicle of truth but it has also been immune to postmodern critique; for it is the science in which the concept of truth and certainty has been most deeply rooted in history; "for millennia mathematicians in the Platonic tradition have described a realm of eternal, perfect abstract objects that exist outside time and space, which mankind knows with certainty" (p. 501). So, at the end of her original and at times intriguing volume, the reflective reader may be at a loss when reading about the destruction of the belief in a general truth or about mathematics characterized as an ideology, a religion, dealing with human meanings, intelligible only within a context of culture. What's wrong with mathematics in the current atmosphere of shifting attitudes towards truth and certainty?

In closing, I would like to formulate a handful of remarks that stem from a very different assessment of both the history of art and of mathematics. First of all, I concur that mathematics is, indeed, an international language of exact thought but which manifests itself through responsibility. This quality can be traced in all colossal architecture, sculpture and painting. Without the responsible practice of mathematics, the Egyptians, for example, would be incapable of erecting massive pyramids, pylons and bridges. Ms. Gamwell doesn't seem to appreciate this quality as a contributing factor to ordinary life; nor does she appear to see its far-reaching implications in the history of Western civilization. Thus, while she concludes the book by observing that mathematics has been largely immune to post-modern critique of terms such as "truth" and "certainty," she omits the historical fact that it lacked sometimes a sense of responsibility.[3] And yet, this lack is, I believe, reflected implicitly in her statement regarding "the overwhelming assertions of power at Auschwitz." If she would add the misuse of mathematics by Third Reich scientists who were very close to developing an atomic bomb shortly before the end of Word War II, she would surely understand that mathematics is not only about "truth and certainty." Second, as stated earlier, because Ms. Gamwell does not extricate the abstract mathematical concepts in art from other influences, her argument that mathematical discoveries often provoke new art (such as Russian Constructivism and minimalism) remains unconvincing. Third, more important, perhaps, a nuanced reading of her book reveals that the author deals with the plastic (or visual) arts (painting, sculpture, and architecture) and their historical epochs randomly and even disproportionately. In its final sections, for instance, there is no

[3] See P. Milén, *Geometrie v dějinách náboženství* (Geometry in the History of Religion), Praha 2015, pp. 40–46.

word about modern architecture and sculpture; nor is there any systematic discussion of the Baroque era in the entire book, let alone a discussion of how a mathematical breakthrough concerning better ways of calculating the 12th root of two inspired one of the most famous Baroque composers, J.S. Bach. Subsequently, it could be straightforwardly argued that, for example, the architect Francesco Borromini in Italy (mentioned on p. 68) or the Dientzenhofers in Bohemia, Poland and Bavaria (not mentioned at all) drew their inspiration not only from mathematics but also from Aristotle's discovery of the ontological movement. As it is often argued by inquisitive philosophers and historians of art, this is why the underlining convex and concave geometry of their architecture is characterized by "moving features."[4] Fourth, although the main thrust of Ms. Gamwell's thesis is on the interplay between mathematics and art along the lines of Platonism, this is far from the whole story. The absence of systematic discussion of the problem of space and void is also a non-negligible problem with her thesis. In fact, it poses the most serious challenge of all if an understanding of space is important for the plastic arts. In a nutshell, it is worth noting that the Egyptians were highly conscious of the cubic-like structure of the world, traversed by two co-ordinates at right angles: the generally south-north flow of the Nile and the east-west passage of the sun across the ceiling of the heavens.[5] This geometric framework underlined the structure of their artwork and thereby reflected their concept of space. By contrast, Aristotle never thought of space in terms of abstract geometric co-ordinates, but always in terms of place (TOPOS). For him, the universe was finite and spherical; it was not surrounded by infinite space and there was no such thing as empty space. His topological conception dominated Western thought until the end of the Middle Ages when artists started seeing the world rather quantitatively (not chiefly qualitatively) and began experimenting with the idea of abstract, undifferentiated space. At that time art escaped, or partially escaped, from Aristotle, and it did so under the guidance of geometry and optics. Seen from the linear perspective, the Renaissance artists were encouraged to look at the world in three dimensions and to see things embedded in space no one had seen before and to do things no one had done before[6]. Masaccio's famous *Holy Trinity* (c. 1425) in Santa Maria Novella in Florence is a fine

[4] J. Patočka, „L'idée d'espace depuis Aristote jusqu'a Leibniz," *Sborník prací filosofické fakulty brněnské university*, 1961, vol. 5, p. 23–41 and his study „L'espace et sa problématique" in *Qu'est-ce que la phénomenologie?*, Grenoble 1988, pp. 17–96.

[5] See C. Aldred, *Egyptian Art*, London 1980, p. 13.

[6] Cf., for instance, E. Panofsky, *Die Perspektive als „symbolische Form"*, originally published in: „Vorträge der Bibliothek Warburg" in 1924–1925, pp. 258–330.

example because it was the first large-scale painting which fully mastered the technique of perspective representation.[7]

While Ms. Gamwell asserts at the beginning of her book that humanity had to overcome the initial chaos, she also concludes that space was conceived as identically mathematical in antiquity because all ancient people "looked at the same natural world and contemplated the same mathematical-world-out-there" (p. 7). If this were true then her conception of the *spatium ordinatum* (as opposed to *spatium ordinans*) would be a contradiction in terms. Consequently, Plato's understanding of space would not differ from Aristotle's teaching. Ultimately, if pushed to an extreme, it would become extremely difficult for her to explain the different notions of space with respect to art history or to expound the differences that have constituted what is known as Antique, Romanesque, Gothic or Baroque.

Although Ms. Gamwell may be guilty of some ambiguity in her views on the history of art, there can be no uncertainty about the provocative stimulus to thought offered by her writings. Our post-industrial era may be a time of chaos and complacency in exact sciences and art, but thinking about them can be both enlivening and unsettling. Ms. Gamwell forces us to reassess, in light of the perennial questions of philosophy, not just the current fortunes of mathematics and art but their essential shortcomings and attractions.

JOSEF NOVÁK – Czech-American philosopher and public intellectual. Educated at the Ohio State University in Columbus and Charles University in Prague, he has strong interests and training in both the history of philosophy and contemporary phenomenology. He has published articles and reviews in many vocational journals including *the Review of Metaphysics*, *les Cahiers de Philosophie*, *les Études philosophique*, *Journal of the British Societty for Phenomenology,* etc. His books include: *On Masaryk: Texts in English and German* (Rodopi), 1988 and *Geometry in the History of Religion* (Prostor), 2015.

JOSEF NOVÁK – filozof amerykański czeskiego pochodzenia, zaangażowany politycznie intelektualista. Ukończył Uniwersytet Stanowy Ohio w Columbus oraz Uniwersytet Karola w Pradze. Interesuje się zwłaszcza historią filozofii i współczesną fenomenologią. Jest autorem artykułów i recenzji publikowanych w takich czasopismach jak: *the Review of Metaphysics*, *les Cahiers de Philosophie*, *les Études philosophique*, *Journal of the British Societty for Phenomenology,* etc. Napisał książki: *On Masaryk: Texts in English and German* (Rodopi), 1988 oraz *Geometry in the History of Religion* (Prostor), 2015.

7 J.T. Paoletti and G.M. Radke, *Art in Renaissance Italy*, London 2011, pp. 232–233. Cf. J.V. Field, *The Invention of Infinity: Mathematics and Art in the Renaissance,* Oxford1997 or her book entitled *Piero della Francesca: A Mathematician's Art,* London 2005.