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Galileo (1564–1642) and Kepler (1571–1630): the modern scientist and the mystic

Галилей и Кеплер от средновековието към модерността на XX век

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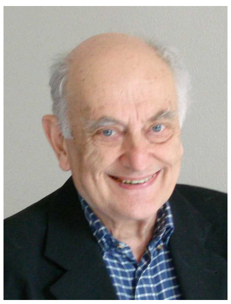

Galileo's place in the history of science has been badly distorted by hero worship.

It was first from his letter to Kepler of 1597, written after reading the preface to the *Mysterium Cosmographicum* which the 26-year old teacher in Graz presented to the professor in Padua, that we learn that “many years ago” Galileo “*became a convert to the opinions of Copernicus*”. Only after 13 more years and the Dutch invention of the telescope, mastered by Galileo, did he make public his views in the *Sidereus Nuncius,* supporting them by his discovery of the Jupiter's satellites, named *Medicea Sidera.* A gifted writer and a brilliant polemicist, Galileo excels in advertising his discoveries - and in making enemies. All that, including the glamorous process against him, was instrumental in changing the prevalent philosophy in the “century of geniuses”.

Galileo, repelled by Kepler's mysticism (and by his Latin), never read his work. He did not accept Kepler's ellipses (*Astronomia Nova,* 1609) even though Cesi wrote him about them in 1612. They reminded Galileo the deformations of the mannerism paintings of his time which he abhorred. The famous *Dialog* of 1632 never mentions Kepler's laws (or Brahe's observations). The true scientific impact of Galileo comes from his often neglected, 45 years long, “early period” (before *The Starry Messenger*) - in his evolving ideas on motion with Archimedes as spiritual guide (like Virgil was to Dante): from the balance and the lever, through the pendulum and the inclined plane, towards the law of inertia and the principles of mechanics, eventually published in his *Mathematical Discourses Concerning Two New Sciences* (Elzevir, Leyden, Holland, 1638).

The art of advertising one's scientific achievements, of which Galileo was an early master, is a trademark of successful modern science. Dedicated believers and mystics of science, such as Kepler, are less popular. Yet, an alleged rigorous rationalist like Wolfgang Pauli [12] found in his later troubled life a kinship to Kepler's “archetypal ideas”.

1. Introduction: “On the shoulders of giants”

Should the phrase[1] “standing on the shoulders of giants”, used by Newton in his 1676 letter to Hook (and featuring in the title of Hawking's book[2]), be given a true meaning in the context of Newton's great achievements, it must refer first and foremost to Kepler and Galileo. There is a striking disparity in their public images. In his Introduction to [2] Gingerich, Harvard's

1 Attributed by John of Salisbury in 1159 to Bernard of Chartres of 12th century
2 *On the Shoulders of Giants, The Great Works of Physics and Astronomy,* edited, with commentary.

astronomer and historian of science, recalls the motivation of [8][3]: While Galileo and Kepler were the two giants on whose shoulders Newton had stood, why was the name of the first familiar to every schoolboy, but the second known to only a small number of intellectuals? At closer reading popularity appears, as usual, intertwined with legend. Galileo's legend is related to the glamorous process of 1633 which is often presented as typifying the clash between modern science and the Catholic Church - a crude simplification, to say the least. By contrast, we are jumping over this popular story altogether, paying more attention instead to some of the great achievements of the two men and to their contrasting approach to science. Readers interested in the ideological struggle(s) of Galileo will find a careful analysis in the corresponding articles of [1], and, may be most thoroughly, in the recent Russian language monography [3].

2. The Renaissance man of Tuscany and the Swabian mystic

After the "*classic work dealing with Galileo's life and scientific achievements*" [4], I enjoyed reading the more recent and lighthearted "*magnificent biography*" (in the words of Peter Machamer [10]) [6] and will try to share some of its flavor:

"*Although Galileo was born in Pisa (in 1564), the hometown of his recalcitrant mother, he prided himself on being a noble of Florence through his father, Vincenzo Galilei, a musician and musical theorist*". (p. 2 of [6]). Or, the eloquent characteristic from the Preface: "*Galileo enjoyed such epithets as "divine mathematician" and "Tuscan Archimedes," and he spent the first half of his career, from 1589 to 1610, as a professor of mathematics. ... For all that, he was no more (or less!) a mathematician than he was a musician, artist, writer, philosopher, or gadgeteer. His last disciple and first biographer, Vincenzo Viviani, boasted that his master could compete with the best lutanists in Tuscany, advise painters and poets on matters of artistic taste, and recite vast stretches of Petrarch, Dante, and Ariosto by heart. But his great strength, Galileo said when negotiating for a post at the Medici court in 1610, was philosophy, on which he had spent more years of study than he had months on mathematics... Galileo the patrician humanist ... underwent a sort of epiphany under the impetus of the telescopic discoveries he made at the age of 45. He had published very little, and nothing of importance, up to that time. He had many good ideas, but held them back...When he had armed himself with the telescope, however, he declared all he knew and more. To the surprise of his colleagues and against their advice, he attacked philosophers, theologians, and mathematicians, taunted the Jesuits, jousted with everyone who contested his priority or his opinions. He became a knight errant, quixotic and fearless, like one of the paladins in his favorite poem, Ariosto's Orlando furioso. This change in behavior, which won him a continually lengthening list of enemies, made his disastrous collision with a pope who for many years had been his friend and admirer intelligible and even inevitable*".

Kepler's biographies are much fewer (than Galileo's) and are mostly based on [2]. From the introduction to the Dover edition of [2]: "*Caspar was eminently qualified to write the standard biography. Like Kepler himself, Caspar was born in southern Germany, had been trained in both theology and mathematics at Tübingen*".

At the age of 25, Kepler (born in Weil der Stadt, "gate to the Black Forest", in 1571) drew unflattering portraits of his parents and ancestors comparing them with their horoscopes ([2] Sect. I.3). He remembered, though, how his mother showed him the great comet of 1577. Matriculated at the University of Tübingen in 1587, he was influenced by Maestlin, his astronomy professor, who knew Copernican astronomy well (his "1543 *De revolutionibus* is probably the most thoroughly annotated copy extant" [5]). Leaving, against his will, the hope to become a clergyman in Tübingen, Kepler found his true calling as a "theologiancosmologist". On the eve of publishing his first book, the *Mysterium cosmographicum* of 1596, the first unabashedly Copernican treatise since *De revolutionibus* itself, he wrote to his teacher (Maestlin): "I wanted to become a theologian, for a long time I was restless. Now, however, behold how through my effort God is being celebrated in astronomy." [5]. This work was for

3. Whose central piece, *The Watershed,* is the first notable English language biography of Kepler

him the beginning of a big project that included "*Astronomia nova*, *Harmonices Mundi*, and *Epitome of Copernican Astronomy*" where his three famous laws are formulated. To quote [5]: *"Kepler's scientific thought was characterized by his profound sense of order and harmony, which was intimately linked with his theological view of God the Creator. He saw in the visible universe the symbolic image of the Trinity. Repeatedly, he stated that geometry and quantity are coeternal with God and that mankind shares in them because man is created in the image of God*". Kepler wrote prolifically, but his intensely personal cosmology was not very appealing to the rationalists of the generations that followed. A much greater audience awaited a more gifted polemicist, Galileo, who became the persuasive purveyor of the new cosmology. "*Kepler was an astronomer's astronomer*". It was the astronomers who recognized the immense superiority of the "*Tabulag Rudolphinae*".

The nature of Kepler's religious views and their unifying role in his work were analysed by Holton [7]: From his earliest writing to his last, Kepler maintained the direction and intensity of his religio-philosophical interest... Next to the Lutheran God, revealed to him directly in the words of the Bible, there stands the Pythagorean God, embodied in the immediacy of the observable nature and in the mathematical harmonies of the solar system whose design Kepler himself had traced – God "whom in the contemplation of the universe I can grasp, as it were, with my very hands." (letter to Baron Strahlendorf, October 1613). Or, in an early letter to his teacher: "the belief in the creation of the world be fortified through this external support, that the thought of the creator be recognized in its nature ... Then man will at last measure the power of his mind on the true scale, and will realize that God who founded everything in the world according to the norm of quantity, also has endowed man with a mind which can comprehend these norms. For as the eye for the color, the ear for the musical sound, so is the mind of man created for the perception not of any arbitrary entities, but rather of quantities; the mind comprehends a thing the more correctly the closer the thing approaches toward a pure quantity as its origin." (letter to Maestlin, April 1597). Kepler saw the universe as a physical machine, as mathematical harmony, and as central theological order. And this was the setting in which conception of the universe led to specific results of crucial importance.

3. Early period. First exchange. The 8-minutes error and the ellipses

The long neglected Galileo's early period (the first 45 years (!) of his life) is important both for displaying his dept to teachers, predecessors (such as Borro, [6], Sect. 2.3, Benedetti, [9], 140-165) and colleagues and for revealing the difficulties he had to overcome on his road to the law of inertia. To quote Hooper [1]: Classical mechanics is still taught by referring new students to the core set of problems that had to be solved by the original investigators like Descartes, Gassendi, Huygens, Wallis, Wren, Hooke, and Newton, all following Galileo's original line of attack. These problems include the analysis of motion on an inclined plane, the motion of a pendulum, the action of a lever, the force of a spring or pull in a rope, the result of collisions between impacting and moving bodies, and so on. The difficulty with the law of inertia stems from the fact that it is never valid on earth because of gravity which was only understood later, in the work of Newton. Galileo analyzed projectile motion into two component motions, the first horizontal and uniform, the other vertical and accelerated. Galileo discussed the motions of bodies upon the moving Earth and of planets around the Sun. He asked questions that led his fellows and successors directly toward inertial mechanics and gave them some of the essential tools to build it.

Galieo was teaching (in Pisa and then in Padua) Ptolemy, preferring privately Copernicus as witnessed by a long letter of 1597 to his elder Pisan friend Mazzoni ([6], *The Copernican confession*). A few months later Galileo received from the hands of a personal messenger a copy of young Kepler's *Mysterium cosmographicum.* Like many people who receive unexpected books, Galileo thanked the author immediately so as not to have to comment in detail. He had had time only to read the preface, he said, from which he gathered that congratulations were in order, not to the writer, but to the reader, for “having acquired such a lover of truth as an ally in the search for truth.” Kepler had found some choice things, which Galileo promised to study, “and that the more willingly since I adopted Copernicus’ opinion many years ago, and deduced from it the causes of many natural effects doubtless inexplicable on the ordinary hypothesis. I’ve written out many reasons for it and many responses to reasons against it, which I have not dared to publish as I’ve been deterred by the fate of our master Copernicus. For although he has gained immortal fame among a few, he has been ridiculed and derided by countless others (for such is the number of fools). I would venture to disclose my thoughts if there were more like you; but as there are not, I will forbear.” Kepler tried to stiffen the backbone of his shy ally. “I was very pleased to receive yours of 4 August, firstly because of friendship begun with an Italian and secondly because of our agreement about Copernican cosmology.” Mathematicians everywhere (Kepler continued) side with Copernicus and calculate according to his principles. If we all speak out together, people ignorant of mathematics will have to take our word for it. “If I’m right, not many good mathematicians in Europe will wish to differ from us; tanta vis est veritas, such is the power of truth. If Italy is not a suitable place for publication, and if you encounter other difficulties, perhaps Germany will grant us this freedom . . . Have faith, Galileo, and go forth.” To this pep talk, and an appended request to make a certain astronomical observation in the common cause, Galileo did not respond at all.

A teacher at the Lutheran school in Graz (asked to teach Virgil, rhetoric and arithmetic) young Kepler made his mark by issuing a calendar and prognostication for 1595, which contained predictions of bitter cold, peasant uprisings, and invasions by the Turks. (All were fulfilled, to the great enhancement of his local reputation.) Meanwhile, just over a year after his arrival in Graz, Kepler’s fertile imagination hit upon what he believed to be the secret key to the universe. There were six known planets at the time and there are exactly five regular polyhedrons (*Platonic solids*: the tetrahedron, cube and octahedron, dodecahedron and icosahedron). Kepler devised a scheme (that worked fairly well [5]) in which each planet moves on a circle inscribed or superscribed around corresponding Platonic solids. Although the principal idea of the *Mysterium cosmographicum* was erroneous, Kepler established himself as the first, and until Descartes the only, scientist to demand physical explanations for celestial phenomena. Seldom in history has so wrong a book been so seminal in the future course of science.

Providence kept helping Kepler as if against his will: By the fall of 1598 Catholic rulers in Graz started chasing away protestants. Being not welcome at his Alma mater (in Tübingen) he had to go to Prague where, upon the death of his host, the great Danish astronomer Tycho Brahe (1546-1601), he became imperial mathematician in the court of Rudolph II. Luckily, he had been assigned (by Tycho) to study the orbit of Mars, the planet with greatest eccentricity, which helped him liberate astronomy from the two-thousand-year-old dogma of circular motion. Remarkably, explaining the precise observations of Tycho was more important to Kepler than apriory aesthetic ideas: “Divine Providence granted us such a diligent observer in Tycho Brahe,” he wrote, “that his observations convicted this Ptolemaic calculation of an error of 8’; it is only right that we should accept God’s gift with a grateful mind.. . . Because these 8’ could not be ignored, they along have led to a total reformation of astronomy.” The first two laws were thus mastered essentially already in *Astronomia nova* (1609) but the precise formulation of all three planetary laws only appears in book V of his *Epitome astronomiae Copernicanae* (1621). The puzzling fact that Galileo never took seriously Kepler's ellipses is explained in [11] by his aesthetic views: for Galileo the ellipsis is a deformed circle reminding him the deformed human faces in the then becoming fashionable mannerism paintings (an opinion also supported in Koyré's *Attitude esthétique et pensée scientifique,* [9], pp. 275-288).

4. The Starry Messenger. Theories of tide

During his Paduan tenure Galileo befriended the enlightened Copernican and influential Venetian Sarpi[4]. In the summer of 1609 a claim came to Italy of Dutch spectacle makers to a gadget that made distant objects appear near. One came into Sarpi's hands in July 1609. Having examined it, he could advise the Senate not to buy it from a traveling salesman who had offered it, together with its "secret," for 1,000 scudi. By then, August 1609, the secret was out. Sarpi's knowledge of optics gave him confidence that the gadget could easily be bettered, and his knowledge of men assured him that Galileo was the one for the job. As Sarpi wrote to a friend, *The Dutch gadget became the Italian telescope* through the efforts of "the mathematician [Galileo] and others here [in Venice] not ignorant of these arts."[6]. In December 1609 Galileo raised his best telescope, then of 20x, to the sky, an exercise for which he was fully prepared (with his firsthand knowledge of perspective among other things). Sometime before 7 January 1610, when Galileo described his lunar discoveries to Antonio de' Medici, he noticed through his 20x telescope that Jupiter had lined up along the ecliptic with three little stars. Galileo immediately recognized a life chance for a real discovery. Even if a friend first saw the event, as the jealous successor of the Florentine in Padua had it [6], Galileo alone was able to identify Jupiter's starlets as elements of a miniature solar system. That took immense skill and application; or "the carefulness and industry of a Florentine." One can follow this care and industry day by day in Galileo's drawings of the changing configurations of Jupiter and the starlets. Galileo's account of his discoveries, rushed into print early in March 1610 under the title *Sidereus nuncius*, included the fanciful designation of Jupiter's moons as Medici stars. Galileo's discoveries were met with skepticism and mistrust, especially in his native Italy; so in April 1610, he sent his book to Kepler in Prague, requesting an opinion. Kepler's response was enthusiastic and generous. Even before having observed Jupiter's moons himself, he starts his message - *Dissertatio* with: "Whom does knowledge of such important things allow to be silent?" ([2] Sect. III. 14, p. 192).

A few remarks are in order. - Galileo never mentioned his human debt to friends and colleagues in Venice and Padua (neglecting to consider the importance of the testimony of trustworthy Venetians, able to certify that the discoveries announced were not optical illusions): he was preoccupied with flattering his former pupil Cosimo II de' Medici while negotiating best possible conditions for his tenure at the Tuscan court. -- He wrote the *Starry message* in Latin, as befitted to a scientific discovery, Galileo's most important contribution to the field of astronomy. (By contrast, his famous *Dialogue Concerning the Two Chief World Systems* of 1632, a masterpiece of Italian prose, is a speculative polemical exposé of 16th century Copernican physics that ignores newer observations and theoretical development by Tycho Brache and Kepler).

It is interesting to compare the different approaches of Galileo and Kepler to similar problems. When Kepler has to face optical observation he studies the theory - in *Astronomiae pars optica* (1604), ... *Dioptrice* (1611), founding on the way the geometric optics. Galileo is playing instead with two lenses and soon produces an improved telescope. Kepler is spending years searching for "the third law of planetary motion" - the precise relation between the cubes of large semiaxes and tthe squares of the corresponding periods. Galileo collects similar data for Jupiter's satellites but does not look for a relation between them thus missing the opportunity to be the first to discover the third law. For him "mathematics" is the Archimedian geometry: he has no taste for analytic and algebraic computaions.

Perhaps the most instructive example of a clash between Galileo's smooth "rational thinking" and Kepler's "mysticism" is provided by their different approaches to the theory of tides. In

4 **Paolo Sarpi** (1552–1623) was an Italian historian, scientist, statesman, active on behalf of the Venetian Republic during the period of its successful defiance of the papal interdict (1605–1607).

1616 Galileo published (in Italian) his *Discorso* on the topic. In his view, it provided *The decisive proof that the Earth moves* [13], p. 224 (the idea having come to him in a flash on one of his frequent trips from Padua to Venice in a large barge whose bottom contained a certain amount of water). Kepler had the right intuition that the tides are caused by the moon's attraction - a view confirmed and further elaborated by Newton and Laplace of the next generations. To quote [6], Sect. 7.2, p. 260: "*Galileo's prevailing misjudgments as a natural philosopher come into view here. Neglecting physical cause, he advanced his pendulum analogy, which was no more than a metaphor, as an explanation. What is it that binds the earth and moon so strongly together that they act as a single pendulum bob? Galileo liked the analogy all the more for this weakness. In the paradoxical way he loved, it gave the moon a role in the drama of the tides "without [its] having anything to do with oceans and with waters." It also allowed him to sidestep the hidden connection between the lunar motions and the diurnal tides, and to rap Kepler, who, "though he had at his fingertips the motions attributed to the earth . . . has nevertheless leant his assent to the moon's dominion over the waters*". In fact, Kepler has anticipated the law of universal gravitation. He stated that gravity was a *mutual* tendency between material bodies toward contact, so the earth draws a stone much more than the stone draws the earth. Heavy bodies are attracted by the earth not because it is the center of the universe, but simply because it contains a lot of material, all of which attracts the heavy body. Kepler realized that the tides were caused by the waters of the oceans being attracted by the moon's gravitational pull. He wrote (in the Introduction to *Astronomia Nova*): *"If the earth ceased to attract the waters of the sea, the seas would rise and flow into the moon..."* and went on to add: *"If the attractive force of the moon reaches down to the earth, it follows that the attractive force of the earth, all the more, extends to the moon and even farther..."* (We recommend the well documented emotional expossition of Sects. 6.8-10, pp. 334-343, of Koestler's book [8] where these quotations are put into context.) One should be also able to understand why for Galileo the mutual attraction at a distance of celestial bodies sounds like a magic. Even Newton has expressed his dissatisfaction in his philosophical queries (if not in the *Principia*). Only with the advent of general relativity one begins to understand gravitation as a local field theory: a dynamical change of space-time geometry by moving bodies.

Quite apart from the theory of tides, this is a good place to illustrate why does one need the insight of both Kepler and Galileo for the Newton synthesis. It seems almost incredible, with hindsight, that Kepler could have understood the gravitational force so well, and yet it did not apparently occur to him that it might play a central role in determining the orbital motions of the planets! The essential reason he failed to make the connection was that he had no intuition for the inertial movement: *he believed the planets needed a constant pushing force, in the direction of motion, to keep them going* in their orbits. This was an ancient belief that Galileo demolished in his discussions of projectiles in *Discourses on the Two New Sciences* (1638). But albeit the Discourses resurrected some work of his "early period" it was only published after Kepler's death (1630). Galileo's insight about projectiles was then extended to the planets by Newton.

5. Final years. Kepler's wine barrels and Galileo's Tuscan wine

When the deposed emperor Rudolph died in January 1612 Kepler went to Linz as provincial mathematician, a post created specially for him. Although his most creative period was laying behind him, his fourteen-year sojourn in Linz eventually saw the production of his *Harmonice mundi* and *Epitome astronomiae Copernicanae* and the preparation of the *Tabulae Rudolphinae*. One bright spot in his Linz career was his second marriage, to Susanna Reuttinger, a twenty-four-year-old orphan, on 30 October 1613. In an extraordinary letter to an unidentified nobleman, Kepler details his slate of eleven candidates for marriage and explains how God had led him back to number five who had evidently been considered beneath him by his family and friends. The marriage was successful, far happier than the first; but of their seven children, five died in infancy or childhood. Likewise, only two of the five children of his first marriage survived to adulthood.

That Kepler, engulfed in a sea of personal troubles, published no astronomical works from 1612 through 1616 is not surprising. Yet he did produce the *Stereometria doliorum vinariorum* (1615), which is generally regarded as one of the significant works in the prehistory of the calculus. Desiring to outfit his new household with the produce of a particularly good wine harvest, Kepler installed some casks in his house. When he discovered that the wine merchant measured only the diagonal length of the barrels, ignoring their shape, Kepler set about computing their actual volumes. Captivated by the task, he extended it to other shapes, including the torus.

In his own eyes Kepler was a speculative physicist and cosmologist; to his imperial employers he was a mathematician charged with completing Tycho's planetary tables. He spent most of his working years with this task hanging as a burden as well as a challenge; ultimately it provided the chief vehicle for the recognition of his astronomical accomplishments. In excusing the long delay in publication, which finally took place in 1627, he mentioned in the preface not only the difficulties of obtaining his salary and of the wartime conditions but also "the novelty of my discoveries and the unexpected transfer of the whole of astronomy from fictitious circles to natural causes, which were most profound to investigate, difficult to explain, and difficult to calculate, since mine was the first attempt." Kepler realized that the improved accuracy of his tables enabled him to predict a pair of remarkable transits of Mercury and of Venus across the disk of the sun. These he announced in a small pamphlet, *De raris mirisque anni* 1631 *phenomenis* (1629). Although he did not live to see his predictions fulfilled, the Mercury transit was observed by Pierre Gassendi in Paris on 7 November 1631.

The 58-year old Kepler died in Regensburg on November 15, 1630 while traveling to collect his salary. He was buried in the Protestant cemetery; the churchyard was completely demolished during the thirty years war. Jacob Bartsch, who had married Kepler's daughter Susanna in March 1630, became a faithful protector of the bereaved and penniless family. He recorded the epitaph that Kepler himself has composed: *I used to measure the heavens, now I shall measure the shadows of the earth*.

The final period of Galileo's life, starting with his *Dialogue Concerning the Two Chief World Systems,* falls after Kepler's death. Picking himself up from his humiliating posture before the cardinals and the gospels, Galileo received permission to stay within the palace of the archbishop of Siena, Ascanio Piccolomini, in anticipation of a return back home to Arcetri after an absence of over a year. The six months that Galileo spent in Siena at Piccolomini's house and table revived his spirits[5]. He started a new work on mechanics "*full of many curious and useful ideas*" - resurging his youthful thoughts. Galileo was enjoying premium wine at the archbishop's table (not trying to determine the volume of the casks) as can be surmised from the letters of his loving daughter Maria Celeste[6]: "I pray that you continue [in good health] by governing yourself well particularly with regard to the drinking that is so hurtful to you ...". Thus Galileo, like Kepler, completes and publishes his ripest work *Mathematical Discourses Concerning Two New Sciences,* which crowns his oeuvre, during the last years of his life. It is a no small feat for the embittered blind old man who has just lost his favorite child. The book resumes the discussions of the three participants of the condemned *Dialogue.* They no longer mention Copernicus but do praise "our Academician" (i.e. Galileo himself) giving an occasion

5 The fine story that when rising from his knees before the inquisition Galileo muttered, "still it moves," is associated with the Piccolomini. A portrait, representing the scene of Galileo's recantation, perhaps by Murillo displays the slogan, *eppur si muove* ([6], p. 327)

6 Galileo's elder daughter Virginia (Suor Maria Celeste, 1600-1634) was confined by him together with her sister to the convent of San Matteo in Arcerti and is buried with her father at Santa Croce - [14]

to the witty Descartes (who never masters Galileo's law of free falling bodies - see [3], Part II) to ironize: “[Galileo’s] *way of writing in dialogues with three persons who do nothing but praise and exalt his inventions in turn certainly makes the most of his wares*”.

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Галилей и Кеплер
от средновековието към модерността на XX век

Galileo (1564–1642) and Kepler (1571–1630):
the modern scientist and the mystic

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Темата на настоящето есе са двамата учени Галилей (1564–1642) и Кеплер (1571–1630) – техните разбирания за света, открития, заблуди и конфликти, а особено техните послания към идните поколения. Понятието *средновековие* не е исторически утвърдено, но условно се приема, че това е интервалът от 5-ти до 15-ти и даже до 17-ти век. Така че Кеплер и Галилей са живели по-скоро в късното средновековие, когато вече е настъпила епохата на Ренесанса. Това е многозначителен факт, тъй като тяхното научно творчество отразява и съдържа както някои предразсъдъци и заблуди от периода на средновековието, така и емблематичните аспекти на ренесансовото мислене. Именно в тази светлина личностите на Галилей и Кеплер са доста обстойно съпоставени в лекцията на акад. Иван Тодоров.

От друга страна споменатото в заглавието понятие "модерност" (или "модернизъм") се свързва с нашето съвремие и означава творчески стил в изкуствата и науките, който значително се отличава от този на предходните епохи. Модернизмът на нашето съвремие се отличава с динамизъм, универсализъм, контактност между учените и широката общественост, публичност (но наред с това секретност), социална, икономическа и политическа насоченост и много други.

Основната цел на настоящето есе е да изясним в какъв вид някои от възгледите и постиженията на Галилей и Кеплер са преминали и са били развити в условията на нашето модернистично съвремие. А тъй като за Галилей се знае още от училищната скамейка, тук е отделено малко повече внимание на личността и творчеството на Кеплер.

От Галилеевия принцип на относителността през класическата механика на Нютон (1643–1727) до СТО и ОТО на Айнщайн (1879–1955)

Първоизточник на Айнщайновата СТО (1905) е основният закон на механиката на Галилей – Нютон, известен като закон за инерцията. Айнщайн обаче допълва този закон с някои твърде съществени представи като относителност на едновременността и на пространственото разстояние, а също така с постулата за постоянството на светлинната скорост във вакуум. Така наред с фундаменталната идея за зависимост на пространствените и времевите интервали от скоростта на движението в СТО за пръв път се появява зависимостта на инертната маса на телата от тяхната енергия.

От историческа и методологична гледна точка построяването на СТО е предшествано от ред мислени експерименти – напълно в духа на Галилеевите мислени експерименти с падащи тела. Тази методология продължава когато Айнщайн си поставя задачата да обобщи Галилеевия принцип на относителността по такъв начин, че да се включи и ускореното движение. Освен това Айнщайн залага в основата на своята обобщена теория принципа за еквивалентност на инертната и тежката маса. Създадената по този начин обща теория на относителността (1916) описва пространството, времето и гравитацията. Въз основа на тази теория са изучени епохално важни проблеми, свързани със строежа и еволюцията на Вселената.

Галилей – универсализъм и емпиризъм на изследването, модерност на научен стил и социално поведение

"*Галилей е най-великият от създателите на модерната наука"* – Бъртранд Ръсел (*Възходът на науката*)

В статията *За метода на теоретичната физика* (1933) Айнщайн дава лаконична, но подчертано отрицателна оценка на съзерцателния метод в науката (очевидно, имайки пред вид метода на Аристотел). Той пише: "*изводите, получени с чисто логически средства, при сравняване с действителността, се оказват съвсем празни. Галилей е осъзнавал това и го е внушавал на учените. Затова той е баща на съвременната физика и фактически на естествознанието изобщо*" [1].

Айнщайн недвусмислено изтъква, че Галилей действително присъства в съвремието на XX век. Доказателство за това е както универсалността на неговите изследвания така и огромният брой създадени от него уреди за експериментиране, а също остроумно поставените мислени експерименти. А сагата на конфликтните му отношения с църквата само повишава стойността на тези негови постижения.

С цялата си личност Галилей изразява модерността на своето време. Това е представено много картинно в пиесата на Бертолт Брехт "*Животът на Галилей*" (1938). В постановката на московския *Театър на Таганка* през 1970-те години образът на Галилей е въплътен от прочутия бард Владимир Висоцки като един динамичен, шумен, дързък и безкомпромисен човек на науката, изцяло отдалечен от образа на светец.

Отшелник в науката

"*Нито бедността, нито неразбирането на съвременниците, тегнещо над целия му живот и над работата му, не са могли да сломят неговия дух*" – Алберт Айнщайн [2]

Немският учен Йохан Кеплер (1571–1630), като че ли по прищявка на съдбата, остава много дълго време в сянката на своя именит съвременник Галилей. Двамата учени са се познавали, но техните отношения ярко илюстрират трудната съвместимост между модернистичния по своя характер Галилей и (по думите на Айнщайн [2]) "*усамотения, от никого не подпомогнат и не разбран*" Кеплер. Като че ли той не е в една лодка с нито едно съвремие – нито със своето, нито с нашето.

Причините за това са много и те не са само в неговия горд и независим характер, но и в склонността му към мистицизъм, към питагорейството в математиката и към религиозните образи, свързани с хармонията на света, светата троица и др. Така например в съчинението си *Хармония на света* Кеплер пише: "*Геометрията е самият бог (защото има ли нещо, което да е в бог и да не е бог?) и му служи като първообраз* (к.м.; т.е. архетип) *при сътворението на света. Заедно с божия образ геометрията прониква в хората и се възприема от тях не само с помощта на очите*".

Горният цитат е приведен в забележителното съчинение "*Влияние на представите за архетип върху формирането на природонаучните теории у Кеплер*" [3] (1952) на известния физик теоретик Волфганг Паули (1900–1958) – откривателят на принципа на забраната (Нобелова награда 1945), на CPT теоремата за симетрията на елементарните частици и много други [4]. Известно е, че Кеплер е бил кумир на Паули. Възниква въпросът: какво общо е можел да има Паули, прословутият рационалист и скептик, с мистично-религиозно настроения Кеплер? И още по-труден въпрос: по какъв начин символиката на светата троица и на *световната хармония* е довела Кеплер до откриването на трите закона за движението на планетите в Слънчевата система? Отговорите на тези (и други) въпроси са дадени в цитираното съчинение на Паули. А преди това друг известен физик теоретик, Арнолд Зомерфелд, пише в своя статия от 1925 година: ”*Кеплер е бил ярък привърженик на мистиката на числата, на светлата мистика по красивия израз на Херман Вайл*”. И после Зомерфелд пояснява: “*Мистиката на Кеплер, разбира се, не е в смисъла на астрологичните, метафизичните и спиритистките увлечения на нашето време, а е за природните закони и за тяхната обосновка*”[5].

Кеплер и архетипът

Изследването на Паули върху ролята на познавателния процес, така както го е схващал Кеплер, се съдържа в цитирания горе негов труд [3]. Тази публикация възниква при тясното сътрудничество на Паули с известния швейцарски психиатър Карл Густав Юнг (1875–1961), създател на т.нар. *дълбочинна психология*, в която централна роля играе идеята за архетипа [4].

Понятието *архетип* (от гръцки “*първообраз*”, “*праобраз*”) се появява в съчинения на християнския философ и богослов Августин (354–430), но не е ясно дали Кеплер го е усвоил от него. Според Паули архетипът е “*подреждащ оператор*, *априорно условие на познанието*, *познавателен инстинкт*”. Юнг дефинира архетипа като “*съдържание на колективното несъзнавано*”, което се е формирало в продължение на хилядолетия при еволюцията на животинските видове и човека. Това е “*акаузална, но смислена връзка*” между материални и психични събития, връзка между сетивното възприятие на външните обекти и вътрешните праобрази [4].

Самият Кеплер разглежда архетипа като “*цел на познавателния процес*”. Паули посочва, че Кеплер се е убедил във верността на Коперниковата хелиоцентрична система не от резултата на отделните астрономични наблюдения, а от “*съответствието*” на тази картина с архетипа, чийто символ е хармонията на светата троица. Именно съответствието с архетипа създава онова “*чувство на радост и щастие*”, което Кеплер нарича “*хармония*” и което предизвиква тържествуващото възклицание “*еврика*!”.

За някои актуални архетипове в нашето съвремие писа в едно много задълбочено изследване известният руски математик Израил Мойсеевич Гелфанд (1913–2009). Статията му “*Два архетипа в психологията на човека*” е публикувана в списание Nonlinear Science Today (1991), а скоро след това преводът ѝ е публикуван в нашето Физико-математическо списание [6] [*Можем само да съжаляваме за загубата на това толкова съдържателно списание. Опасявам се, че същата участ може да сполети и списанието на Съюза на физиците в България Светът на физиката].

Статията на Гелфанд анализира съдържанието и перспективите на два дълбоко вградени в подсъзнанието на човека архетипа – разумността и мъдростта. След като изяснява техния смисъл, авторът излага тезата си, че в математиката са налице и двата архетипа. Стъпвайки на тази постановка той прави задълбочен анализ на съставните елементи на двата архетипа и прави забележителни по своя обхват прогнози, отнасящи се до еволюцията на човешкото общество и на самия човек, до проблемите на глобализацията, необходимостта от адекватен език в цялата съвременна култура и конкретно в математиката, за структурния подход и синергията в живите системи.

Така Кеплеровото схващане за евристичната роля на архетиповете намира конкретна реализация в нашето съвремие, което повече от всякога се нуждае от вярна прогноза и диагноза.

Кеплер и квазикристалите

Кеплер не е бил модернист. Иначе не би си “*губил времето*” с изучаването на шестоъгълни снежинки и на пчелни пити [7], а вероятно би продължил от законите на

Слънчевата система към закона за гравитацията. Във всеки случай той сигурно е знаел, че нито Галилей, нито по-късно Нютон би изоставил своите астрономични изследвания за да търси причината цветовете да имат по пет листенца или как от "*божествената пропорция*" на Фибоначи (1180–1240) възникват Платоновите тела додекаедър и икосаедър. Воден от своите изследвания на симетрията в природата, Кеплер (в *Mysterium Cosmographicum*, 1596 година) опитва с помощта на Платоновите тела да намери закона за разстоянията на планетите от Слънцето). А по-късно изследва математически (*Harmonices Mundi*, 1619 година) задачата за плътно паркетиране (покриване на повърхности с различни многоъгълни плочки без празнини и застъпвания).

Изминават повече от четири столетия и през 1943 година в разгара на войната намиращият се в емиграция създател на вълновата механика Ервин Шрьодингер изнася в Дъблин курс лекции върху физическите аспекти на живота. Той посочва, че на най-ниско структурно ниво безжизненият каменен къс е агрегат от кристали с периодично повтарящи се едни и същи структурни елементи. От друга страна в органичната молекула всяка група атоми играе индивидуална роля, различна от ролята на другите атоми. Такъв агрегат от атоми с уникална и непериодична подреденост Шрьодингер нарича апериодичен кристал (по-късно наречен квазикристал). Неговата идея е, че генът или даже цяла хромозомна нишка представлява апериодично твърдо тяло [8].

Това смело предположение ни напомня изследванията на Кеплер върху симетрията на Платоновите тела и върху проблема за паркетирането. Следвайки идеите на Кеплер Шрьодингер обобщава схващането за кристала като периодично повторение на една структурна единица до идеята за *далечен порядък*. Докато кристалът има транслационна симетрия, квазикристалът няма транслационна симетрия, но пък има оси на ротационна симетрия от 5-ти (а също от 8-и, 10-и и 12-и) порядък, които липсват в кристалите [9]. Това разкри интригуващата перспектива да се разбере как в природата е осъществен преходът от нежива към жива материя. Тук важна роля може да изиграе строежът на вирусите. Известно е, че в зависимост от външните условия вирусът може да представлява кристал или квазикристал, да има поведение на нежива или жива материя.

Дали модерността на 21-и век няма да ни изведе от Кеплеровите снежинки до отговора на фундаменталния въпрос как се е зародил животът във Вселената? Този отговор може да се крие, по идеята на Паули, в Кеплеровия архетип за "*огледалната симетрия*" между разума и природата.

Заключение

Колкото по-задълбочено изучаваме творческото присъствие на Кеплер и Галилей в нашето съвремие, толкова повече се убеждаваме колко прав е бил Хегел когато е казал, че движението в науката напред е връщане назад към основите.

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