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Islamic Science and Modern Science within The Framework of Paradigms*

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Öz

İslam bilimlerinin bilim tarihi içerisindeki yeri ve önemi, genellikle pozitivist bilim tasarımı açısından ele alınıp ve değerlendirilmiştir. Pozitivizme göre ideal bilim örneği, 17. yüzyıl Batı kültüründe ortaya çıkan modern bilim olduğu için İslam kültüründe ortaya çıkan bilimsel faaliyetler de o kadar önemli ve değerli görülmez. Pozitivistler tarafından modern bilim ölçüt alınarak yapılan bu İslam bilimleri yorumu, 1970'li yıllarda Kuhn'un bilim tasarımı çerçevesinde değişmeye başlar. Kuhn kısaca, tek bir bilim anlayışından ziyade her medeniyetin kendine özgü bir bilim anlayışının olduğunu, dolayısıyla da İslam bilimlerinin önem ve değeri açısından modern bilimden çok da geride olmadığını işaret eder. Kuhncu bilim tasarımı çerçevesinde İslam bilimlerinin yorumu, Batı literatüründe hatırı sayılır bir yere gelmişse de bunun ülkemiz açısından yeterli olduğu söylenemez. Bunun en bariz göstergesi de günümüzde halen bazı akademisyen ve yazarların İslam bilimlerini, modern bilime benzetmeye ve ona göre değerlendirmeye çalışmasıdır. Oysa bu tutum hem pozitivist hem de Kuhncu bilim tasarımı açısından hatalıdır. Bu çerçevede çalışmanın temel amacı, İslam bilimlerine Kuhncu bilim tasarımından bakmayı sağlayan bir argüman oluşturmak olmuştur. Bunun için de İslam ve modern bilim tasarımları arasındaki temel farklılıkları açık bir şekilde ortaya koymak ve bu iki bilim geleneğinin

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birbirlerinden yapıca farklı olduğunu göstermek başlıca gayemiz olmuştur. Bunun için de İslam ve modern bilim geleneklerinin sırasıyla oluşum ve gelişim süreçleri, dayandıkları doğa felsefeleri ve buna göre yapılan bilim pratikleri (astronomi ve fizik bilimleri) karşılaştırmalı olarak analiz edilmiştir. Neticede her iki bilim geleneğinin gerek doğa kavrayışının gerekse yöntemlerinin birbirlerinden çok farklı oldukları dolayısıyla da bunların bilim tarihi içerisinde kendi ölçütlerine göre değerlendirmeleri gerektiği vurgulanmıştır.

Anahtar Kelimeler: İslam Bilimi, Modern Bilim, Pozitivist Bilim, Kuhncu Bilim.

Islamic Science and Modern Science within The Framework of Paradigm

Abstract

The place and importance of Islamic sciences in the history of science has generally been discussed and evaluated in terms of positivist science design. According to positivism, since the ideal example of science is modern science that emerged in the 17th century Western culture, the scientific activities that emerged in Islamic culture are not considered as important and valuable. This interpretation of Islamic sciences, which was made by positivists by taking modern science as a criterion, began to change in the 1970s within the framework of Kuhn's design of science. In short, Kuhn points out that each civilisation has its own understanding of science rather than a single understanding of science, and therefore Islamic sciences are not far behind modern science in terms of importance and value. Although the interpretation of Islamic sciences within the framework of Kuhnian science design has gained a considerable place in the Western literature, it cannot be said that this is sufficient for our country. As a matter of fact, the most obvious indicator of this is that some academics and writers still try to liken Islamic sciences to modern science and evaluate them accordingly. However, this attitude is wrong in terms of both positivist and Kuhnian science design. In this framework, the main purpose of this study is to create an argument that enables to look at Islamic sciences from the Kuhnian science design. For this purpose, our main aim has been to clearly reveal the fundamental differences between Islamic and modern scientific designs and to show that these two scientific traditions are structurally different from each other. For this purpose, the formation and development processes of Islamic and modern scientific traditions, the philosophies of nature on which they are based, and the scientific practices (astronomy and physical sciences) accordingly have been analysed comparatively. As a result, it has been emphasised that both the conception of nature and the methods of both scientific traditions are very different from each other, and therefore they should be evaluated according to their own criteria in the history of science.

Keywords: Islamic Science, Modern Science, Positivist Science, Kuhnian Science.

Introduction

Since the positivism movement has been dominant for many years in terms of understanding and explaining science, the place and importance of Islamic sciences in the history of science has generally been handled and evaluated in terms of positivist science design. According to the positivists led by A. Comte (E. Renan, J.S. Mill, E. Mach), science is a product of the evolution of the human mind in the historical process, that is, the transition from theological and metaphysical to the positive phase (Comte, 2001, pp.32-33). The product of this process, called the positive stage, is modern science that emerged in Western Europe in the 17th century (Comte, 2001, p.30). In other words, for positivists, science begins with the positive phase and this corresponds to the modern science that emerged in the 17th century Western culture. In this context, for positivist thinkers, the scientific activities produced in Islamic civilisation are not considered very important and valuable since they correspond to the metaphysical stage of the human mind. As a matter of fact, the metaphysical stage and the positive stage are very different from each other in terms of their conception of nature and methodology.

This positivist understanding of science and the interpretation of Islamic sciences continued to dominate the intellectual community until the 1960s. After this period, the emergence of conceptions of science that criticise and deny positivism leads to the breakdown of this understanding. At this point, the works of the American thinker T. Kuhn are groundbreaking. In his work The Structure of Scientific Revolutions (1962), Kuhn states that, contrary to positivism, science was not characterised in Western Europe in the 17th century, and that the activity called science started before the 17th century, that is, it has existed since the Ancient Greek culture (Kuhn, 1996). According to Kuhn, science is an activity whose ontology, epistemology and methodology change according to ages and cultures. In other words, science is one of civilisations' unique ways of understanding and comprehending nature. In this framework, Kuhn implies that Islamic civilisation also has a unique understanding of science. Therefore, according to this perspective, the importance and value of Islamic sciences are revealed in their own context, not in comparison with modern science.

This interpretation of Islamic sciences within the framework of Kuhn's design of science began to attract attention in the Western literature after the 1970s, especially among Muslim thinkers. In this context, Muslim thinkers such as Seyyid Hussein Nasr and Ziya al-Din Serdar evaluated Islamic sciences within the framework of Kuhnian science. Although this perspective on Islamic sciences has a considerable place in the Western literature, it cannot be said that this is not enough in our country. As a matter of fact, the most obvious indicator of this is that some academics and writers still try to liken Islamic sciences to modern science and evaluate them accordingly. In this context, these authors often argue that some of the innovations and discoveries achieved through modern science were actually discovered by Muslim thinkers in Islamic culture (for one of the examples, see Bayraktar, 1992). However, this attitude is erroneous in terms of both positivist and Kuhnian science design. Because both scientific traditions accept that Islamic science and modern science are based on different principles, assumptions and methods, and therefore the results obtained will be different.

Within the framework of this information, the main purpose of this study is to create an argument that enables us to look at Islamic sciences from the Kuhnian design of science. For this purpose, our main goal has been to clearly reveal the fundamental differences between Islamic and modern scientific designs and to show that these two scientific traditions are structurally different from each other. For this purpose, the formation and development of Islamic and modern scientific traditions, the philosophies of nature on which they are based, and the scientific practices (astronomy and physical sciences) that they have performed accordingly have been analysed comparatively.

1. Islamic Science

1.1. The Formation of the Islamic Scientific Tradition and the Natural Philosophy on ıts Basis

The classical narrative states that activities such as science and philosophy in Islamic civilisation began during the Abbasid period (750-850), especially as a result of translations from Greek and Syriac into Arabic. Considering the main aims of the caliphs and those around them who directly supported the translation movement, it can be said that this movement was primarily driven by practical and pragmatic concerns (Saliba, 2007, pp. 89-90; Masood, 2009, pp.32-33). However, Islamic thinkers' understanding and comprehension of Greek science and philosophy over time led to the emergence of a scientific tradition specific to Islamic culture.

It is known that for the emergence of a scientific tradition, a philosophy of science, more specifically a philosophy of nature and metaphysics, is needed. As of the period, Islamic thinkers met these requirements from two different sources. The first and more predominant one is the Greek philosophy and the other is the information from the holy book. In this framework, the conceptions of nature belonging to Pythagorean, Atomist and Platonic philosophies, especially Aristotelian philosophy, are effective in the works of Islamic philosophers and schools. On the other hand, it can be argued that a certain conception of nature that comes with the holy book in Islamic thought is also effective in forming a philosophy of nature. As a matter of fact, the Qur'an mentions seven earths, seven heavens and seven arshs in a gradual and hierarchical manner regarding the order of the universe (Nasr, 2001, p.94).

In this way, Islamic thinkers tried to create a unique philosophy and conception of nature by being influenced and benefited from both Greek philosophy and, to a lesser extent, the knowledge from the holy book. However, one cannot speak of a single philosophy and conception of nature specific to Islamic thought. Because it is seen that different views and schools have emerged in Islamic thought depending on the degree of influence from the sources in question. The most well-known and prominent of these is the Peripatetic school, known as the followers of Aristotle. This was followed by thinkers and movements such as materialism (Dehriyyun) represented by Ibn al-Rawandi (827-911), naturalism (Tabi'iyyûn) led by Abu Bakr al-Razi (854-925) and atomistic teachings led by theologians, and in later periods, schools such as "Ghazalism", "Illuminationism" and "Sufism" (Fahri, 1998, pp. 110-120).

Although almost all of these thinkers and movements, in general terms, had a view against the Peripatetic understanding of nature, it can be said that the theological atomists, al-Ghazali (1058-1111), and the movements that developed after him shaped their attitudes towards the universe and nature almost entirely within the framework of religious aims. For these thinkers and movements, nature was not considered as a field that needed to be directly studied and known, but rather as a work and evidence of God, and as a field that was interpreted in favour of the holy book. In short, it can be said that although these schools had their own conception of nature, it was not of a kind that would encourage natural science and research.

Apart from this, it can be said that the conceptions of nature put forward by movements in Islamic thought such as materialism led by Ibn al-Rawandi and naturalism led by al-Razi encouraged natural science research. As a matter of fact, it is known that al-Razi, in particular, had remarkable works in fields such as alchemy, physics and cosmology, especially in medicine. But unfortunately, such studies could not take a dominant position in Islamic thought, especially due to the pressure of religious circles, nor could they form a scientific tradition. On the contrary, it is seen that the Peripatetic school, known as the representatives of Aristotelian philosophy in Islamic thought, created a natural philosophy and a tradition of natural science. However, it cannot be said that Aristotelian philosophy in Islamic thought had an impact only on the Peripatetics. Apart from this, it is possible to see many thinkers who did not call themselves Peripatetics but were influenced or benefited from Aristotle's philosophy in some way.

1.2. Natural Sciences in the Islamic Scientific Tradition

After the formation of a scientific tradition in Islamic civilisation, scientific studies were carried out in various fields. In today's terminology, Islamic thinkers made very important studies in many fields such as mathematics, astronomy, physics, optics, chemistry, and medicine. In this context, the works and studies of Khwarazmī in algebra, Ibn Sina in medicine, Ibn al-Haytham in optics, Jabir Ibn Hayyan in alchemy, Tusi, Urdi and Ibn al Shatir in astronomy are valuable in terms of originality (Lindberg, 2007, pp.176-190). However, in this study, we will focus more on astronomy (mathematical astronomy) and physics. The most important reason for this is that these disciplines constitute the basis for the formation of modern science, that is, modern science established itself through these disciplines. In this way, we will have the opportunity to compare Islamic science and modern sciences, which is one of the aims of our study.

1.2.1. Astronomy Studies

There are two important sources that influenced and determined the formation and development of the science of astronomy in medieval Islamic culture. One of these is the works and ideas of Aristotle and the other is Ptolemy's. In this direction, it can be said that theoretical astronomical studies began with the translation of Aristotle's works on *Physics* and the *Heavens* and Ptolemy's *Almagest* from Greek into Arabic.

Astronomy, which came from Greek thought, also brought its problems with it. Briefly mentioned, the Earth-centred system of spheres proposed by Aristotle could not fully explain the planetary movements of his time. In particular, issues such as the Moon and the Sun approaching and moving away from the Earth and sometimes moving fast and sometimes slow were problematic. Ptolemy, in his work *Almagest*, added some additions to this Aristotelian system (additions such as eccentric and epicyclical) and tried to explain it mathematically. According to this understanding, the planets moved around a circle (exocircle) and the centre of this circle was located on a larger circle (exocenter) different from the Earth (for detailed information, see Unat, 2013, pp. 47-52).

With this attitude, Ptolemy solved the problems in mathematical terms; on the other hand, this model was in contradiction with Aristotelian physics and the design of the universe, which was the dominant view at the time. According to Aristotelian physics, heavy bodies such as the Earth, which contained the element earth, were located at the centre, while the planets, which contained lighter elements, moved in a circular motion around the Earth. Now Ptolemy had shifted the Earth from the centre with the eccentric device, and with the epicycle (outer circle) he assumed that there was a planet in the sky that was in the centre like the Earth (Saliba, 2007, p.151). In short, in both cases Aristotelian physics was violated.

As the historian of Islamic science George Saliba points out, it did not take long for Muslim thinkers to realise the contradiction between these two works when both Aristotle's Physics and Ptolemy's Almagest became known in the Islamic world. As a matter of fact, the subsequent astronomical studies in the Islamic world were mainly on this axis (Saliba, 2007, p.116). Ibn al-Haytham (965-1039) was one of the first thinkers to realise this contradiction. In his work Al-Shukūk ʻalā Batlamyūs (Doubts Concerning Ptolemy), Ibn al-Haytham criticised the Ptolemaic model, arguing that the eccentric and epicyclic models used by Ptolemy had no counterpart in the physical world (Saliba, 2007, pp. 122-124; Masood, 2009, pp. 101-102).

This attitude of Ibn al-Haytham is important in the history of astronomy. Because the criticism of Ptolemy, which started with Ibn al-Haytham, became the initiator of a voluminous accumulation in Islamic thought that would lead to a great change with Copernicus (Saliba, 2007, p. 130; Iqbal, 2000, p. 541). As a matter of fact, after Ibn al-Haytham's criticism of Ptolemy, a considerable corpus was formed in Islamic astronomy. Accordingly, almost most of the thinkers thought that Aristotle's physics and cosmology were correct while the Ptolemaic Almagest was erroneous, so they developed new mathematical models and sphere systems to correct it and tried to reconcile it with the known Aristotelian physics. In this direction, the works of thinkers such as Nasir al Din al-Tusi (1201-1274), Qutb al-Dīn Shirazi (1236-1311), Mu'ayyad al Din al-Urdi (1200-1266) and Ibn al-Shaṭir (1304-1375), especially in kinematic (mathematical) style, are remarkable (Sezgin, 2009, pp. 14-23).

In his work *Al-Tadhkira*, Tusi proposed a new mathematical model known as the "Tusi pair" instead of Ptolemy's equations. "Using this idea, Tusi was able to simplify the Ptolemaic system, that is, to get rid of the problematic equants for planets such as the Sun, Saturn, Jupiter and Mars, but not for Mercury and the Moon." However, later on, Tusi's student Shirazi solved the problem with Mercury and Ibn al-Shaṭir solved the problems with the Moon (Saliba, 2007, pp. 136-137; Masood, 2009, pp. 104-105). Ibn al-Shaṭir even goes further and criticises Aristotle's universe in a way, investigating why the stars, planets and the sun emit light while the spheres that carry them do not, and concludes that the sky is not homogeneous as Aristotle states. Ibn al-Shaṭir, thus, puts forward a different mathematical model by stating that Ptolemy's eccentrics cannot be accepted, but epicycles, i.e. outer circles, can be accepted (Saliba, 2007, pp. 150-151; Lindberg, 2007, pp. 178-179).

In the Islamic world, such studies in the field of astronomy, in other words, studies within the framework of the Aristotelian and Ptolemaic model of the universe, maintained their vitality until the sixteenth century. In this process, Muslim thinkers, like Aristotle and Ptolemy, accepted that the Earth was at the centre of the universe without moving and that all other planets, including the Sun, orbited around it in circular orbits with constant speeds. In this process, almost no Muslim thinker thought of placing the Sun at the centre of the universe instead of the Earth (arz). At this point, the following question comes to the fore: Were Islamic thinkers really capable of a Greek-style natural philosophy, that is, a criticism of the basic principles and assumptions of nature? George Saliba, a historian of Islamic science, states the following:

Islamic civilisation did not formulate a critique of astronomy that questioned the natural philosophical foundations of Greek astronomy. Some religion-based cosmologies have addressed this issue, but no astronomer that I know of has adopted these views or made astronomical interpretations of these cosmologies (Saliba, 2007, p. 158).

With these statements, Saliba points out that Islamic thinkers failed to develop a Greek-style natural philosophy. Similarly, D. Lindberg, one of the contemporary historians of science, supports this argument, stating that the originality and originality in Islamic thought was manifested in the form of correction, development, and adaptation of the Greek heritage to new fields rather than a Greek-style creativity (Lindberg, 2007, p. 176).

As a matter of fact, as mentioned, Muslim astronomers, first and foremost, carried out their work by accepting the Earth-centred universe paradigm as true and certain. Therefore, they could not bring any objection or criticism to this paradigm. Although Islamic thinkers could put Ptolemy aside, they could not give up Aristotle when they reached an impasse. The Earth-centred universe model proposed by Aristotle was presented within the framework of a system. In today's terminology, this system was interwoven with various disciplines such as physics, chemistry, biology, and metaphysics. Therefore, at the time, denying Aristotle meant, in a sense, denying the holistic system in question. In order to take this daring step, it was first of all necessary to have a Greek-style natural philosophy, that is, to question nature and the universe holistically in terms of their principles, foundations and assumptions. However, this did not happen, and Islamic thinkers were trapped in the Aristotelian paradigm.

Adherence to this paradigm did not bring to the minds of Muslim astronomers the ideas that would later be attributed to modern astronomers such as Copernicus and Kepler, such as that the Sun could be at the centre, the Earth could be mobile, and the planets could follow elliptical orbits. In this context, it can be said that Muslim thinkers could not overcome the Aristotelian paradigm, especially in fields such as astronomy and cosmology, and could not open the "main road" leading to modern science. However, the positivist argument that scientific endeavours should lead to a single goal is a matter of debate here. Because the practice of Islamic thinkers in doing science is not a defect, but only a matter of preference. Therefore, as stated by thinkers such as Kuhn and Lindberg, it is also an important option to evaluate the studies carried out in Islamic culture in their own context.

1.2.2. Physics Studies

In medieval Islamic culture there was no physics as an independent science in its present sense. Physics, as understood by Islamic thought, came from the Greek philosopher whose terminology, subject and problems were determined by Aristotle. It can be said that studies in the field of physics began with the translation of Aristotle's *Physics* (Physike) into Arabic (Nasr, 2007, p. 135). Aristotle's *Physics* (Physike) was predominantly referred to as "el sema el'tabii" in Islamic literature (especially by the Peripatetics) and classified within natural philosophy and sciences (Kaya, 1983, p. 133).

Later, with the recognition and assimilation of this work, it can be said that the knowledge and ideas of Islamic thinkers about physics were shaped and, in this context, roughly two opposing attitudes emerged. One of them, as mentioned earlier, was the Peripatetic school, known as the followers of Aristotle in Islamic thought, and the other was the thinkers and schools such as Abu Bakr al-Razi and the theological atomists (al-Allaf and Bākillani) who criticised this school and Aristotelian views (Nasr, 2007, p. 136).

As mentioned, although the theological atomists criticised Aristotelian ideas, they did so in the name of religion, not science. On the other hand, as an exception, sources state that Razi wrote a work in which he criticized Aristotle's understanding of motion, but which has not survived to the present day. It is said that in this work, Razi denied the Aristotelian principle that there is no motion without force and argued that motion does not come to the body from the outside, on the contrary, motion exists as a principle in the body itself (Kaya, 2004, p. 480). However, since Razi's work in question does not exist today, we cannot provide detailed information on this subject. Instead, we will refer to the ideas of the Peripatetic school, which represents the dominant views in Islamic thought.

1.2.2.1. Peripatetics and Physics

It can be argued that the thinkers who conducted detailed and systematic studies on physics in medieval Islamic thought were the Peripatetics. With the recognition and assimilation of Aristotle's "Physike" by the Peripatetics, it is seen that the Peripatetic philosophers' knowledge and views on physics were shaped within the framework of the topics determined by Aristotle. Aristotle had defined concepts such as "force", "motion", "speed" and "void" on the basis of the principle that "there is no motion without force". However, Aristotle could not satisfactorily explain some issues within this framework. For example, issues such as the motion of thrown objects and whether or not velocity can be infinite depending on the void remained as fundamental problems (see also Aristotle, 2008).

The Peripatetic philosophers' encounter and confrontation with these problems regarding Aristotle's physics led to the emergence of some works in this direction. It is known that philosophers such as Farabi, Ibn Sina (Avicenna), Ibn Bajja (Avempace) and Ibn Rushd (Averroes) carried out remarkable works in this framework. Although almost all of these philosophers basically accepted Aristotle's principles of physics, they tried to elucidate the problems that they believed he had left insufficient and incomplete in some detailed issues (Nasr, 2007, p. 136).

One of the first philosophers we encounter in this direction is Farabi. Farabi, who is known as the second teacher after Aristotle in the Islamic world, also adhered to Aristotle's basic physical principles. In his article "On Emptiness", Farabi, like Aristotle, argued that there is no emptiness. Aristotle rejected emptiness by stating that if there were emptiness, the speed would be infinite, that is, the object would be in more than one place at a time. Farabi, following in Aristotle's footsteps, tries to defend this idea in his article as follows: "If a bowl is immersed in a container filled with water with its mouth downwards, it is seen that no water goes into the bowl; because air is a body and prevents water from entering because it fills the entire container. On the other hand, if a bottle is immersed in water after some air has been sucked from its mouth, it is seen that the water rises in the bottle. So there is no void in nature." (Farabi, 1985, pp. 5-6).

After Farabi, Ibn Sina was one of the philosophers who tried to clarify Aristotle's physical doctrine, especially his understanding of motion. Although Ibn Sina also accepted the Aristotelian doctrine of motion, he tried to clarify some of the problems that arose in this regard. Aristotle, who argued that there could be no motion without force, attributed the movement of thrown objects after the force was removed to the force transferred to the air. In other words, the air moved the thrown objects by carrying the force. On the other hand, the same air provided a resistance to stop the objects. Ibn Sina was one of the first thinkers to realise this contradictory situation in the medieval Islamic world. According to Ibn Sina, the reason why thrown objects move after the force is removed is the will to move that is imparted to the object. Ibn Sina called this desire, which is given to the object as a result of the force, "kasri inclination" (Topdemir, 2010, p. 90). According to him, kasri inclination is more in heavy objects than in light objects. Therefore, when a cork and a piece of stone are thrown together, this is the reason why the stone falls farther (Grant, 1986. p.57). In addition, Ibn Sina also says that the kasri inclination obtained will continue as long as it does not encounter any resistance, that is, this acquired movement will not be exhausted. With these statements, Ibn Sina shows how close he is to the "principle of inertia", which is considered one of the basic principles of modern physics (Topdemir, 2010, p. 90).

In the Islamic world of the Middle Ages, after Ibn Sina, the physical problems of the Aristotelian paradigm were also analysed by thinkers such as Ibn Bajja (Avempace) and Averroes. Ibn Bajja argued that the velocity in the void is finite by opposing the assertion of Aristotle and his follower Farabi that motion in the void is not possible, in other words, that the velocity in the void is infinite (Grant, 1986. p.50). Aristotle rejected the void on the grounds that the speed would be infinite in the absence of resistance, that is, the object would be in multiple places at the same time. However, according to Ibn Bajja, even if there is a void, the force applied to the object requires a certain amount of time to pass in order for it to create a movement, so the velocity is continuous (Topdemir, 2012, p. 92). Thus, it can be said that Ibn Bajja proposed the formula of velocity = force-resistance (V=F-R) instead of Aristotle's formula of velocity = force/resistance (V=F/R), which had previously been proposed by the Neo-Platonist philosopher Philoponus.

In the process, Ibn Bajja's views were criticised by Averroes, a fanatical Aristotelian. Ibn Rushd, following in the footsteps of his master, argued that there is no vacuum and that objects move in a resistive environment, and stated that motion in a vacuum is indefinite, that is, velocity should be infinite in a vacuum (Grant, 1986. p.49). Although both Ibn Bajja and Averroes defended different ideas about whether motion in a vacuum would take time or not, they accepted the basic principle of Aristotelian physics, namely that "motion without force cannot exist". Considering that Ibn Sina and al-Farabi also accepted this basic principle, it can be seen that the physics studies of the Peripatetics were almost entirely along Aristotelian lines.

However, it is also seen that the studies in question follow within the framework of the Aristotelian scientific method. Like Aristotle, the Peripatetic philosophers accepted and used the inductive-deductive method, which is based on deduction (syllogism), as the only valid method (for detailed information, see Nasr, 2001).

2. Modern Science

2.1. The Formation of the Modern Science Tradition and the Philosophy of Nature on its Basis

Modern science can be broadly defined as the paradigm of acquiring knowledge based on a new conception and methodology of nature that took shape in Western Europe in the 17th century. Modern science, of course, did not emerge out of nowhere; it emerged as an alternative to the old understanding of science, namely the Aristotelian understanding of science. In fact, at this point, many thinkers consider the transition from Aristotelian science to modern science as a "scientific revolution" (for detailed information, see Salğar, 2023). The scientific revolution is roughly a conceptualisation of a discontinuous and interrupted transition from Aristotelian science to modern science. This shows that modern science is completely different from Aristotelian science and its derivative Islamic sciences in terms of both its conception of nature and its methodology. Therefore, in this framework, it is possible to define modern science as an innovation that emerged based on the criticism and negation of the Aristotelian understanding of science. In this context, it would be appropriate to start the formation process of modern science with the criticism of Aristotelian science.

Looking at historical sources, it is possible to trace the criticism of Aristotelian science back to Islamic thinkers and even Neo-Platonic philosophers. As a matter of fact, it is possible to speak of a criticism of Aristotle in these periods as well. However, as we have already seen, the criticism of Aristotle in Islamic thought was more constructive, that is, restorative of Aristotelian science. On the other hand, the criticisms put forward against Aristotelian science during the Renaissance were more destructive, that is, they radically changed Aristotelian science. Therefore, as many historians emphasise, it would not be wrong to see the Renaissance as a turning point in the formation of modern science (Henry, 2008, pp. 9-10).

In general terms, it can be said that the Renaissance contributed to the formation of modern science in two different ways. One of these is the emergence of works and sources that enabled the establishment of modern science, and the other is the thinkers who falsified and denied Aristotelian science by making use of these sources. At this point, the fact that humanist thinkers brought the works of Pythagorean, Platonic and atomist philosophies from original sources into Latin culture reveals the idea that there are different alternatives to Aristotelian science for Renaissance intellectuals (Çörekçioğlu, 1997, pp. 44-45). As a matter of fact, the arguments put forward by scientists such as N. Cusanus, Copernicus, Brahe, Kepler and Gassendi, who were nourished and inspired by these philosophies in the process, both negate the Aristotelian understanding of science and justify modern science.

Here, it is seen that the thinkers in question made great use of Ancient Greek metaphysics and natural philosophy in order to justify and construct modern science. In this process, two important Greek sources were utilised in terms of natural philosophy. One of these is Platonic philosophy (especially Neo-Platonic philosophy) and the other is atomist philosophy. During the Renaissance, it is seen that Neo-Platonist philosophy was primarily effective against the Aristotelian understanding of science (Soldato, 2023). In this framework, thinkers such as Cusanus, Copernicus, Kepler, Galileo and Bruno tried to create a new understanding of science inspired by Platonic and to some extent Pythagorean philosophies. These thinkers, fundamentally different from Aristotle, argued that nature is the reflection of God, that it is essentially mathematical and quantitative in character, and that there is a mathematical harmony and harmony in nature, and that nature can only be understood through mathematics (Westfall, 1978). From this point of view, Cusanus argued that nature should be spatially unlimited, and Copernicus argued that the sun should be at the centre of the universe in accordance with mathematics. Subsequently, thinkers such as Kepler and Galileo tried to justify this design of nature, which sprouted with Cusanus and Copernicus, both mathematically and physically with the arguments they put forward.

The conception of science put forward by these thinkers based on Platonic philosophy, while important, was not sufficient both to completely eliminate the Aristotelian conception of science and to create a new scientific design. For example, when Copernicus proposed a heliocentric universe model against the Aristotelian universe design, there were some problems that he could not explain. Accordingly, problems such as the planets approaching and receding from each other, sometimes accelerating and sometimes decelerating, how the Earth moves and why the planets are together were the main ones. Kepler could not go beyond answering the first two of these problems with the laws he proposed. When we look at Galileo, we see that although he criticised and rejected the Aristotelian understanding of physics and method, he could not replace it with a holistic design of nature (Salğar, 2018).

Considering all these, it can be argued that thinkers such as Copernicus, Kepler, and Galileo contributed to modern science to a certain extent, but they were not at a level to replace the Aristotelian understanding of science in a holistic sense. At this point, it can be said that the ideas coming from atomist philosophy are complementary to modern thinkers. Although atomicist philosophy has been tried to be developed in the name of modern science by thinkers such as Gassendi, Boyle and Charleton since the Renaissance, it reaches its most mature form in the works of Isaac Newton. In a sense, by combining the mathematical conception of nature with the atomistic mechanistic design of nature, Newton completes the design of nature of the new understanding of science that started with Copernicus and continued with Kepler, Bacon, Galileo and Descartes (Westfall, 1987).

According to Newton, everything that exists in nature arises from the combination and separation of atoms moving in space in different ways. All these movements of atoms and matter proceed according to mechanical, causal, deterministic and quantitative principles, which shows that nature works on its own like a clock (Westfall, 1987, p. 159). This design of nature, shaped with Newton, now becomes the subject matter of the new science. Aristotle's nature, which was the subject of science, was a limited, purposive, heterogeneous, hierarchical and qualitative place. Newton's nature, on the other hand, becomes a place where unlimited, mechanical, homogeneous and quantitative characteristics come to the fore. In this way, Newton ends the Aristotelian understanding of nature, which had been dominant for nearly two thousand years.

2.2. Pioneering Disciplines of Modern Science: Astronomy and Physics

2.2.1. Astronomy Studies

When we use the term astronomy in a broad sense to include cosmology, it can be said that modern science built itself primarily through the discipline of astronomy. It can be said that the first important studies in this direction began in the Renaissance, that is, after the second half of the 15th century (Soldato, 2023). In this process, destructive arguments were put forward against the Aristotelian understanding of astronomy and cosmology.

Aristotle and his followers had argued that the universe was infinite in time, limited in space, geocentric, hierarchical, and heterogeneous (sub-lunar and supra-lunar universe). Aristotle's design of the universe continued its existence until the Renaissance by being fed with constructive criticisms in medieval Islamic and Christian cultures. However, this situation changed during the Renaissance and the views of some philosophical movements from Greek culture were put forward against Aristotelian science. As mentioned, two dominant philosophical currents were at the forefront against Aristotle during the Renaissance, one of which was Neo-Platonism and the other was atomist philosophy. It is seen that Renaissance thinkers firstly utilised Neo-Platonism in the fields of astronomy and cosmology.

In this process, the German thinker Nicolaus Cusanus (1401-1464) was one of the thinkers who both criticised the Aristotelian understanding of the universe and paved the way towards the modern universe design by feeding on Platonic philosophy. Like his contemporaries, Cusanus was disturbed by the relationship between God, nature and human beings as stated in Aristotle's natural philosophy. Therefore, in his most important work, De Docta Ignorantia (On Learned Ignorance), Cusanus saw it as his main aim to put forward the idea of unity between God, nature and man (Miller, 2024).

In this work, Cusanus, based on Neo-Platonic philosophy, identifies God and nature in a sense, and argues that nature is limitless and infinite (Miller, 2024). This argument put forward by Cusanus was groundbreaking for Renaissance natural philosophy. In this way, Cusanus criticised and rejected the Aristotelian limited universe design that had been dominant since the Middle Ages. In fact, the famous historian of science A. Koyre declared Cusanus as the first thinker to reject the medieval cosmology (Koyre, 1957, pp.13-14).

On the other hand, Cusanus, while asserting that nature is limitless and infinite, also points out that there cannot be a centre in the universe (Miller, 2024). This is again an argument that destroys the Aristotelian universe design. Because according to Aristotle, the universe was a limited, Earth-centred, heterogeneous and hierarchical place. However, Cusanus argues that there is no boundary in the universe and reveals the impossibility of a centre.

Although these views of Cusanus criticised and denied the Aristotelian understanding of the universe of his time, they were not strong enough to completely overthrow the authority of Aristotle. Nevertheless, Cusanus took an important step on the road to modern science, seriously criticising the old cosmology and pointing out the idea of a new cosmology to the scientists who came after him.

The thinker who took the first radical step in establishing this new cosmology was undoubtedly Nicolaus Copernicus (Copernicus) (1473-1543). In his work De Revolutionibus (The Motion of the Celestial Spheres, 1543), Copernicus puts the Sun at the centre and defines the other planets as bodies that make circular movements around the Sun at constant speeds (Copernicus, 2020). These views of Copernicus are generally described as a "revolution" in Western literature. According to this understanding, Copernicus puts forward a brand-new theory that is incompatible with and not a continuation of the understanding of cosmology and astronomy put forward by Aristotle and Ptolemy and adopted in medieval Islamic thought.

The accuracy of this view in the case of Copernicus is a matter of debate. This is because Copernicus's new design included some of the ideas found in the old one. For example, in the new cosmology, the ideas that the universe is spherical, that the Earth is spherical, and that celestial bodies are nailed to spheres and move in a smooth circular motion were re-adopted (Copernicus, 2020, pp. 19-vd.). The only difference in the new system was that the Sun was placed at the centre instead of the Earth, and at the same time the Earth was claimed to be moving. However, although it may seem simple for us here, it can be said that Copernicus's centring the Sun and attributing mobility to the Earth had devastating consequences for the traditional understanding of science. Aristotelian science had constructed the whole system of existence and its epistemology by putting the Earth at the centre. In this context, when the "Earth" is removed from the centre, the whole system of existence, knowledge and value is overthrown. Therefore, it would not be wrong to look for the revolutionary aspect of the Copernican system here. By putting the sun at the centre, Copernicus overthrows Aristotle's Earth-centred, heterogeneous, hierarchical universe design (Kuhn, 1995; Koyre, 1957).

However, these views of Copernicus did not have the competence and evidence to completely eliminate the Aristotelian understanding of science and to justify modern astronomy. First of all, Copernicus brought along some problems by putting the Sun at the centre and attributing a motion to the Earth. Accordingly, issues such as the planets moving closer and further away from each other, sometimes accelerating and sometimes decelerating, and how the Earth moves could not be explained. Therefore, this project, which started with Copernicus, later became more mature with the works of thinkers such as Brahe, Kepler and Galileo.

At this point, although he did not directly defend the Copernican system, Tycho Brahe (1546-1601) was one of the thinkers who made important contributions to the support of this system. Copernicus had denied the Aristotelian heterogeneous and homogeneous universe design by putting the Sun at the centre with a mathematical modelling. Brahe, on the other hand, justified this with observations, both supporting the Copernican system and falsifying the Aristotelian universe design. Brahe's observations of some stars and comets in 1572 and 1577 were of a nature to deny the Aristotelian universe design (Unat, 2013, pp. 150-151). These observations reveal arguments such as that there is no distinction between the sub-lunar and supra-lunar universe, that the supra-lunar universe is not immutable and perfect, and that the stars and planets are not fixed on transparent solid spheres as Aristotle stated.

Johannes Kepler (1571-1630), who came after Brahe, believed in the correctness of the Copernican system instead of his master Brahe's system from the very beginning and developed his studies in this direction. Copernicus had not been able to fully explain the distances, approaches, accelerations and decelerations of the planets. At this point, Kepler explained these problems under the name of Kepler's laws by utilising the observations of his teacher Brahe and based on his own observations (Unat, 2013, pp. 155-157). Kepler's first law reveals that the orbits of the planets are ellipses, not circular as it is believed. In this way, he also reveals the rationale for the planets' states such as distance, convergence and acceleration. With these and other laws, Kepler strengthened the Copernican system, weakened the Aristotelian system, and brought modern astronomy into a mature form.

After Kepler, Galilei Galileo was one of the important thinkers who carried out studies to justify the Copernican system and to reject the Aristotelian system. As a result of the observations made by Galileo in 1609, contrary to the Aristotelian understanding, data such as there are spots on the Sun, there are mountains and plains on the Moon, and Jupiter has 4 satellites are revealed (Unat, 2013, 165-166). Galileo collected and published these observations in his work *Sidereus Nuncius* (The Starry Messenger, 1610).

2.2.2. Physics Studies

Another important discipline in which modern science manifested itself was physics. In this field, as in astronomy, Aristotle and his followers were the only rivals that modern thinkers had to face.

Aristotle's physics is closely related to his metaphysics and natural philosophy. In this framework, Aristotle based his understanding of motion on the Earth, making the distinction between sub-lunar and supra-lunar. Accordingly, in the sublunar universe, which is dominated by formation and decay, objects not only consist of four elements (earth, water, air, fire), but also move according to the proportions in which they contain these elements. Here Aristotle explained natural motion by associating it with the "heavy" or "light" qualities of objects. Accordingly, the matter containing more of the element "earth" is heavier, while the matter containing the element "fire" is relatively lighter. Aristotle argued that in the sub-lunar universe, there is a necessary motion in addition to natural motion, and that this motion is directly related to elements such as force and resistance. On the other hand, Aristotle argued that the objects in the supra-lunar universe, where there is no formation and decay, are composed of the element "ether" and therefore move in a smooth circular motion (Aristotle, 2001, 260b-25).

Aristotle's understanding of physics based on metaphysics and natural philosophy was shaken by the criticisms of astronomy and cosmology during the Renaissance. As mentioned, the arguments of Cusanus, Copernicus, Brahe and Kepler denied Aristotle's limited, Earth-centred, heterogeneous and hierarchical universe design. This also eliminated Aristotle's understanding of physics. At this point, it was essential for modern thinkers to develop a new understanding of nature and physics.

Galilei Galileo (1564-1642) is the first important thinker we encounter in this framework. Of course, it can be said that many thinkers (Descartes, Gassendi, etc.) contributed to the formation of modern physics. However, it is generally accepted that modern physics started with Galileo and reached its final form with Newton. Therefore, for the purpose of our study, we deemed it sufficient to explain the adventure of the formation of modern physics through these thinkers.

Galileo's first systematic criticism of the Aristotelian understanding of motion can be seen in his De Motu (On Motion, 1589). In this work, Galileo criticises Aristotle's understanding of "natural motion", which is explained in terms of qualities such as "weight" and "lightness" depending on the four elements (earth, water, air, fire), and instead tries to explain the motion of a body in terms of the relationship between the density of the medium in which it moves and its own density. Accordingly, for Galileo, the element "fire" did not rise because it was light, but because it was lighter than air (Drake, 1978, p. 11). These views of Galileo can be considered as an indicator of the transition from the Aristotelian conception of nature to the modern one. Thus, Galileo explains natural motion not according to a purposive, heterogeneous and essential design of nature like Aristotle, but according to a mechanical, homogeneous interaction between objects.

Galileo also finds Aristotle's definition of necessary motion flawed in his Dialogues on the Two Great World Systems. Aristotle had argued that concepts such as force and resistance must be essential for necessary motion. However, Galileo, accepting that resistance is not everywhere and that there is a vacuum in a sense, says that force is not necessary for an ideal motion (Galileo, 2001). This principle, also known as the law of inertia, also explains the motion of the earth.

Galileo had taken an important step in motion and put forward a new understanding of motion against the Aristotelian theory. However, this understanding could not explain some phenomena (for example, it could not explain why the Earth moves around the Sun) and was not presented within the framework of a system. Newton overcame this deficiency and brought modern mechanics to its mature form. In his Principia (1687), Newton put forward three laws of motion and a principle of gravitation on the basis of the axioms of absolute time, absolute space and absolute motion, thereby both drawing the framework of modern motion and nature design and showing that he completely broke away from the Aristotelian understanding of physics (Newton, 1974). The clearest indication of this break is the meaning of the principles and laws underlying the system. For example, while continuous motion without force is impossible according to Aristotle, it is possible according to Newton's first law. Similarly, while force in Newton is directly related to mass and acceleration, Aristotle does not have such terms and concepts such as gravitational force. These examples clearly show that the understanding of science that emerged with Newton is not a continuation of the Aristotelian one, as stated by the distinguished historian of science T. Kuhn (Kuhn, 2000, pp. 13-33).

In addition to all these changes, the modern scientific method also changed with Newton. In the Islamic scientific tradition, the Aristotelian-based deductive inductive-deductive method was adopted. The modern method, which started with Galileo and reached its final form with Newton, became a method based on inductive mathematics and controlled experiments.

Conclusion

It is obvious that Islamic science, that is, Aristotelian science, which is dominant in the Islamic scientific tradition, differs from modern science in terms of its conception of nature, methodology and practices of doing science. This shows that both scientific traditions try to understand and explain nature with their own principles, rules and methods. Accordingly, the truth and falsity of each scientific tradition is not according to another theory, but according to its own internal criteria. Therefore, comparing these two scientific traditions ontologically, epistemologically and methodologically and trying to show that one is superior to the other in terms of theoretical explanation is a futile effort. Because in the end, both scientific traditions constitute themselves from different principles and assumptions. In addition to this, it can be said that efforts such as trying to liken Islamic sciences to modern science and trying to attribute the results of modern science to Islamic science are also meaningless.

At this point, one may rightly ask the following question: If both scientific traditions have equal value in terms of theoretical explanation, then why is modern science considered more dominant and valuable today?

The most obvious answer lies in the practical aspect of modern science, namely the technology it has produced. The Aristotelian-based Islamic sciences were not suitable for producing technology because they were based on a purposive and heterogeneous design of nature. On the other hand, modern science, based on a homogeneous and atomistic mechanistic design of nature, was capable of producing technology. As a matter of fact, modern science, which gradually manifested itself with technology after the 17th century, gradually gained the favour of intellectuals, societies, and states. For modern man, technology facilitates life with the tools it produces, creates a comfort zone, enables dominance over the environment, increases the level of development among societies and changes the balance of power among states. All this has led intellectuals, societies, and states to attach importance and value to modern science in the context of technology and even to believe that it provides the knowledge of truth.

To summarise, modern science has been and is seen as superior and valuable to Aristotelian and Islamic sciences not because it explains something theoretically correct or good, but because it provides technology.

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