NAZARİYAT

A Non-Aristotelian Interpretation of Orbs in the Post-Classical Islamic Age: Shams al-Dīn al-Samarqandī in Science of the Cosmos and the Soul

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Abstract: The history of Islamic astronomy falls under the influence of Aristotelian cosmology, in which orbs have a principal role in holding and moving the planets. Based on the prevalent accepted Aristotelian idea, these orbs are spherical shells that rotate around their center and are made of a particular substance called aether. No lightness or heaviness, rarefaction or condensation, and generation or corruption exist in the aether-filled heavens. Subsequently, any tearing or mending of these orbs is impossible. This assumption leads to a basic rule: the planets do not move *in* an orb but *by* an orb. During the medieval Islamic age, new models emerged for solving some of the anomalies in Ptolemaic astronomy; however, the assumption above was rarely disputed. This paper will introduce an unordinary case based on the book *Science of the Cosmos and the Soul* by Shams al-Dīn al-Samarqandī in which, besides the standard Ptolemaic system, some alternative models were briefly presented: in these new models, the tearing or mending of these orbs is possible. Considering that this assumption conflicts with Aristotelian physics, these models can be regarded as non-Aristotelian.

Keywords: Shams al-Dīn al-Samarqandī, *Science of the Cosmos and the Soul*, post-Classical Islamic astronomy, non-Aristotelian physics, planetary models, Ptolemaic astronomy

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Introduction

Aristotle formed the cosmological framework of Greek astronomy in his book *De Caelo* [On the Heavens]. In this book, he introduces the substance of *aether*, also known as the fifth element,[1] whose characteristics are distinguished from the four sublunary elements as follows:

(1) Aether is neither heavy nor light,
(2) It is not susceptible to generation or corruption, and
(3) It moves only circularly and uniformly.[2]

Characteristic (3) provoked astronomers to consider aether as the conveyor of planets. In his work on the cosmology of the heavens, *Planetary Hypotheses* (*Kitāb al-iqtiṣāṣ ʾaḥwāl al-kawākib*), Ptolemy addresses the same subject as follows:

> The natural analogy (*qīyās al-tabīʿī*) leads us to say that the aethereal bodies could not be affected or changed … their shapes are circular, and their actions are similar to the actions of things with similar parts (*mutashābahat al-ʾajzāʾ*).3

Ptolemy noticed the visible motions of planets to be non-uniform, so their motion models would need to be achieved by a combination of several uniform circular motions. The Aristotelean-Ptolemaic image of the heavens was thus configurated as follows: The heavens are made of aether, which moves circularly and uniformly, covering equal arcs of its circular trajectory in equal times.[4] The motions of planets are motivated by several movers known as orbs. Each orb has a particular natural movement, and the combination of these motions devises the path of a planet in the sky.

This image and framework were transferred to astronomy in the classical Islamic age.[5] The modification and reform of this Aristotelean-Ptolemaic tradition

1 Aristotle, *De Caelo*, Book I, III/ 270b 23–24.
2 Aristotle, *De Caelo*, Book I, III/269b 18–270a12.
3 Goldstein, "The Arabic Version," 36.
والقياس الطبيعى يؤدينا إلى أن نقول إنّ الأجسام الأثيرية لا تقبل الانفعال ولا تتغير... إنّ أشكالها مستديرة وإنّ أفعالها أفعال أشياء متشابهة الأجزاء
4 A detailed look at the relationship between Aristotle's and Ptolemy's works is a matter for another extensive research project. In this article, our argument's assumption is the accepted idea in the history of astronomy that Ptolemy constituted his models based on the three above-mentioned originally Aristotelian principles.
5 The classical Islamic age begins with the translation movement from Greek into Arabic (ca. 900 until 1100 AD); on the other hand, the post-classical Islamic age is usually thought of as beginning around 1100 with Ibn Sīnā and to continue until 1900 AD.

through the proposition of new models was a scientific activity of astronomers in this era. The results of these activities are known as non-Ptolemaic models due to these new models not being faithful to Ptolemy's image;[6] however, they did respect the Aristotelian framework. In this paper, we introduce a case that is Ptolemaic but non-Aristotelian. This model is a notable instance of challenging Aristotle's natural philosophy, which did not frequently occur in medieval astronomy.[7]

In this article, Section 1 introduces the content and genre of Al-Samarqandī's *Science of the Cosmos and the Soul*; Section 2 analyzes his philosophical and theological arguments for the possibility of the tearing and mending of the orbs; and Section 3 reports on his planetary models, wherein he applied the possibility of the tearing and mending of the orbs.

1- Al-Samarqandī's *Science of the Cosmos and the Soul*

Shams al-Dīn Muḥammad ibn Ashraf al-Ḥusaynī al-Samarqandī (d. ca. 1322) was a scholar from Samarkand, a city in today's Uzbekistan.[8] His main surviving works are on mathematics, astronomy, theology, and logic, as well as his works on astronomy as listed below:[9]

(1) *A* sharḥ [commentary] *on Nasīr al-Dīn al-Ṭūsī's* Taḥrīr [recension] of Ptolemy's *Almagest*

(2) *al-Tadhkira fī ʿilm al-hayʾa*

6 For a brief history of the research on non-Ptolemaic astronomy in the Islamic era, see Saliba, "The First Non-Ptolemaic Astronomy," 571–576; Saliba, "Arabic planetary theories after the eleventh century AD," 75–126.

7 We should mention that the planetary models of Aristotle in the Book λ of *Metaphysics* were mostly ignored in the Classical and post-Classical Islamic age except in the philosophical tradition of Andalusia during the 12th century. Aristotle's natural philosophy was not the only authority, while the theologians had another theory called Kalām. However, the bond between Aristotelian natural philosophy and Ptolemaic astronomy was strong (for the deferent methodology of scholars in the post-Classical Islamic age, see Fazlıoğlu, "Between Reality and Mentality Fifteenth-century Mathematics and Natural Philosophy Reconsidered," 1–39).

8 For his biography and bibliography, see Fazlıoğlu, "Samarqandī"; Qurbānī, 285–288; Samarqandī, English introduction, 1–10; Rosenfeld and Ihsanoğlu, 230–231.

9 Al-Samarqandī's other astronomical works apart from *ʿIlm al ʾāfāq*... are surveyed and discussed in the authors' forthcoming article entitled: "Astronomical Works of Shams al-Dīn al-Samarqandī: A Preliminary Study with an Edition of Two Persian Texts, the Astronomical Section of *The Subtleties of Wisdom* (*Laṭāʾif al-ḥikma*) and *A Chapter on Knowing the Degrees of Temporal Hours* (*Faṣl dar maʿrifat-i ʾajzāʾ-i sāʿāt-i zamānī*) in *Journal for the History of Science* (*Tārikh-e Elm*), Institute for the History of Science, University of Tehran.

(3) ʿAmāl *al-taqwīm li al-kawākīb al-thābita* [A star calendar for the years 1276–1277]

(4) *Laṭāʾif al-ḥikma*

(5) *Second Mazhar of the Science of the Cosmos and the Soul*

The book *ʿIlm al-ʾāfāq wa al-ʾanfus* [*Science of the Cosmos and the Soul*] was probably written after 1289 AD.[10] It is neither a standard astronomical nor theological book but rather a philosophical encyclopedia portraying a mystical journey. The book is composed of four parts called *maẓhar*s [manifestations], with the first *maẓhar* being dedicated to theological subjects, the second *maẓhar* being related to the supernal world (i.e., *hayʾa*), the third *maẓhar* concerning the sublunar world (i.e., the world of generation and corruption), and the fourth *maẓhar* dealing with the human being (*al-ʾInsān*). The first three *maẓhar*s are related to what is called *ʿIlm al-ʾāfāq* [*Science of the Cosmos*], while the last part concerns *ʿIlm al-anfus* [*Science of the Soul*], and this structure reflects the world as a macrocosm and human being as a microcosm.[11]

The book's first *maẓhar* is divided into three *maqṣad*s [destination]: God and his attributes, spiritual beings, and the properties of bodies. Every *maqṣad* contains some controversial subjects in philosophy and theology. The third *maqṣad* includes eight problems, most of which provoke a metaphysical debate about a physical issue (e.g., the indivisibility of particles and *horror vacui*).

The second *maẓhar* involves the configuration of the world (*Hayʾat al-ʿālam*) and has 16 *faṣl*s [chapters]. It could be considered a reaction to the works on *hayʾa* in the Marāgha School. Al-Samarqandī arranged his contents similar to a *hayʾa* work.

The third *maẓhar* is about the four substances and is divided into three *maqṣad*s, while the fourth *maẓhar* is on the human being and contains four *qism*s [devisions].

10 Samarqandī, English Introduction, 8.

11 Samarqandī, English Introduction, 7–10.

2- Al-Samarqandī's Arguments for the Possibility of the Tearing and Mending of the Orbs

2-1- Philosophical Argument

Al-Samarqandī laid the philosophical groundwork for his planetary models in the third *maqṣad* of the first *maẓhar*. In the sixth debate (*baḥth*) of this *maqṣad*, he elaborates on his idea about the nature of the orbs. In the seventh debate, he proves the possibility of the tearing and mending of the orbs based on his results from the previous debate. His arguments in this section are formulated according to an implicit logical structure. He presents both direct and indirect proofs, and the arguments are interconnected.

The first through fifth, and sixth through eighth arguments are respectively related to the sixth and seventh debates. All arguments are put forward by al-Samarqandī except the sixth argument, which is an opposing argument that al-Samarqandī attributes to his predecessors (*Qudamā*).[12] These arguments are reproduced as syllogisms in which Pa is the first premise, Pb is the second premise, and C is the conclusion. The numbers after Pa, Pb, and C indicate the number of arguments (the logical structure of his arguments is presented in Chart 1, and the conceptual relation between the results in Chart 2).

The first argument is:[13]

Pa1: a body possessing the principle (*mabdaʾ*) of circular motion is unable to have straight motion.

12 It seems that the umbrella term, *qudamā*, in this context, refers to the Peripatetic school in ancient Greek Philosophy.

13 Samarqandī, *Science of the Cosmos*, 125–126.

الفلک يمتنع عليه الحركة المستقيمة إذ فيه مبدأ حركة مستديرة، و إذا كان كذلک يمتنع عليه الحركة المستقيمة؛ أمّا أنّ فيه مبدأ حركة مستديرة فلأنّ بقاء كل جزء من الفلک فى حيّزه غير واجب لبساطة الفلک فجاز حصول كل جزء منه فى حيّز الجزء الآخر فجازت الحركة على الفلک بحسب ذاته ففيه مبدأ حركة مستديرة لامتناع الحركة بحسب الذات بدون مبدأها. وإذا كان فيه مبدأ حركة مستديرة يمتنع أن يكون فيه مبدأ حركة مستقيمة وإلّا لكانت الطبيعة الواحدة فى حالة واحدة مقتضية للميل إلى جهة والميل عنها وذلک محال.وإذا لم يكن فيه مبدأ حركة مستقيمة يمتنع أن يتحرک بحسب ذاته الحركة المستقيمة وإلّا لكان فيه مبدأ حركة مستقيمة كما مرّ. الخرق جائز على الأفلاک وكذا الالتيام خلافاً للقدماء؛ أما الالتيام فظاهر وأمّا الخرق فلأنّه هو انفصال أجزاء الجسم وأجزاء الفلک عند الكوكب منفصلة لكون الكواكب مركوزة فى الأفلاک فجاز الخرق عليها. احتج القدماء بأنّا بينا امتناع الحركة المستقيمة على الفلک فلو جاز عليه الخرق والالتيام لجازت عليه الحركة المستقيمة؛ إذ الخرق والالتيام إنّما يكون بالحركة المستقيمة. والجواب أنّ ما ذكرتم إنّما دلّ على امتناع الحركة المستقيمة على الفلک لا على أجزائه وحكم الكل لا يجب أن يكون للجزء؛ ولأنّ سلّمنا لكن ذلک إنّما دلّ على امتناع الحركة المستقيمة التى بحسب الذات لا بالقسر فجاز أن يتحرک بقسر القاسر وهو اللّه تعالى.

Pb1: Orbs possess the principle of circular motion.

C1: Orbs are unable to have straight motion.

The second argument is:

Pa2: The parts of an orb do not need to stay in their place (because the orb is a simple body [*basiṭa*]).

Pb2 (=Pb1): Orbs possess the principle of circular motion.

C2: The parts of an orb can take the place of other parts.

The third argument is:

Pa3: To move due to an essence (*dhāt*) without principle is impossible.

Pb3 (=Pb1): Orbs possess the principle of circular motion.

C3: Orbs are unable to move due to their essence.

The fourth argument is a *reductio ad absurdum*:

Pa4: Orbs possess the principle of straight motion.

Pb4: Straight motion results in either an inclination toward or opposite a direction.

C4: Orbs move either inclined toward a direction or opposite a direction.

However, C4 leads to absurdity because orbs, having a single nature, are unable to move in more than one direction; as such, orbs do not possess the principle of straight motion (~Pa4).

The fifth argument is:

Pa5 (=Pa4): Orbs do not possess the principle of straight motion.

Pb5 (=Pa3): Movement due to an essence without principle is impossible.

C5: Orbs are unable to move straight due to their essence.

This section's three first arguments are dedicated to the characteristic of orbs' motion, parts, and essence and are derived from one proposition: Orbs possess the principle of circular motion. The fourth and fifth arguments are joint arguments, in which the conclusion of the fourth argument serves as the premise for the fifth argument. The last and main conclusion of the sixth argument is that orbs are unable to have straight motion due to their essence, and this is also a combination of the results from the first and third arguments (C1 and C3).

The seventh debate begins with the statement that the tearing of orbs is possible, as well as their mending. As al-Samarqandī reminds the reader, the statement contradicts his predecessors' ideas. Regarding the context, he seems to refer to the Greek philosophers as his predecessors. Principles such as the impossibility of the tearing and mending of the orbs are traceable to Aristotle's *De Caelo,* even though he indirectly addresses the tearing and mending of the orbs. Aristotle stated that a body with circular motion could not change, is not susceptible to "either growth or alteration," and is "non-generated and indestructible." Hence, the tearing and mending of an orb could be categorized under the concept of alteration. This conceptual derivation is an explanation for the impossibility of the tearing and mending of the orbs. Meanwhile, the primary argument for the impossibility in the classic Islamic age considered this impossibility to be the result of the impossibility of rectilinear motion in the heavens. This argument is presented explicitly by Avicenna in Chapter 4 of his book *Al-Samāʾ wa al-ʿĀlam* "On the Disposition of the Body That Moves in a Circle and the Kinds of Alterations in It Which Are Permissible or Impermissible," which is the principal report of Aristotle's *de Caelo* in Arabic. Al-Samarqandī restated this argument in his work (see Pa6, Pb6, and C6) in order to analyze and reject it.[14]

In the first step, al-Samarqandī declared explicitly that the possibility of mending is evident. He did not explain why it is evident; however, this evidence is probably based on the logic that if an orb can be torn up, then subsequently, it should also be mendable. Concerning the tearing, he wrote it to be nothing other than the disjunction of the parts of a body, with the orb's parts already being disjoined by placing a planet within its body. In this sense, the tearing of an orb is acceptable.

In the next step, he attributed the following argument to his predecessors:

Pa6: Tearing and mending are the results of straight motion.

Pb6: Orbs do not have straight motion.

C6: The tearing and mending of the orbs are impossible.

Then he presented his first refuting argument:

Pa7: All these conditions about tearing and mending relate to the orbs and not their parts.

Pb7: The predicate for the whole does not necessarily hold true for the parts (a rule of logic).

C7: The tearing and mending of an orb's parts are possible.

14 Avicenna, 26.

This argument is based on his interpretation of tearing as a disjunction and on the result from the second argument of the sixth debate (C2), in which the orb's parts can change their place.

His second refuting argument is as follows:

Pa8: Having straight motion is possible due to a force.

Pb8 (=C5): Orbs cannot have straight motion due to their essence.

C8: Orbs can have straight motion due to a force.

This is his main argument for the possibility of the tearing and mending of the orbs. The argument is founded on the main result from the fifth debate on the nature of orbs (C5). What kind of force can cause orbs to have straight motion in this case? Al-Samarqandī closed the debate by pointing out that orbs could move due to the force of God (for a summary of this discussion, see Table 1).

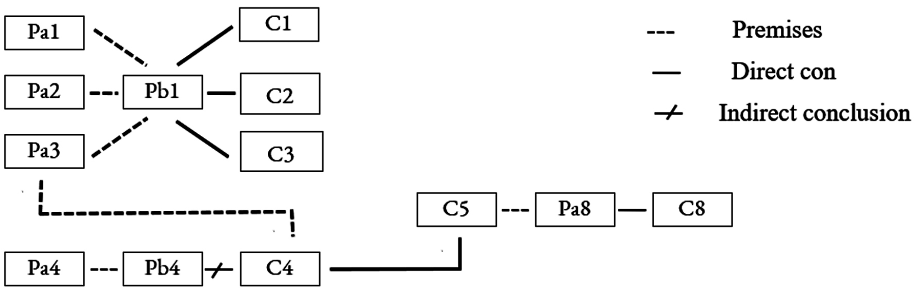


Chart 1. The Logical Structure of al-Samarqandī's Arguments

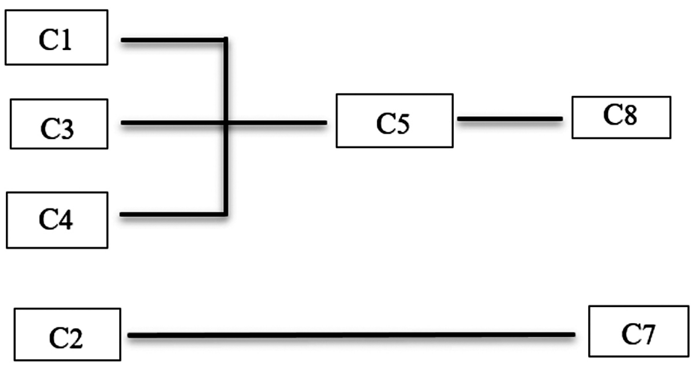


Chart 2. The Conceptual Relation Between Results

Table 1.
A Summary of the Discussion

Orb motion	Due to essence	with the principle of circular motion	with the principle of straight motion	Due to force	Possibility
straight/ circular	+	-	-	-	-
straight	+	+	-	-	-
circular	+	+	-	-	+
straight	+	+	-	+	+

2-2- Theological Metaphor

In the fifth *faṣl* of the second *maẓhar*, al-Samarqandī presents his model for the sun, writing:

> If the tearing of orbs were authorized, then it would be permissible for the sun to have one orb, and the sun would swim in the orb like a fish in the water ... Here it is necessary to mention the words of God Almighty, who says, "And each swims in a circuit."[15]

A fish in the water is a well-known metaphor for rejecting the possibility of the tearing and mending of the orbs in the *hayʾa* tradition.[16] It is also in contrast with another metaphor for the case of an orb and a planet: a gemstone on a ring.[17] In the first metaphor, the planet is a fish, and the orb is a river, so the possibility exists for the fish to swim in the river. Meanwhile, in the second metaphor, the planet is a gemstone, and the orb is a ring, with the gemstone fixed on the ring and turning only with the motion of the ring. The reference at the end of the passage to the Quran (Surah Yasin, 36:40) is also a metaphor. The two terms in this verse could have astronomical senses. The first is *falak*, which literally means a ship but may also refer to the orb. The second is *sabaḥa* (س-ب-ح) as the root of the verb, which literally means swim and could refer to the motion of the planets.

15 ولمّا ثبت جواز الخرق فجاز أن يكون للشمس فلک واحد وهي تجري فيه كالحوت في الماء على مدار خارج المركز، وكذا في باقي الكواكب كما يجئ وإلى هذا وقعت الإشارة بقوله تعالى «كل في فلک يسبحون».

16 al-Kharaqī, *Muntahā* (Intro.), 3; al-Ṭūsī, *al-Risāla* (Bk 1, Ch. 2), 31.

17 al-Kharaqī, *Muntahā* (Bk 2, Ch. 9), 43; al-Ṭūsī, *al-Risāla* (Bk 2, Ch. 6), 67.

3- Al-Samarqandī's Planetary Models Assume the Possibility of the Tearing and Mending of the Orbs

3-1- The Astronomical *Mazhar*

The sixteen chapters of this *Maẓhar* are divisible into four principal subjects of *hayʾa*:[18] Introduction (*Faṣl 1*), the configuration of the heavens (*hayʾat al-ʿālam, Faṣls 2-12*), mathematical geography (*hayʾat al-ʾarḍ, Faṣls 13-15*), and the distances and masses of the heavenly bodies (*al-ʾabʿād wa al-ʾajrām, Faṣl 16*).

The introduction consists of mathematical definitions for geometric objects such as point, line, and angles. The works included in the *hayʾa* tradition have different content and structure, but in the four-division standard in *hayʾa* works, such as *al-Tadhkira* by al-Ṭūsī, the introduction mainly consist of two parts, with the first part being dedicated to introductory mathematical information and the second part being a short exposition on natural philosophy.[19] Natural philosophy is vastly discussed in the first *maẓhar,* but it is almost entirely absent from the introduction. Nevertheless, the definition of orbs is included in the introduction as a list of the characteristics: spherical in shape, a transparent body circumscribed by two spherical convex and concave surfaces, and not belonging to the four elements. The motion of the orb is either simple or compound: a simple body moves in simple motion, whereas compound motion combines several simple motions. The titles of the *faṣls* are shown in Table 2.

18 Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 1: 36–41.

19 For instance, see Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 1: 92–101; al-Ṭūsī, *al-Risāla* (Bk 1, Ch. 1-2), 23–31.

Table 2.
The Chapters in the Second Maẓhar of the Science of the Cosmos and the Soul

Chapter	Title
1	Introduction
2	On the sphericity of the sky and the Earth, the Earth being the center of the world, and the Earth not having an appreciable amount of the heavens
3	On the arrangement of the bodies
4	On the well-known great circles
5	On the orbs and motions of the Sun
6	On the orbs and motions of the Moon
7	On the orbs and longitudinal motions of Mercury
8	On the orbs and longitudinal motions of the remaining planets
9	On the latitudes of the planets
10	On total obliquity
11	On parallax
12	On the variation in the Moon's illumination and on Lunar and Solar eclipses
13	A general summary of the configuration of the Earth
14	On the differences in the state of the heavens in relation to locations and days and nights
15	On dawn and dusk
16	On the measurements of the distances and the bodies

3-2- The Model for the Sun

In *Faṣl*s 5-8 of the second *maẓhar*, al-Samarqandī presents his planetary models, which in many aspects are the same as the models in standard *hayʾa* books. However, at the end of the fifth *faṣl*s, he emphasizes this structure as being based on the assumption of the possibility of the tearing and mending of the orbs and proposes some modifications based on this assumption. In the case of the sun, he wrote:

> They established two orbs for the sun to avoid the tearing of the orbs; but if the tearing of orbs were authorized, then it would be permissible for the sun to have one orb ... in an eccentric circuit (madār), and likewise in the rest of the planets.[20]

20 Samarqandī, *Science of the Cosmos*, 143.

وإنّما أثبتوا لها فلكين لئلّا يلزم الخرق ولمّا ثبت جواز الخرق فجاز أن يكون للشمس فلك واحد ... على مدار خارج المركز، وكذا في باقي الكواكب

The two orbs are a parecliptic orb and an eccentric orb. The parecliptic moves the apogee of the eccentric orb, while the eccentric is responsible for the diurnal motion of the sun. It is a standard model in the *hayʾa* tradition.[21] Al-Samarqandī proposes to eliminate the eccentric. If the tearing and mending of the orb are possible, then the sun can move freely according to its diurnal motion in the parecliptic orb.

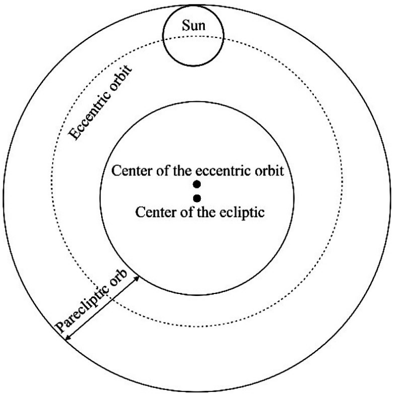


Figure 1. Al-Samarqandī's model for the Sun

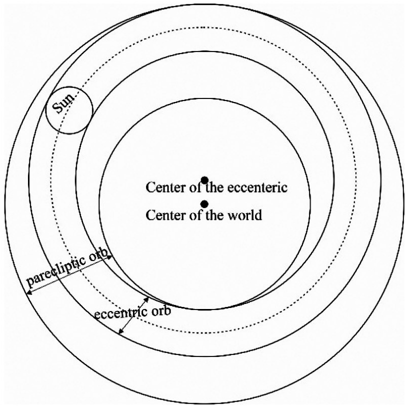


Figure 2. The Ptolemaic model for the Sun

3-3- The Model for the Moon and the Other Planets

Ptolemy was confronted with another anomaly in the planets' motions: they were neither uniform with respect to the center of the world nor to the center of a deferent orb. He proposed inventing a point called "the point of equant," with respect to which motion was uniform. This structure was transferred to the classical Islamic age, and this point is called *Nuqṭat al-Muḥādhāt* [prosneusis point] for the moon and *Nuqṭat al-muʿaddil li-l-masīr* [the point of equant] for the other planets.[22]

In the post-classical Islamic age, the astronomers of the Marāgha School considered this point's invention to be against the world's physical principles because, according to Aristotle, the circular motion should be uniform concerning

21 Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 1: 145–147; al-Ṭūsī, *al-Risāla* (Bk 2, Ch. 4), 60–62; al-Kharaqī, *Muntahā* (Bk 2, Ch. 8), 33–34.

22 For a list of the most outstanding problems in Ptolemaic astronomy as expounded in the *Almagest* and *Planetary Hypotheses* see: Saliba, "Arabic Planetary Theories," 60–62; see also Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir*..., 1:48–51 (al-Ṭūsī's Criticism of Ptolemy's Model).

its center, so only the center of the deferent could be accepted as the center of uniform motion. The scholars of the Marāgha School tried to solve this problem by adding new orbs and devising new models, such as the models explained in al-Ṭūsī's and Shīrāzī's works. [23]

Al-Samarqandī referred to these astronomers as his contemporaries (*Mutaʾakhkhirīn*). He was aware of the new model but was not content with them. He believed the new models did not solve the main problem and stated that the problem was sometimes not even solved by adding new orbs. In addition, these new orbs would result in new mistakes and perturbations in motions. Some of these new orbs also played no role in the planets' motions.[24]

Al-Samarqandī put forward his model for the moon, in which instead of the four orbs (i.e., parecleptic, inclined, deferent, epicycle) in the standard models, his model just had two orbs (i.e., inclined, epicycle). The deferent could be eliminated because if the tearing and mending of the orbs are possible, then the epicycle can move independently within the body of the inclined orb. The duty of the parecliptic orb in moving the nodes also could be done by an inclined orb, so a parecliptic orb would be useless.

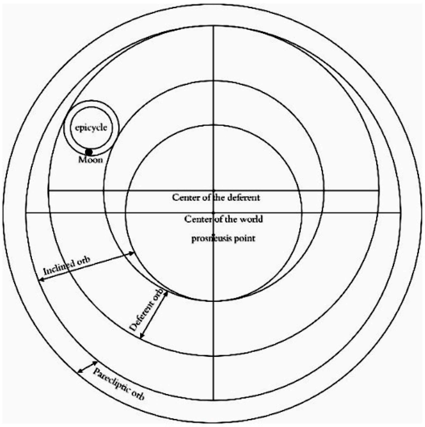
As Al-Samarqandī stated, the motion of the epicycle in his model is on an oval circuit (*ʿala madār bayziyy al-shikl*).[25] Firstly, the circuit in al-Samarqandī's text is distinguished from an orb. He did not define a circuit; however, a circuit contextually appears as a mathematical entity that shows the trajectory, while the orb is a body with physical properties. Secondly, the motion of the epicycle on an oval circuit is al-Samarqandī's idea about how the center of the epicycle moves. The *hayʾa* books are generally silent about this controversial subject, but al-Ṭūsī's *al-Tadhkira* was probably the main source for al-Samarqandī and provides some information.[26] However, this oval circuit has a pivotal role in al-Samarqandī's models because by eliminating some orbs, the motion of the epicycle becomes a key concept. Al-Samarqandī mentioned this oval circuit only in describing Mercury's model.

23 Saliba, "Arabic Planetary Theories," 62, 87–126.

24 Samarqandī, *Science of the Cosmos*, 164.

25 *Ibid*, 150.

26 Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir*..., 1: 162–163.



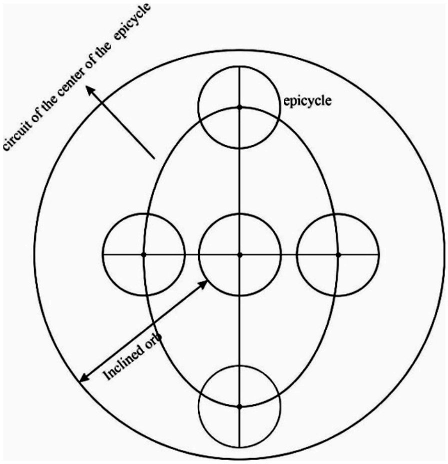


Figure 3. The Ptolemaic model for the Moon. **Figure 4.** Al-Samarqandī's model for the Moon.

Al-Samarqandī's model for the other planets also works using only two orbs. He addressed the issue regarding the other planets so briefly by mentioning only the names of the orbs. The comparison between orbs in *Science of the Cosmos and the Soul* and the standards models is presented in Table 3.[27]

Table 3.

Comparison Between the Orbs in Science of the Cosmos and the Soul and in Ptolemaic Models

Planet	Sun		Moon		Mercury		Venus and Superior Planets	
Orbs	al-Ṭūsī	Samarqandī	al-Ṭūsī	Samarqandī	al-Ṭūsī	Samarqandī	al-Ṭūsī	Samarqandī
Parecliptic	*	*	*	-------	*	*	*	*
Inclined	-------	-------	*	*	-------	-------	-------	-------
Dirigent	-------	-------	-------	-------	*	-------	-------	-------
Eccentric/ Deferent	*	-------	*	-------	*	-------	*	-------
Epicycle	-------	-------	*	*	*	*	*	*

27 Authors of *hayʾa* works use the term "inclined orb" to describe the deferent orb for planets' motions regarding latitude; however, here we use the term "inclined" exclusively for the second orb of the Moon.

Al-Samarqandī stated that his models not only solve the problem raised by the point of equant but also do not make the astronomical calculations (*ʿamal al-zījāt*) awkward.[28] This remark shows that his concerns in astronomy were not limited to natural philosophy, and he was also afraid that adding new orbs to models would complicate their practical use.

Conclusion

Al-Samarqandī's project in *Science of the Cosmos and the Soul* had two steps: first, a revision of principles borrowed from natural philosophy, and second, an adaptation of planetary models based on the results from the first step. He adopted *a realistic attitude* in the first step: He believed that the orbs have genuine physical parts that could be disjointed. In the second step, he committed to *the principle of simplicity*: He eliminated nine orbs from the 24 standard orbs of the astronomy of his time.

By insisting on observational evidence in the section "Concerning the Supposed Dependence of Astronomy upon Philosophy" from *Sharḥ Tajrīd al-ʿAqāʾid*, ʿAli al-Qūshjī (1403-December 16, 1474) tried to show that astronomy should be independent of philosophy. He begins the section by saying:

> It is stated that the positing of the orbs in [that] particular way depends upon false principles taken from philosophy, for example, the denial of the volitional Omnipotent and the lack of possibility of tearing and mending of the orbs, and that they do not intensify nor weaken in their motions, and that they do not reverse direction, turn, stop, nor undergo any change of state but rather always move with a simple motion in the direction in which they are going, as well as other physical and theological matters, some of which go against the Law and some of which are not established since their proofs are defective.[29]

Almost a century after al-Samarqandī, al-Qūshjī deemed the possibility of the tearing and mending of the orbs to be false because its proofs were insufficient. Upon reading al-Samarqandī's proofs discussed in this article, it would not be easy to agree with al-Qūshjī.

Al-Samarqandī's logical attitude toward the structure of science is manifested in his arguments in favor of the possibility of the tearing and mending of the

28 Samarqandī, *Science of the Cosmos*, 164.

29 Ragep, "Freeing Astronomy," 66–67 [includes Arabic text].

orbs. He did not leave his conclusion in natural philosophy as a philosophical contemplation but attempted to apply his conclusion to astronomy. The outcomes of this application are planetary models more straightforward than the standard models of his time. He moved in the face of his predecessors in Marāgha School by decreasing the number of orbs instead of increasing it. In this way, he had a critical attitude toward questioning Aristotelian principles.

Bibliography

Aristotle. *De Caelo* (*On the Heavens*). With an English translation by W. K. C. Guthrie, The Loeb Classical Library. London: William Heinemann LTD, 1971.

Avicenna. *al-Samā wa al-ʿālam, Ṭabīiyy at-i Shifaʾ*. Edited by Ebrahim Madkur et al. Qom: Marʿashī publication, 2012.

Fazlıoğlu, İhsan. "Between Reality and Mentality Fifteenth-century Mathematics and Natural Philosophy Reconsidered." *Nazariyat* 1/1 (Nov.2014): 1-39.

Fazlıoğlu, İhsan. Samarqandī, https://islamsci.mcgill.ca/RASI/BEA/Samarqandi_BEA.htm .

Goldstein, Bernard R. "The Arabic Version of Ptolemy's *Planetary Hypotheses*." *Transactions of the American Philosophical Society* 57, no. 4 (June 1967): 3-55.

al-Kharaqī, ʾAbū Muḥammad ʿAbd al-Jabbār. *Muntaha al-ʾIdrāk fī Taqāsīm al-ʾAflāk*. Edited, introduction and translated into persian by Hanif Ghalandari. Tehran: Mirase Maktoob, 2020.

Qurbānī, Abū al-Qāsim. *Zindagī-nāmah-i riyāḍī'dānān dawrah-i Islāmī*. Tehran: Markaz-i Nasr-i Danişgah, 1986-1987.

Ragep, F. J. *Naṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy* (*al-Tadhkira fī ʿIlm al-Hayʾa*). Introduction, edition, and translation by F. J. Ragep. Springer Verlag, 1993.

Ragep, F.J. "Freeing Astronomy from Philosophy: An Aspect of Islamic Influence on Science." *Osiris* 16, (2001): 49-64 + 66-71.

Rosenfeld, Boris A. & Ihsanoğlu, Ekmeleddin. *Mathematicians, Astronomers and Other Scholars of Islamic Civilization and their works* (*7th -19th c.*). Istanbul, 2003.

Saliba, George. "Arabic planetary theories after the eleventh century AD." *Encyclopedia of the History of Arabic Science*. Edited by Roshdi Rashed, vol I: Astronomy theoretical and applied. London and New York: Routledge, 1996: 59-128.

Saliba, George. "The First Non-Ptolemaic Astronomy at the Marāgha School." *Isis* 70, no. 4 (Dec. 1979): 571-576.

Samarqanī, Shams al-Dīn. *Science of the Cosmos and the Soul* (*ʿlm al-ʾāfāq wa al-ʾanfus*). Edited with notes and introductions in English and Persian by Gholamreza Dadkhah. California: Mazda Publisher, 2014

al-Ṭūsī, Naṣir al-Dīn. *al-Risāla al-Muʿīniyya*. Edited by Sajjad Nikfahm Khubravan and Fateme Savadi. Tehran: Mirase Maktoob, 2020.