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Astronomy in the Fanārī-Circle: The Critical Background for Qādīzāde al-Rūmī and the Samarqand School

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Introduction

Our goal in this paper is to provide a brief overview of the understanding of astronomy within the Fanārī circle as gleaned from the *Unmūdhaj al-ᶜUlūm* of Muḥammad Shāh al-Fanārī and the *Sharḥ al-Mulakhkhaṣ fī al-Hayᵓa* by Badr al-Dīn Abd al-Wājid ibn Muḥammad. Muḥammad Shāh al-Fanārī (d. 839 H/1435-6 CE) was, of course, the son of Muḥammad ibn Ḥamza al-Fanārī (d. 834/1431). Badr al-Dīn Abd al-Wājid ibn Muḥammad ibn Muḥammad al-Ḥanafī (d. 838/1435) was originally from Khurāsān in Northeast Iran, but eventually settled in Kütahya in Anatolia, where he was a prominent teacher at a *madrasa* (the Wājidiyya) that was apparently renamed in his honor. It was among this group of scholars that Qāḍīzāde al-Rūmī (ca. 760/1359-ca. 845/1441), who was destined to become one of the most important members of the Samarqand mathematical/astronomical school led by Ulugh Beg, was first educated in the science of astronomy.

In order to avoid potential confusion, we should note from the outset that the modern science of astronomy does not correspond exactly with any particular discipline that existed during the premodern Islamic period, and in fact the scope and denotation of astronomy in Islam evolved over time.[1] During the earliest centuries of Islam, one often encounters a discipline called *ᶜilm al-nujūm*, which corresponded to the Greek ἀστρονομία. This discipline included both what we would call astronomy and astrology. After the eleventh century, the more common term one encounters is *ᶜilm al-hayᵓa* (the science of

1 For an overview of astronomy in Islam, see Ragep, F. Jamil, "Astronomy", *Encyclopaedia of Islam*, 3rd ed., Part 1, Brill, Leiden 2009, 120-150.

structure or configuration), which did not include astrology but instead was intended to give a complete picture of the universe, and in particular the bodies that composed the universe. Typical is the definition of *ᶜilm al-hayʾa* given by the Egyptian encyclopaedist Ibn al-Akfānī (d. 749/1348):

> It is the science from which one learns the situations of the lower and upper simple bodies, their forms, their positions, their magnitudes, the distances between them, the motions of the orbs and the planets and their amounts. Its subject is the aforementioned bodies from the point of view of their quantities, positions, and inherent motions.[2]

One needs to say a bit about this notion that astronomy is the study of bodies. Since at least the time of the Greek philosophers in the fifth and fourth centuries BCE, the heavens were held to be a solid, spherical plenum made of a substance (the "aether") essentially different from the materials (composed of "the four elements") with which we are familiar here on Earth. Within this spherical firmament, there were conceived concentric spherical shells or orbs (in Arabic: *falak/aflāk*), one inside the other, that carried the numerous fixed stars and the seven, irregularly moving "planets" (the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn). At the center of this firmament rested the immobile, spherical Earth. According to Aristotle, each celestial orb should furthermore have uniform, circular motion about the center of the universe.[3]

The problem for the astronomer was how to predict celestial motion while adhering to these natural philosophical principles. This had proven difficult for Greek astronomers, who were compelled to introduce eccentric and epicyclic orbs that were not centered on the Earth as well as a variety of irregular motions, such as that resulting from the equant point. This latter was introduced by Ptolemy and caused a planetary sphere to rotate with irregular motion.[4]

It is remarkable that a number of Islamic astronomers would fundamentally disagree with their Greek predecessors on these compromises

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2 Witkam, J. J., *De Egyptische arts Ibn al-Akfānī*, Ter Lugt Pers, Leiden 1989, 408 (my translation).

3 The "proofs" for these propositions, for the most part, are made in his *De caelo*; an enumeration of the actual orbs that would be necessary to account for what we observe is made in *Metaphysics*, XII.8.

4 A good introduction to Greek astronomy can be found in Evans, James, *The History and Practice of Ancient Astronomy*, Oxford University Press, New York & Oxford 1998.

and insisted that the physical principles of astronomy must be consistently adhered to, leading them in a number of cases to propose new models more in keeping with physical principles. Among the best known examples of these reformers of Ptolemaic astronomy were the Persians Naṣīr al-Dīn al-Ṭūsī (d. 672/1274) and Quṭb al-Dīn al-Shīrāzī (d. 710/1311), and the Syrians Muʾayyad al-Dīn al-ʿUrḍī (d. ca. 664/1266) and Ibn al-Shāṭir (d. ca. 1375). Their work was carried on in the fifteenth and sixteenth centuries by astronomers working in Iran, Central Asia, Ottoman lands, and Europe (most notably Nicholas Copernicus).[5] It is this active Islamic astronomical tradition in the post-classical period that forms an important part of the background for the work of Muḥammad Shāh al-Fanārī and Abd al-Wājid.

I. Astronomy in the *Unmūdhaj al-ʿUlūm of* Muḥammad Shāh al-Fanārī[6]

Under the rubric *ʿilm al-hayʾa*, Muḥammad Shāh al-Fanārī deals with several topics (which he calls *aṣl/uṣūl*). The first of these concerns the ten great circles used in astronomy, namely:[7]

1. *minṭaqat al-falak al-aʿẓam* (*=falak muʿaddil al-nahār = dāʾirat muʿaddil al-nahār*): the equator of the greatest orb (=equinoctial orb = the circle of the equinoctial)

2. *minṭaqat falak al-burūj* (*=falak al-burūj*): the equator of the ecliptic orb (=orb of the ecliptic)

3. *al-dāʾirat al-mārra bi-ʾl-aqṭāb al-arbaʿa*: the circle passing through the four poles

4. *dāʾirat al-mayl*: circle of declination

5. *dāʾirat al-ʿarḍ*: circle of latitude

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5 For an overview of non-Ptolemaic astronomy in Islam, see Saliba, George, "Arabic Planetary Theories after the Eleventh Century AD", *Encyclopedia of the History of Arabic Science* (ed. Roshdi Rashed), Routledge, London 1996, 58-127. For biographies of individual astronomers, see *The Biographical Encyclopedia of Astronomers* (ed. Thomas Hockey et al.), Springer, New York 2007, whose Islamic astronomers are online at http://islamsci.mcgill.ca/RASI/BEA/

6 References to the *Unmūdhaj al-ʿUlūm* are to Istanbul, Süleymaniye MS Hüsrev Paşa 482.

7 *ʿIlm al-hayʾa* is covered in ff. 158a-161b. Discussion of the great circles occupies a good part of this section, ff. 158a-160b.

6. *dā᾿irat al-ufuq*: horizon circle

7. *dā᾿irat nisf al-nahār*: meridian circle

8. *dā᾿irat al-mashriq wa-᾿l-maghrib*: east-west circle

9. *dā᾿irat wasaṭ samā᾿ al-ru᾿ya* (=*dā᾿irat ᾿arḍ iqlīm al-ru᾿ya*): ecliptic meridian circle (=circle of the local ecliptic latitude)

10. *dā᾿irat al-irtifā*ᶜ: altitude circle

For the most part, Muḥammad Shāh's presentation here closely follows what one finds in Book II, Chapter 3 of Naṣīr al-Dīn al-Ṭūsī's *al-Tadhkira fī ᶜIlm al-Hay᾿a*, one of the classic presentations of astronomy, which was written in Marāgha (in Azerbaijan) during the time Ṭūsī was director of the great observatory build there under Mongol patronage.[8] What is striking is that Muḥammad Shāh offers these circles as somehow exemplifying *ᶜilm al-hay᾿a*. But in fact, as we have seen above, the subject matter of *hay᾿a* was usually held to be physical bodies, not mathematical circles. One might conclude that Muḥammad Shāh was therefore not interested in dealing with the cosmological/philosophical aspects of astronomy but rather only in its practical side. However this is belied by the last part of this section, where he goes into great detail regarding one of the most difficult parts of *hay᾿a*, namely the motion in latitude of Mercury and Venus. And what is particularly noteworthy is that he alludes to how Ṭūsī dealt with this problem in the context of the latter's reform of the Ptolemaic system.

Muḥammad Shāh begins by presenting an *ishkāl* (difficulty) in the form of a question: "why is Venus's maximum inclination [in latitude] always northerly, while Mercury's is always southerly, contrary to what is reasonable?"[9] The solution (*ḥall*), which then goes on for almost two pages, again follows Ṭūsī's *Tadhkira* (Book II, Chapter 10, paragraphs 1-2).[10] At the end of this section, Muḥammad Shāh, again paraphrasing Ṭūsī, states that these motions in latitude require movers, "which were not mentioned by anyone before." He

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8 Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy (al-Tadhkira fī ᶜIlm al-Hay᾿a)*, Springer-Verlag, New York 1993, 112-121.

9 *Unmūdhaj al-ᶜUlūm*, f. 160b.

10 Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 188-191.

then refers his readers to the *Tadhkira*, where, he states correctly, "Ṭūsī has elucidated them."[11]

To understand what is involved in Ṭūsī's solution, let us refer to Figures 1 and 2. In order to produce the necessary motion in latitude according to Ptolemy's theory of the planets, one must have an oscillation of the planes inclined to the ecliptic that produce the inclination component for each of Mercury's and Venus's motion in latitude, so that Venus's maximum inclination is always northerly, while Mercury's is always southerly. Since such a motion, according to the celestial physics of the time, needed uniformly rotating movers, i.e. orbs, Ṭūsī had proposed using the curvilinear version of his so-called "Ṭūsī-couple", whereby a series of three concentric orbs enclosing each of the inclined orbs of Mercury and Venus could result in the needed oscillation of their inclined orbs along a great circle arc.[12]

Again, planetary latitudes were usually considered an advanced topic, and the situation of the inferior planets, i.e. Mercury and Venus, was particularly difficult. So it is not at all clear why Muḥammad Shāh chose this aspect of planetary latitudes as his one *ishkāl* in his section on *ᶜilm al-hayʾa*. This is especially odd since his main exposition of *ᶜilm al-hayʾa* had been a simple presentation of the main circles used in astronomy. Perhaps he simply wished to stimulate interest in the subject by presenting a difficult problem for his students, while at the same time introducing Ottoman scholars and students to Ṭūsī's innovative work.

Muḥammad Shāh presents material related to astronomy in a number of other sections of his *Unmūdhaj*. That he separates astronomical information in a number of sections is again an indication that he is not seeking to provide a coherent account of *ᶜilm al-hayʾa* as it had developed between the eleventh and fourteenth centuries, even though he was obviously using a primary text of the tradition, i.e. the *Tadhkira*, as the source of most of his information. In the next section after *ᶜilm al-hayʾa*, Muḥammad Shāh deals with what he calls *ᶜilm khawāṣṣ al-aqālīm* (the science of the characteristics of the climes), which

11 *Unmūdhaj al-ᶜUlūm*, f. 161b.
12 Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir*, Bk. II, Ch. 11, paras. 19-20, pp. 218-221; for an extended explanation of how this works, see ibid., pp. 454-456.

concerns the characteristics of the seven divisions of the inhabited world.[13] Although this topic may seem unrelated to astronomy, it had come to be treated in the third part of *hayʾa* works, where it was called "On the Configuration of the Earth" (*Fī hayʾat al-arḍ*). There were two reasons for this inclusion. *Hayʾa* dealt with all bodies, both celestial and sublunar. Thus it was legitimate for a *hayʾa* writer to discuss the sublunar realm, including the Earth's surface, as part of a general overview of all bodies in the universe. The second reason was that the characteristics of the climes, as well as other aspects of the terrestrial region, were obviously affected by their relationship to the celestial bodies, in particular the Sun. Although the inclusion of terrestrial phenomena (such as latitudes of places) could often be found in Greek astronomical works, this was considerably expanded in Islamic astronomy.[14] Muḥammad Shāh, however, chooses to treat it as a discipline separate from *hayʾa* even though much of his material closely follows what one finds in Book III of the *Tadhkira*, Chapters 1-6. For his *ishkāl* (difficulty) for this section, Muḥammad Shāh chooses the interesting problem of time zones and why, for example, it may be Thursday for someone while it is Friday for someone else. To solve this conundrum, Muḥammad Shāh uses the example from the *Tadhkira* of three individuals: one travels due west, one due east and the other stays in place. When the westward traveler returns from the east, he will have counted one fewer days than the person who stayed in place, while the eastward traveler returning from the west will have one more. This is because the westward traveler will have lengthened each day and thus distributed one revolution among his total number of days, whereas the eastward traveler will have shortened each day and thus will have accumulated one revolution among his total number of days.[15]

The topic of the next section as well is usually part of a *hayʾa* work. Entitled *ᶜilm maqādīr al-ᶜilwiyyāt* (the sizes of the celestial bodies), it was dealt with in the fourth and last book of the *Tadhkira*, where it is called *Fī maᶜrifat maqādīr al-abᶜād wa-ʾl-ajrām* (On finding the measurements of the distances and bodies).[16] The content of this section is quite close to that of the *Tadhkira*; in

13 *Unmūdhaj al-ᶜUlūm*, ff. 161b-163b.
14 Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 38.
15 *Unmūdhaj al-ᶜUlūm*, ff. 162b-163b; cf. Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 244.
16 *Unmūdhaj al-ᶜUlūm*, ff. 163b-165b; Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 310-341.

fact one can see that Muḥammad Shāh is using the earlier (Marāgha) version of the *Tadhkira* since he gives the area of the actually inhabited zone on the Earth's surface as 3,765,420 parasangs, which was corrected in the later (Baghdad) version of the *Tadhkira* to 3,756,420.[17] Muḥammad Shāh then turns to the sizes of the Sun and Moon, closely following the Marāgha version of the *Tadhkira*, Book IV, Chapter 4. His additions are arithmetical, explicitly showing how one uses algebra in a proportion to obtain the desired results. (This was done elliptically in the *Tadhkira*).[18] For the remaining planets (Venus, Mercury, Mars, Jupiter and Saturn), he again depends heavily on the earlier version of the *Tadhkira* (Book IV, Chapter 5[7]; Book IV, Chapter 5[8]; Book IV, Chapter 6[2-3]; Book IV, Chapter 6[5]; and Book IV, Chapter 6[7]).[19]

Other astronomical topics dealt with by Muḥammad Shāh include sections on using the astrolabe and the quadrant (*ᶜilm al-asṭurlāb* and *ᶜilm rubᶜ al-daᵓira*).[20] He also has a section called *ᶜilm al-nujūm* (science of the stars), where he describes the lunar mansions as well as zodiacal and other constellations and how to find them, illustrated with schematic diagrams.[21] Included in this section is a discussion of the astrological characteristics of the planets. Other sections give additional astrological information: one on *ikhtiyārāt* (elections) and another on the *daᶜwat al-kawākib* (apparently on the auspicious events brought about by certain planetary configurations).[22] What is interesting here is that Muḥammad Shāh seems not to be concerned about religious objections to astrology that one finds in his contemporary Ibn Khaldūn or in later Ottoman writers such as Ṭāshkubrīzāde.[23]

Muḥammad Shāh seems to wish to have a fairly strict demarcation between *ᶜilm al-hayᵓa*, which was usually considered a mathematical discipline, and natural philosophy. Thus he leaves all questions of the physics of astronomy to his earlier section on *al-samāᵓ wa-ᵓl-ᶜālam* (On the heavens and the

17 *Unmūdhaj al-ᶜUlūm*, f. 164a; Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 312-313, 511.
18 *Unmūdhaj al-ᶜUlūm*, f. 164a-164b; Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 326-327.
19 *Unmūdhaj al-ᶜUlūm*, ff. 164b-165b; Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 332-339.
20 *Unmūdhaj al-ᶜUlūm*, ff. 184a-185a.
21 Ibid., ff. 181a-183a.
22 Ibid., ff. 183a-184a, 185a-187a.
23 Ibn Khaldūn, *The Muqaddimah: An Introduction to History* (tr. Franz Rosenthal), Princeton University Press, Princeton 1967, III, 258-267; Aḥmad b. Muṣṭafā Ṭāshkubrīzāde, *Miftāḥ al-Saᶜāda wa-Miṣbāḥ al-Siyāda*, Dār al-Kutub al-Ḥadītha, Cairo 1968, I, 364.

world).[24] This approach is somewhat at odds with what one usually finds in the later *hayʾa* literature, where the subject matter of *hayʾa* is usually considered to be bodies and thus an introductory section on physics becomes mandatory. These later *hayʾa* writers distinguish between the physics needed in astronomy, which is concerned with the external manifestations of bodies, and the physics of natural philosophy, which deals with their essential characteristics.[25] Muḥammad Shāh avoids the problem of how to differentiate the physics of *ʿilm al-hayʾa* from that of *al-samāʾ wa-ʾl-ʿālam* in natural philosophy by never stating that the subject matter of *ʿilm al-hayʾa* is the simple bodies.

In his section on *al-samāʾ wa-ʾl-ʿālam*, however, he does take up a number of questions related to the physics of the celestial region, and many of his examples and problems come from the *Tadhkira*. He begins by stating that the simplest, natural form or shape (*shakl*) is a sphere, since it is the only simple body from which arises uniform action.[26] In the rest of the section, he confronts a number of seeming counter-examples. For example, he deals with the issue of the Earth's shape, which is generally but not perfectly spherical. Extending an example from the *Tadhkira* showing that the largest mountain has a minimal ratio to the diameter of the Earth,[27] Muḥammad Shāh must still deal with the possible objection that *any* departure from perfect (i.e. mathematical) sphericity would invalidate the claim that the Earth is in its simplest, natural form. Likewise, he deals with the objection that the heavens contain a variety of bodies (hollowed-out spherical shells, planets, eccentric orbs, etc.) that exhibit different forms of sphericity but are not all perfect spheres. In the first case he points out that there are external, sublunar factors at work (e.g. winds and rain) that cause these minor imperfections in the Earth. For the heavens, the various shapes still conform, according to Muḥammad Shāh, to the requirements of uniformity and simplicity despite the variety of shapes. (A close analysis of this section would be quite worthwhile since it shows sophistication in both the objections and in Muḥammad Shāh's defense of traditional cosmology.)

In summary, we can say that Muḥammad Shāh has attempted to deal with a number of astronomical issues but the manner of presentation (with

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24 *Unmūdhaj al-ʿUlūm*, ff. 134b-136b.
25 Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 33-41.
26 *Unmūdhaj al-ʿUlūm*, f. 134b.
27 Ragep, F. J., *Naṣīr al-Dīn al-Ṭūsī's Memoir*, 104-105, 314-315.

multiple chapters dealing atomistically with a variety of subjects) works against any coherent account as one would normally expect in a *hayʾa* work. On the other hand, he clearly is well acquainted with Ṭūsī's *Tadhkira* and has studied at least parts of it in detail. He thus becomes an important link between the Marāgha and Samarqand schools through the intermediation of Qaḍīzāde.

II. The *Sharḥ al-Mulakhkhaṣ* of Abd al-Wājid

As mentioned earlier, Badr al-Dīn Abd al-Wājid originally came from Khurāsān; after studying with Muḥammad ibn Ḥamza al-Fanārī, presumably in Bursa, he settled in Kütahya, where he taught at the apparently eponymous Wājidiyya Madrasa. Among his astronomical works are: the *Sharḥ al-Mulakhkhaṣ fī al-Hayʾa*, which was perhaps dedicated to Sultan Murād II (lived 806/1404–855/1451; ruled 824-848/1421-1444, 850-855/1446-1451); the *Sharḥ Sī Faṣl*, which is an Arabic commentary on Ṭūsī's Persian work on practical astronomy; and *Maᶜālim al-Awqāt wa-Sharḥuhu*, a work on the astrolabe written in verse and consisting of 552 couplets, dedicated to Muḥammad Shāh Fanārī.[28] According to Aydın Sayılı, a local legend connects the *madrasa* where Abd al-Wājid taught with an astronomical observatory. Though Sayılı believed that astronomical teaching went on there (as confirmed by Abd al-Wājid himself, as we shall see), he does not think that there was a full-fledged observatory.[29]

Al-Mulakhkhaṣ fī ᶜIlm al-Hayʾa by Sharaf al-Dīn Maḥmūd ibn Muḥammad ibn Umar al-Jaghmīnī was the most widespread astronomical textbook of the premodern Islamic world. Written in the early thirteenth century, it was the subject of numerous commentaries, supercommentaries, and glosses.[30] Abd al-Wājid's commentary on the *Mulakhkhaṣ* was no doubt an important textbook in the Fanārī circle. In the introduction to his commentary, Abd al-Wājid tells us he has been since his youth enthralled (*mashghūf*) with *ᶜilm al-hayʾa* and had studied various books on the subject with friends and colleagues. The book that he found most appealing, because of its clear exposition, was Jaghmīnī's *Mulakhkhaṣ*. There were already a number of

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28 Topdemir, Hüseyin, "Abd al-Wajid", *The Biographical Encyclopedia of Astronomers* (ed. Thomas Hockey et al.), Springer, New York 2007, 5-6.

29 Sayılı, Aydın, *The Observatory in Islam and Its Place in the General History of the Observatory*, Türk Tarih Kurumu, Ankara 1960, 246, 254-255.

30 Ragep, Sally, "Jaghmīnī", *The Biographical Encyclopedia of Astronomers* (ed. Thomas Hockey et al.), Springer, New York 2007, 584-585.

commentaries in circulation by his time, but he found them a bit too advanced for a beginner. Therefore he decided to write his own commentary, one without the complications and difficulties of other commentaries. He spent three months on it, trying to make it as clear and accessible as possible.[31]

From a cursory reading of the text, it does indeed seem that Abd al-Wājid has generally kept to his plan of presenting a simple commentary geared for the beginning student. He does, though, occasionally use material from more advanced texts, including Ṭūsī's *Tadhkira* and Quṭb al-Dīn al-Shīrāzī's (d. 1311) *Nihāyat al-Idrāk fī Dirāyat al-Aflāk* and *al-Tuḥfa al-Shāhiyya*. Quṭb al-Dīn had spent some time in Siwās, where he wrote the *Tuḥfa*. The *Nihāya* is explicitly quoted in the introduction when Abd al-Wājid is discussing the meaning of *hayʾat al-ʿālam* (the configuration of the world) and in particular what is meant by *al-ʿālam* (the world).[32] In the section on maximum daylight and the latitude of the climes, Abd al-Wājid explicitly mentions the following works: Ṭūsī's *Tadhkira*, Shīrāzī's *Nihāya* and *Tuḥfa*, and *al-Tabṣira fī ʿIlm al-Hayʾa* by Shams al-Dīn al-Kharaqī (d. 1138-39).[33] Abd al-Wājid has clearly encountered difficulties in this section since he found discrepancies in the values given in different manuscripts of the *Mulakhkhaṣ*. Thus he turned to other texts, in particular the *Tadhkira*, to help him sort through the conflicting data. Abd al-Wājid has thus provided us with considerable insight on the evolution of Jaghmīnī's text. Originally the *Mulakhkhaṣ* had presented the numbers for maximum daylight and the latitude of the climes based upon Ptolemy's *Almagest*. But over time various copyists and commentators revised the numbers in accordance with the more accurate values that one finds in Ṭūsī's *Tadhkira*, whose numbers themselves originate with Abū al-Rayḥān al-Bīrūnī (d. ca. 1050).[34] We can thus see that by Abd al-Wājid's time copyists and commentators had already begun changing the original values of the

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31 Abd al-Wājid, *Sharḥ al-Mulakhkhaṣ fī al-Hayʾa*, Istanbul, Süleymaniye MS Laleli 2127, ff. 1b-2a.

32 *Sharḥ al-Mulakhkhaṣ*, ff. 2b-3a; cf. Quṭb al-Dīn al-Shīrāzī, *Nihāyat al-Idrāk fī Dirāyat al-Aflāk*, Berlin, Staatsbibliothek MS Petermann I 674, f. 8b.

33 *Sharḥ al-Mulakhkhaṣ*, f. 102b. On Kharaqī, see Langermann, Y. Tzvi , "Kharaqī", *The Biographical Encyclopedia of Astronomers* (ed. Thomas Hockey et al.), Springer, New York 2007, 627.

34 On this modification of the *Mulakhkhaṣ* over time, see Ragep, F. J., "On Dating Jaghmīnī and His *Mulakhkhaṣ*", *Essays in honour of Ekmeleddin Ihsanoğlu* (ed. Mustafa Kaçar & Zeynep Durukal), Research Centre for Islamic History, Art and Culture (IRCICA), İstanbul 2006, 461-466.

Mulakhkhaṣ for those in the *Tadhkira* (which are also to be found in Shīrāzī's works). Clearly Abd al-Wājid is confused by the conflicting numbers but, being a meticulous scholar, he has given us the alternative values, thus providing a wealth of information for the historian.

Conclusion

The *Unmūdhaj al-ᶜUlūm* of Muḥammad Shāh al-Fanārī and the *Sharḥ al-Mulakhkhaṣ* of Abd al-Wājid give us a window on the beginnings of the Ottoman astronomical tradition. Clearly it is heavily dependent upon earlier traditions, especially those of Iran and Central Asia. The influence of the "Marāgha School" and especially of Naṣīr al-Dīn al-Ṭūsī is particularly evident. The level of learning, though, was still fairly elementary despite Muḥammad Shāh's discussion of the difficult problem of the latitude models for Mercury and Venus. On the other hand, there is clearly considerable interest and appreciation of astronomy, especially by Abd al-Wājid, who unashamedly tells us of his lifelong love of the subject. It is in this context that we can understand the background in astronomy that Qaḍīzāde al-Rūmī, took with him from Bursa and the passion for the mathematical sciences that would be decisive in the development of the Samarqand Madrasa and Observatory.[35] This passion would not only lead to a new beginning of Ottoman science through Alī Qushjī (d. 1474), a student of Qaḍīzāde's who would come in the latter part of his life to Istanbul at the invitation of Mehmet II, but would also leave its impact on world science across the Eurasian expanse, stretching from China to India to Europe.[36]

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35 Fazlıoğlu, İhsan, "The Samarqand Mathematical-Astronomical School: A Basis for Ottoman Philosophy and Science", *Journal for the History of Arabic Science*, 14 (2008), 3-68, esp. pp. 25-34. (Note that an earlier, Turkish version of this article appeared as "Osmanlı Felsefe-Biliminin Arkaplanı: Semerkand Matematik-Astronomi Okulu" *Dîvân: İlmî Araştırmalar*, 14 (2003/1), 1-66.

36 For an overview of these influences with further bibliography, see Ragep, F. J., "Astronomy" 147-148, 150. For the particular influence of the Samarqand School on the Copernican revolution, see Ragep, F. J., "Copernicus and His Islamic Predecessors: Some Historical Remarks" *History of Science*, XLV/1 (2007), 65–81.

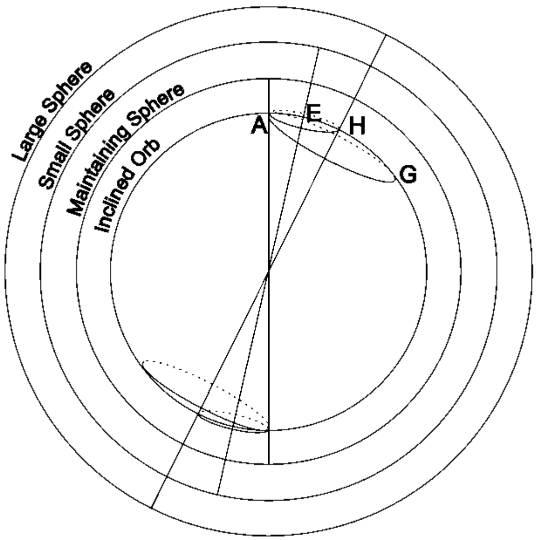

Figure 1: Ṭūsī's Additional Spheres to Resolve the Oscillation of the Inclined Orbs of Mercury and Venus

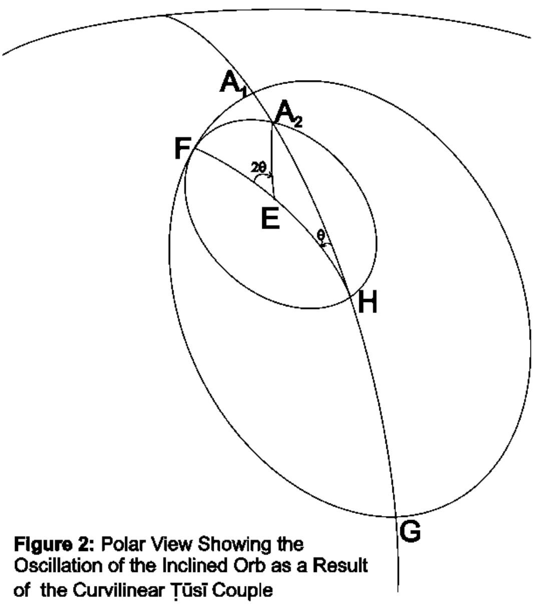

Figure 2: Polar View Showing the Oscillation of the Inclined Orb as a Result of the Curvilinear Ṭūsī Couple