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ḴAFRI, ŠAMS-AL-DIN

ḴAFRI, ŠAMS-AL-DIN, Moḥammad b. Aḥmad-e Kāši, one of the most competent of all the mathematical astronomers and planetary theorists of medieval Islam (d. 956/1550), and perhaps the most competent of all of them. Ḵafri was born in the city of Ḵafr, located south east of Firuzābād in the province of Fārs. Although his date of birth is unknown, he was active during the reign of Shah Esmāʿil (907-30/1501-24) and already important and famous enough to be invited by him to denounce the first three caliphs when the shah decided to establish Shiʿism as the state religion. Assuming that he attained fame no sooner than his early twenties, when mathematical geniuses invariably do, we can estimate that he was born sometime during the 1480s.

Ḵafri's date of death is equally problematic. In the most modern and extensive biography devoted to him, namely Moḥammad-Karim Ešrāq's *Bozorgān-e Jahrom* (pp. 273-95), according to the first source cited (p. 275), Ḵafri died on 28 Ṣafar 942/28 August 1535, and was buried in the city of Kāšān. However, at least two other sources are subsequently cited (pp. 278, 279) which state that he died in the year 957/1550. Similar conflicting information about Ḵafri's death date is cited by the more recent biographer, Qāsem Kākāʾi, in an article devoted to one of the logical works by Ḵafri (Kākāʾi, p. 72). He asserts that two primary sources agreed on the date 28 Ṣafar for Ḵafri's death, and that this was a Sunday, but differed on the year of his death, one stating 942/1535 and the other 957/1550. This would make the date of his death equivalent to either 28 August 1535, or 18 March 1550, respectively, but unfortunately neither of these two dates fell on a Sunday. In addition there is a manuscript of one work

of Ḵafri, cited by Kākāʾi, which claims that that it was completed in the year 950/1543. This would mean that Ḵafri was still alive in that year, and so his death date would need to be pushed forwards towards the year 957/1550. This date is also accepted by the historian Moḥammad-Taqi Rażawi (p. 404).

Most biographical sources follow Šuštari (d. 1610/11), the author of *Majāles al-moʾmenin*, in reporting that Ḵafri was one of the students of Ṣadr-al-Din Daštaki Širāzi (d. 903/1498), which, if true, would mean that he was still a young man during that studentship. Others connect him with Saʿd-al-Din Taftāzāni, which is hardly credible, since the latter died even earlier, in 791/1389, about a century before Daštaki.

Ḵafri's Works. A complete list of Ḵafri's works is given in Ešrāq's aforementioned biography (op. cit., pp. 273-95). It includes some twenty works of varying length, dealing with as diverse subjects as astronomy, mathematics, logic, theology, and Koranic exegesis. His fame seems to have been earned primarily by his works devoted to mathematical astronomy, in particular to the theoretical treatment of planetary motions, a field which was specially developed in Islamic times in order to reform Greek planetary theories. In this regard, Ḵafri's various biographers describe him justifiably with epithets such as "the miracle of his time" in the field which they call "the science of the stars."

The inadequacy of Greek astronomical theories having become widely acknowledged before Ḵafri's time, various astronomers had already started to compete in the production of independent reformulations of those theories. For instance, Ptolemy (fl. 150), the most famous of the ancient Greek astronomers and the most sophisticated of their theoreticians, had set for himself a seemingly simple task, namely to devise mathematical models that could account for the various observable motions of the seven wandering planets known in antiquity, and at the same time to described those models in a language that would be cosmologically consistent with the then generally prevailing Aristotelian conception of the nature of the celestial bodies. He seems to have achieved only a relative success in the first, while failing badly in the second. Though they admired his observational skills and ingenious theories, the astronomers of Islamic civilization did not overlook the faults that were embedded within the Ptolemaic legacy that had reached them. These included major flaws in the observational results, and the fact that the mathematical models of the cosmological structures that he had stipulated for the motion of the planets harbored major inconsistencies. The first four

centuries or so of Islamic astronomy were devoted to the rectification and re-determination of the basic observational results. Once that was achieved, the next step was to attend to the more fundamental issue of the inner consistency of the theories of planetary motions. By the 5th/11th century, enough mistakes and inconsistencies had already been uncovered and clearly articulated to embolden astronomers to embark on the most important project of medieval times, namely to try to bring some inner consistency to the inherited Greek tradition, or, in case of failure, to overhaul that tradition altogether, by creating an entirely new astronomy to replace it. One can safely say that the Copernican revolution was in tandem with this project.

From the 7th/13th century onward, astronomers like Moʾayyad-al-Din ʿOrdi (d. 664/1266), Naṣir-al-Din Ṭusi (d. 672/1274), Qoṭb-al-Din Širāzi (d. 710/1311) and Ebn al-Šāṭer of Damascus (d. 776/1375), to name only the most famous ones, each produced at least one treatise that dealt with this particular project. From among the works that they produced the most influential for the succeeding generations of astronomers were Ṭusi's relatively short work (about 65 folios in most surviving copies) *al-Taḏkera fi ʿelm al-hayʿa*, composed in 657/1259-60, and two works by his student Širāzi, called, respectively, *Nehāyat al-edrāk fi derāyat al-aflāk* and *al-Toḥfa al-šāhiya*. Both of Širāzi's works, which were composed after 679/1281and within a few years of each other, were in essence extensive (some 250 folios each in most surviving manuscripts) commentaries on Ṭusi's *Taḏkera*.

Later astronomers, including Neẓām-al-Din Nišāburi (d. ca. 729/1329), Šarif Jorjāni (d. 815/1413), Fatḥ-Allāh Širwāni (d. 815/1486) and Ḵafri himself, as well as his contemporary ʿAbd-al-ʿAli Birjandi (d. 931/1525), also wrote extensive (approx. 200 folios) commentaries on Ṭusi's *Taḏkera*. However, Ḵafri is responsible for the lion's share of the production of such works, for he actually composed two major astronomical commentaries, one devoted to Ṭusi's *Taḏkera*, which he called *al-Takmela fi šarḥ al-Taḏkera*, and the other to Širāzi's two works, which he called *Montahā al-edrāk fi madārek al-aflāk*, thus echoing the title of Širāzi's own *Nehāyat al-edrāk fi derāyat al-aflāk*.

In the *Takmela*, which has to be considered the cornerstone of Ḵafri's astronomical production, he states quite clearly that he intended to use Jorjāni's commentary on Ṭusi's *Taḏkera* as a base in order to "derive blessings" from his words, although he promised also to go beyond that work by resolving the problems that had been left unanswered by both Ṭusi and Jorjāni. Hence, his choice of the term *Takmela* (completion) for the title. Ḵafri

fulfilled his promise by producing a work of some 250 folios that combed the texts of both his predecessors, but chiefly addressed the work of Ṭusi, the more competent of the two, and supplied whatever new material he considered necessary to resolve the theoretical problems encountered in them – problems that ultimately dated back to the very Greek astronomical tradition upon which they were both based. Far from being the kind of traditional commentary where the author limits himself to explaining the language and intent of the original text in order to make it accessible to students, a category to which Jorjāni's commentary belongs, Ḵafri's commentary used those original texts as a pretext for launching his very own innovative ideas in the guise of commentaries. At times his remarks on a problematic theoretical detail extend to some ten to fifteen folios, and include all the innovative solutions that he himself had devised for the various problems.

The technical details of Ḵafri's contributions to theoretical astronomy have already been surveyed in a recent study of his *Takmela* (Saliba, 1994). This study enables one to follow in detail Ḵafri's objections, not only to the Greek astronomical tradition, but also to the reformulations of that tradition which had been produced in the Islamic period before his time. When taken together, the new proposals that he put forth in the *Takmela* amounted to a veritable reconstruction of the whole system of Greek planetary theories. They spanned all such aspects as the motions of the moon and the upper planets (which included in this tradition Saturn, Jupiter, Mars and Venus), as well as the motion of the inferior planet Mercury.

Not only did Ḵafri manage to resolve all of these issues at once, thereby far surpassing his predecessors, including Širāzi, who was the most competent of them all, but he also managed to articulate a fresh vision of the new kind of astronomy that he was now charting. Unlike Širāzi, who thought that the problems of Greek astronomy were resolvable on the cosmological mathematical level, by resort to a unique mathematical solution which represented the true nature of the planetary motions, Ḵafri was able to see that such problems did not yield a unique mathematical solution, but could be solved in a variety of mathematical ways, all of them meeting the basic requirements of observation and mathematical cosmological consistency. In one stroke, Ḵafri came to recognize the limited nature of mathematical methods for determining the "true" nature of physical phenomena, and that mathematics was simply a language used to describe those phenomena, without any inherent value in determining their reality one way or the other.

This innovative departure from the classical conception of mathematical methods and their role in mathematical astronomy comes closest to the modern conception of the role of mathematics in science in general, which also redefines it as a descriptive language of scientific processes. This crowning achievement already realized by Ḵafri in the sixteenth century is the subject of a recent study on the very nature of this new redeployment of mathematics (Saliba, 1997).

Ḵafri's second monumental astronomical work, which is also some 250 folios in length, is called *Montahā al-edrāk fi madrak al-aflāk*. While the *Takmela* used Jorjāni's commentary on Ṭusi's *Taḏkera* as its base, the *Montahā* used the two aforementioned works of Širāzi instead for that role. In his first commentary, the *Nehāya,* Širāzi had attempted not only to explain Ṭusi's *Taḏkera* but to go beyond by filling the remaining gaps in it, using the work of ʿOrdi. For example, Širāzi ended up producing several mathematical models that could account for the motions of the planet Mercury, giving him reason to boast about his excellence in mathematics. This achievement was especially important because everybody had acknowledged that the motions of the planet Mercury were the most difficult to describe with a mathematical model. This included Ṭusi himself, who conceded in his *Taḏkera* that he was waiting for God's grace to grant him the solution. However, in a much later work called *Faʿalto fa-lā talum*, Širāzi confessed that of the nine mathematical models which he had proposed for the motion of this planet in his *Nehāya*, only one was actually valid. He added that he had explained the faults of six of the other eight in his second commentary on Ṭusi's *Taḏkera*, namely his *al-Toḥfa al-šāhiya*, which he composed a few years after the *Nehāya,* while he had deliberately left the remaining two unexplained in the *Toḥfa* as a test for students. Širāzi's intention was not only to test students and show off his own ability, as he seemed to be doing by taking up this challenge in the first place, but also to keep on pursuing that unique model that would describe the motions of Mercury, as well as all other planets.

In Ḵafri's *Montahā*, we are told that he did not intend to follow the text of just Širāzi's first two works, in the same fashion as he had followed the Jorjāni's text in his *Takmela*, but that he would also follow Širāzi's second, more mature and revised commentary, namely his *al-Toḥfa al-šāhiya*. He seems to have wanted to imply by this that he could outsmart the very best work that Širāzi had been able to produce. By leaving none of Širāzi's problems unanswered, Ḵafri proved his point. In terms of technical innovation, the *Montahā* did not

extend far beyond what Ḵafri had already established in his *Takmela*, but it stressed once more that the planetary motions did not have the unique solutions that Širāzi was hoping to discover.

After having managed to outsmart both Jorjāni and Širāzi at their best, to say nothing of the poor Ṭusi, by using their very own words and individual styles for his own super-commentaries on their respective commentaries, Ḵafri now felt prepared to gather together his final contributions to the field into an independent book of his own, written in his own words. He felt there was no need to exert more effort in detailing the elementary concepts of astronomy, for they had already been covered in dozens of independent elementary astronomical texts, and in such commentaries as the ones he was commenting on and ultimately agreeing with on such elementary matters. But he did feel the need to restate the significant problematic issues that could both characterize the novelty of Islamic astronomy as it was attempting to reformulate Greek astronomy on purely consistent grounds, and at the same time, point to the very nature of the interplay between mathematics as a language and the physical natural phenomena that this language was attempting to describe. Ḵafri tellingly entitled the short treatise (about 60 folios) that he composed to respond to this need, *Ḥall mā lā yanḥall*, or "Resolving That Which Could not be Resolved (by his predecessors)." An article devoted to this work has recently been published (Saliba, 2000; see also idem, "A newly found work…"), and a critical edition of it is currently being prepared (Saliba, 2004).

On the basis of what is known of Ḵafri's aforementioned astronomical works, he already emerges as a genius in mathematical astronomy and a pioneering innovator with a profound insight into the nature of the science of astronomy itself. Only once all of his scientific works have been made available in critical editions, will it be possible to decide whether or not his contribution to the field was really unequaled. Ḵafri's other works, which are theological, legal and mathematical in content, have not been discussed here, since the preliminary studies necessary for an informed assessment of them have not yet been carried out.

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