From: Thomas Hockey et al. (eds.). *The Biographical Encyclopedia of Astronomers, Springer Reference*. New York: Springer, 2007, pp. 623-624

http://dx.doi.org/10.1007/978-0-387-30400-7_754

Khafrī: Shams al-Dīn Muḥammad ibn Aḥmad al-Khafrī al-Kāshī

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Born **probably Khafr near Shiraz, (Iran)**, ***circa* 1470**

Died **probably (Iran), after 1525**

Khafrī was an Iranian theoretical astronomer who produced innovative planetary theories at a time well beyond the supposed period of the decline of Islamic science. Little is known about his life. Various Shīʿī writers claim Khafrī as one of their own religious scholars, and the sources assert that he was influential in the program of the Safavid Shāh Ismāʿīl (died: 1524) to make Shīʿism the official Islamic sect of Iran. The fact that Khafrī wrote works in the fields of both religion and astronomy seems to indicate that at his time and place Islamic religious scholars saw no insuperable conflict between science and religion. This appears contrary to the traditional view that science and religion were constantly at odds in Islamic society, and that, long before the lifetime of Khafrī, religious scholars effectively squelched the scientific impulse in Islam. Other examples of Islamic scientists who also were religious scholars include **Bahāʾ al-Dīn al-ʿĀmilī** and **Niẓām al-Dīn al-Nīsābūrī**.

Khafrī's fame as an astronomer rests mainly on his astronomical treatise *al-Takmila fī sharḥ "al-Tadhkira"* (The completion of the commentary on the *Tadhkira*). This was a commentary on **Naṣīr al-Dīn al-Ṭūsī**'s important astronomical treatise, *al-Tadhkira fī ʿilm al-hayʾa* (Memoir on astronomy). As was the custom of the time, in both the Arabic and Latin worlds, a scholar often presented his own theories within the context of a commentary on the work of an esteemed author.

Consistent with the Islamic tradition in theoretical astronomy, in which astronomers had sought to reform Ptolemaic astronomy by revising **Ptolemy**'s planetary models into physically consistent forms, Khafrī presented new models. Ptolemy had devised models of planetary motion involving spheres that were required to rotate with nonuniform velocity with respect to poles (the most notorious being the equant) other than their centers. In particular, Khafrī presented new models for the motions of the Moon, the upper planets, and Mercury, some more successful than others in meeting the criticisms of earlier astronomers such as **Ibn al-Haytham**.

Khafrī's model for the lunar motion combined the best features of two previous theories, namely those of **Muʾayyad al-Dīn al-ʿUrḍī** and **Quṭb al-Dīn al-Shīrāzī**. He managed to employ only spheres that moved uniformly around their own centers, the basic criterion for physical consistency in Islamic astronomy. Khafrī discussed various solutions to the irregular lunar motions, including

those of Ṭūsī, Shīrāzī, and himself. However, there are some problems with his model. Because he attempted to make the predictions of his model coincide as closely as possible with the Ptolemaic lunar model, especially at the critical points including quadrature, his model replicated certain errors of Ptolemy's model, including the absurd prediction that the Moon should appear twice its actual size. **Ibn al-Shāṭir** had solved this problem, but Khafrī seems to have been unaware of his work. The fact that Khafrī adheres so closely to Ptolemy's observations and reproduces one of the major predictive failings of Ptolemaic theory suggests that Khafrī was more of a theorist than an observational astronomer.

Khafrī solved the equant problem for the upper planets, Mars, Jupiter, and Saturn, by following ʿUrḍī's model with a few adjustments, such as introducing a second deferent as well as an "epicyclet," *i. e.*, an epicycle on an epicycle. Again, this model essentially duplicates all of the Ptolemaic planetary positions while preserving a physically consistent model.

Khafrī described four such models for Mercury's motion, one devised by ʿ**Alī Qūshjī** and three by him. Khafrī employed all of the techniques and theoretical mechanisms devised in the Islamic tradition of mathematical astronomy (the Ṭūsī Couple, epicyclets, *etc.*) and, in each case, the result was a physically consistent model.

The work of Khafrī raises the important question of the status of theoretical models in science. In the *Takmila*, Khafrī offered several possible models for the motion of Mercury, each of which was essentially equivalent in predictive power. This seems to imply that for Khafrī, the model apparently was simply a tool for predicting planetary positions. If so, then Khafrī made a significant departure from his predecessors in the entire Graeco–Islamic tradition. Alternatively, Khafrī may have been attempting to find all the possible solutions to a scientific problem, from which the scientist must employ observational criteria to choose the most correct configuration. In any case, it is not yet known what impact, if any, the work of Khafrī had or whether it led to any broad reassessment of the aims of science in Islam.

Two other works by Khafrī are mentioned in several sources, but have yet to be studied: *Muntahā al-idrāk fī al-hay'a* (The ultimate comprehension of astronomy), written as a refutation or a commentary on the *Nihāyat al-idrāk fī dirāyat al-aflāk* (The ultimate understanding of the knowledge of the orbs) of Shīrāzī; and *Ḥall mā lā yanḥall* (Resolution of that not [yet] solved).

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