From: Thomas Hockey et al. (eds.). *The Biographical Encyclopedia of Astronomers, Springer Reference*. New York: Springer, 2007, pp. 1161-1162

http://dx.doi.org/10.1007/978-0-387-30400-7_1404

ʿUrḍī: Muʾayyad (al-Milla wa-) al-Dīn (Muʾayyad ibn Barīk [Burayk]) al-ʿUrḍī (al-ʿĀmirī al-Dimashqī)

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Born **probably** *ʿUrḍ between Palmyra and Ruṣāfa, (Syria),* ***circa*** **1200**

Died **Marāgha, (Iran)**, ***circa*** **1266**

ʿUrḍī was one of the major figures of Islamic astronomy in the 13th century, and participated in a number of important scientific innovations and developments. Sometime before 1239, ʿUrḍī moved to Damascus, where he worked as an engineer, a teacher of geometry. and, possibly, of astronomy as well. In 1252/1253, as he says in his *Risālat al-Raṣd*, he built the socalled perfect instrument for al-Malik al-Manṣūr, Lord of Ḥimṣ. In the 1250s **Naṣīr al-Dīn al-Ṭūsī** asked him to come to Marāgha in Azerbaijān (now in northwest Iran) to help in the building of an observatory under the patronage of the Mongol ruler Hülegü. The observatory, one of the most important ever built in the Islamic world and arguably the first full-scale observatory in the modern sense, was founded in 1259, and ʿUrḍī arrived in Marāgha in that year (or shortly before). He took part in building the observatory outside the city and erected special devices and water wheels to raise the water to the observatory hill; he also participated in the construction of a mosque and a special building for Hülegü's residence. At the observatory in Marāgha, ʿUrḍī probably joined in the observations for Ṭūsī's *Īlkhānī Zīj* and was mentioned in this treatise. Though a noted astronomer and instrument maker, his participation in the observatory was limited to its early years, in as much as he constructed instruments there only before 1261/1262. Several instruments for which ʿUrḍī tells us he prepared models were actually seen by later visitors, further suggesting that he was not the only instrument maker at Marāgha. His son Muḥammad, also a member of the observatory staff, made a copy of his father's *Kitāb al-Hayʾa* and constructed a celestial globe, now preserved in Dresden, which was used at the observatory. ʿUrḍī, as well as Ṭūsī, was a member of the so called School of Marāgha, which also included **Quṭb al-Dīn al-Shīrāzi** and a number of other astronomers.

ʿUrḍī's *Risāla fī Kayfiyyat al-arṣād* (or simply *Risālat al-Raṣd*) is a rich and informative treatise on observational instruments, preserved in a unique manuscript in Paris. Some of the instruments mentioned in this treatise were well known, others were invented by ʿUrḍī himself. The treatise mentions the instruments built before and up to 1261/1262. The introduction describes the determination of the meridian by means of an “Indian circle.” ʿUrḍī tells us the place and time of the erection of the instruments, and he also outlines his relationship to Ṭūsī. The following instruments are mentioned: a mural quadrant, that seems to be used in general for altitude measurement, as well as for a careful determination of the latitude of Marāgha and the obliquity of the ecliptic; an armillary sphere for the measurement of the ecliptic longitude and latitude; a solstitial armilla for the determination of the obliquity of the ecliptic; an equinoctial armilla for the determination of the entry of the Sun into the equatorial plane and the path of the Sun at the equinoxes; a so called dioptrical ruler of **Hipparchus** for the measurements of the apparent diameters of the Sun and the Moon and the observation of eclipses; an azimuth ring for the determination of the altitude and the azimuth; and several other rulers and instruments, such as the "perfect instrument" for the measurement of the azimuth. ʿUrḍī ends with a critique of the parallactical ruler described by **Ptolemy**. As for the size of the instruments, ʿUrḍī remarks that the instruments should be as large as possible to have the required division of the scales.

ʿUrḍī's *Kitāb al-Hayʾa*, written sometime before ʿUrḍī reached Marāgha in 1259, is a work on theoretical astronomy that includes a critique of Ptolemy's *Almagest* and his *Planetary Hypotheses*. There exist two versions of ʿUrḍī's treatise: an earlier one compiled sometime between 1235 and 1245 and a later version in which he edited whole chapters of his original text to make the arguments more consistent. In the *Kitāb al-Hayʾa* ʿUrḍī introduces the reader to Ptolemaic astronomy and then explains the difficulties arising from some of Ptolemy's methods and techniques. He then presents his own astronomical models as an alternative. For ʿUrḍī, as well as for other astronomers of the so called School of Marāgha, the main problem in Ptolemaic astronomy was the lack of consistency between the mathematical models and the principles of natural philosophy. Examples occurred in the prosneusis point for the Moon, the deferent in the lunar model, the equant in the model for the superior planets, the inconsistencies in the planetary distances, and the inclination and deviation of the spheres of Mercury and Venus that were meant to account for latitude. In ʿUrḍī's opinion, these inconsistencies violated the essential consistency between the theoretical mathematical models and the accepted natural and physical axioms. ʿUrḍī held to the basic principles of Greek astronomy, especially the circular and uniform motion of the heavenly bodies, and the Earth as the unmovable center of the Universe; he also appreciated the validity of the Ptolemaic planetary observations as quoted in the *Almagest*. But he objected to the mathematical models that Ptolemy had devised to describe the motions of the planets. ʿUrḍī tried to find astronomical models that would preserve Ptolemy's observations, and which would also be consistent mathematically as well as physically. To this end, he devised the ʿUrḍī lemma, a developed form of the theorem by **Apollonius** that transformed eccentric models into epicyclic ones. ʿUrḍī stated that if we construct two equal lines on the same side of any straight line so that they make two equal angles with that straight line, be they corresponding or interior, and if their endpoints are connected, then the line resulting from connecting them will be parallel to the line upon which they were erected (*Kitāb al-Hayʾa*, p. 220). The new technique of bisecting the Ptolemaic eccentricity allowed him to preserve Ptolemy's deferent, while preserving the uniform, circular motions of the celestial orbs that revolve on their own centers, thus avoiding the apparent contradictions in Ptolemy's model. ʿUrḍī's *Kitāb al-Hayʾa* was written within a tradition of astronomical literature that was critical of Ptolemy, but it apparently did not depend upon the work of Ṭūsī, who also presented alternative models in several of his works (many of which were based upon the Ṭūsī couple that transforms circular motion into linear motion). ʿUrḍī's work was quoted by **Ibn al-Shāṭir**, and influenced **Bar Hebraeus** and Quṭb al-Dīn al-Shīrāzī. Furthermore, there are many similarities to **Nicholaus Copernicus**'s work. ʿUrḍī's technical alternative to Ptolemy's model for the upper planets is essentially the same as that in Copernicus's *De revolutionibus*.

ʿUrḍī also wrote some minor treatises: a commentary on **Kharaqī**'s astronomical treatise *Kitāb al-Tabṣira fī ʿilm al-hayʾa*, that closely follows Kharaqī's wording (extant in a unique manuscript in Madrid); a supplement to a problem in the *Almagest*, probably preserved in Mashhad and Ankara; a short treatise on the determination of the solar eccentricity, preserved in Ankara and Istanbul; and a *Risālat al-ʿAmal fī al-kura al-kāmila* on the armillary sphere, mentioned in ʿUrḍī's *Risālat al-Raṣd* as well as in his *Kitāb al-Hayʾa*, which seems no longer extant. In addition, ʿUrḍī himself, or his son, copied in 1252/1253 the recension of the *Almagest* by Ṭūsī, which is preserved in Cairo.

Both of ʿUrḍī's main works, the *Risālat al-Raṣd* and the *Kitāb al-Hayʾa*, are characterized by improvement and refinement. On the one hand, he tried to make precise instruments – some standard, others of his own invention – that would result in the best observations possible. The *Risālat al-Raṣd* gives the reader a rare insight into the equipment of a medieval Islamic observatory. On the other hand, he attempted to make the Ptolemaic astronomy more consistent by developing new and highly sophisticated planetary theories, some of them mathematically identical to Copernicus's non-Ptolemaic models.

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