How to cite this document:

Naṣīr al-Dīn al-Ṭūsī. *al-Risāla al-Muʿīniyya*, book 2, chapter 3. In F. Jamil Ragep, Fateme Savadi, Sajjad Nikfahm-Khubravan. *al-Risāla al-Muʿīniyya (al-Risāla al-Mughniya) and its Supplement*. Vol. II, *English Translation* (Tehran: Mirath Maktoob), 39–45.

and south; and the fourth between east and south. Each of these three circles is unique in type but numerous in individuation, according to given localities on the Earth. If one takes a celestial locus and desires to know its distance from the horizon, a circle should be taken that passes through it, namely, that locus, and the two poles of the horizon, i.e., the zenith and its opposite. This circle is called an **altitude circle**. What is between the horizon and that locus on this circle is called the [arc of] altitude. When the star reaches the meridian, this circle will coincide with the meridian; what is between this circle and the initial azimuth on the horizon circle is called the **azimuth** of the star. If the star has no azimuth, its altitude circle will be the initial azimuth. Considering the celestial loci, there are also numerous altitude circles.

[15] From this discussion, nine great circles are now known: [1] the equinoctial; [2] the zodiacal orb; [3] the solstitial colure; [4] the declination circle; [5] the latitude circle; [6] the horizon circle; [7] the meridian circle; [8] the initial azimuth circle; and [9] the altitude circle. This then is the intention of this chapter.

CHAPTER THREE
An Exposition of the Circumstances of the Eighth Orb and the Fixed Stars

[1] Every star, aside from the Sun and Moon (lit., the luminaries) and the five vacillating planets, is reckoned one of the fixed stars, and all of these stars are fixed on the eighth orb, which we call the orb of the fixed stars and the orb of the zodiacal signs. They are called "fixed" due to the slowness of their movement, i.e., fixed compared to the planets, or due to the immutability of their positions [in the sky] and with respect to one another, since these stars always maintain their latitude and move only in longitude. Their longitudinal movements were not perceived by the ancients, who reckoned them as fixed; but later, dur-

ing the time of Ptolemy and Menelaus, their movement was perceived, and it was said that every hundred solar years they move one degree. When the moderns compared their observations with those of the ancients, [it became known] they move one degree every sixty-six solar years. The view of this latter group has been accepted.

[2] Each of these stars has two circuits: one for primary motion, which is one of the diurnal circuits; and the other one for the second motion, which is one of the latitude circuits. The latitude circuit never becomes larger and smaller—because the latitude of these stars is never-changing—but the diurnal circuit does become larger and smaller. Therefore, every star that has no latitude, by being on the zodiacal equator, reaches the equinoctial equator twice in every revolution, [and therefore] for about 12,000 years it is in the north, and for about 12,000 years in the south. A star whose latitude is less than the total obliquity also reaches the equinoctial equator twice, but the duration of its stay in the north and south is unequal. One whose latitude is equal to the total obliquity reaches the equinoctial equator once in every revolution, but does not shift from side to side. One whose latitude is greater than the total obliquity never reaches the equinoctial equator. One whose latitude is equal to the complement of the total obliquity reaches the pole of the equinoctial equator once in every revolution and then has no diurnal circuit.

[3] Now it has become known from this that the positions of the fixed stars with respect to the horizon of any given locality fluctuate. Sometimes [a star] that never rises will come to rise when its colatitude is greater than the difference between the latitude of the locality and the total obliquity; and sometimes a permanently visible one becomes invisible under the same condition. Sometimes [a star] that used to transit the zenith will move away from the zenith, and sometimes one that did not reach the zenith will transit it. After one complete revolution, they all return to their initial positions. When Polaris [α Ursae

Minoris], a star in *Banāt al-naʿsh-i ṣughrā* [Ursa Minor] whose latitude is close to the complement of the total obliquity, reaches the first of Cancer—which will be after 870 years from our current date—it will fall closer to the north [celestial] pole, and then observation of the pole will be easy, since its altitude will be equal to the latitudes of the localities.

[4] There are too many fixed stars to enumerate, as can be easily perceived. However, the larger ones, on which the gaze can be fixed, have been counted. They are said to be of six magnitudes. The largest are of the first magnitude, then the second magnitude, and so on to the sixth. Those of the sixth magnitude are one sixth of those of the first magnitude, and those of the fifth magnitude are one third and so on. All the counted and observed stars are 1,022: first magnitude, 15; second magnitude, 45 stars; third magnitude, 208 stars; fourth magnitude, 474 stars; fifth magnitude, 217 stars; and sixth magnitude, 49 stars. There are nine obscure stars, which Ptolemy calls "faint."[1] There are five nebulae which are like wisps of cloud. There are three other stars similar to faint stars, which are called Dhuʾāba or Ḍafīra; they are not included among the stars.

[5] For convenience, constellations have been imagined out of several stars, so that they can be easily specified in such a way that a given star can be said to be "on the hand" or "on the head" of a given constellation. There are 21 such constellations to the north [of the zodiacal equator], 12 on the zodiacal equator, and 15 to the south [of the zodiacal equator]. Some of these stars are within the constellations, while others are outside the constellations. The constellations are as

1. In the *Almagest*, these are called amauros, which Toomer translates as faint (Claudius Ptolemy, *Ptolemy's Almagest*, trans. G.J. Toomer (London: Duckworth,1984), 16).

follows:[1]

[6] Northern Constellations:

(1) Ursa Minor, contains seven stars, one outside;
(2) Ursa Major, contains twenty-seven stars, seven[2] outside;
(3) Draco, contains thirty-one stars;
(4) Cepheus, contains eleven stars, two outside;
(5) Boötes, contains twenty-two stars, one outside;
(6) Corona Borealis, contains eight stars;
(7) Hercules, contains twenty-nine[3] stars, one outside;
(8) Lyra, contains ten stars;
(9) Cygnus, contains seventeen stars, two outside;
(10) Cassiopeia, contains thirteen stars;
(11) Perseus, contains twenty-six stars, three outside;
(12) Auriga, contains fourteen stars;
(13) Ophiuchus, contains twenty-four stars, five outside;
(14) Serpens, eighteen stars;
(15) Sagitta, five stars;
(16) Aquila, nine stars, six outside;
(17) Delphinus, ten stars;
(18) Equuleus, four stars;
(19) Pegasus, twenty stars;

1. There are problems with the numbers for a few constellations (noted in the following footnotes). These are discrepancies with what one finds in the *Almagest* that result in totals different from those Ṭūsī gives. We have left these "mistakes" in both the edition and the translation, since they are attested by our most reliable manuscript witnesses. As far as we can ascertain, Ṭūsī here relied on a manuscript of Kharaqī's *Muntahá* that may have been the origin of these mistakes. However, in his recension of the *Almagest* (completed in 644 H/1247 CE), he has the "correct" numbers. One hopes further research will clarify the situation.

2. Eight in the *Almagest* (343).

3. Twenty-eight in the *Almagest* (349).

(20) Andromeda, twenty-two[1] stars;
(21) Triangulum, four stars.

[7] Constellations of the zodiacal equator:

(1) Aries, thirteen stars, five stars outside;
(2) Taurus, thirty-three[2] stars, eleven stars outside;
(3) Gemini, eighteen stars, seven stars outside;
(4) Cancer, seven[3] stars, four stars outside;
(5) Leo, twenty-seven stars, eight stars outside;
(6) Virgo, twenty-six stars, six stars outside;
(7) Libra, eight stars, nine stars outside;
(8) Scorpius, twenty-one stars, three stars outside constellation;
(9) Sagittarius [*Rāmī*] which is called *Qaws*, thirty-one stars;
(10) Capricorn, twenty-eight stars;
(11) Aquarius [*Sākib al-māʾ*] which is also called *Dalw*, forty-two stars, three stars outside constellation;
(12) Pisces, thirty-four stars, four stars outside.

[8] Southern Constellations:

(1) Cetus, twenty-two stars;
(2) Orion, thirty-eight stars;
(3) Eridanus, thirty-four stars;
(4) Lepus, twelve stars;
(5) Canis Major, eighteen stars, eleven stars outside;
(6) Canis Minor, two stars;
(7) Argo, forty-five stars;

1. Twenty-three in the *Almagest* (360).
2. Thirty-two in the *Almagest* (363).
3. Nine in the *Almagest* (366).

(8) Hydra, twenty-five stars[1];
(9) Crater, seven stars;
(10) Corvus, seventeen[2] stars;
(11) Centaurus, thirty-seven stars,
(12) Lupus, nineteen stars;
(13) Ara, seven stars;
(14) Corona Australis, thirteen stars;
(15) Piscis Austrinus, eleven stars, six stars outside.

[9] Thus the sum of the stars of the northern constellations is 360. The sum of the stars of the zodiacal constellations is 346, and of the southern constellations, 316.

[10] The names of the zodiacal constellations have been given to the twelve divisions of the zodiacal equator—i.e., the Twelve Signs—because, by chance, they are equivalent to these divisions. As these stars move from those places, they say, e.g., that the stars of Aries have entered Taurus. Nonetheless, the name of Aries—which is the first of the zodiacal divisions and is contiguous with the point of the vernal equinox—remains fixed. If Aries were to be called Pisces, it would make no difference because the important thing is the meaning, not the name. The twelve signs, to which the six latitudinal circles give rise, primarily for the zodiacal sphere and secondarily for all the spheres of the stars, have no connection with the bodies of the stars. Since all parts of the zodiacal sphere move with the primary motion, its two poles move around the two poles of the equinoctial equator. When it reaches the greatest and lowest altitude of its path, i.e., on the meridian, the solstitial colure coincides with the circle of the meridian.

1. *Almagest* adds 2 outside (393).

2. Seven in the *Almagest* (394).

[11] The Arabs divide these constellations in a different way. They imagine twenty-eight stations close to the equator, and these they call the "mansions of the Moon," since a complete revolution of the Moon is accomplished in approximately twenty-eight nights. The names of the mansions are: (1) Sharaṭayn; (2) Buṭayn; (3) Thurayyā; (4) Dabarān; (5) Haqʿa; (6) Hanʿa; (7) Dhirāʿ; (8) Nathra; (9) Ṭarf; (10) Jabha; (11) Zubra; (12) Ṣarfa; (13) ʿAwwā; (14) Simāk; (15) Ghafr; (16) Zubānā; (17) Iklīl; (18) Qalb; (19) Shawla; (20) Naʿāʾim; (21) Balda; (22) Saʿd-i dhābiḥ; (23) Saʿd-i bulaʿ; (24) Saʿd-i suʿūd; (25) Saʿd-i akhbiya; (26) Fargh muqaddam; (27) Fargh muʾakhkhar; (28) Rashā.

[12] Every $2+\frac{1}{3}$ of these mansions is a zodiacal sign, and the relation of the stars of the mansions to the mansions is exactly the relation of the stars of the constellations to the constellations. Anyone who wants to learn about the fixed stars in detail should consult books on this science, which is an art unto itself. The best book done on this subject is the *Ṣuwar al-kawākib* by ʿAbd al-Raḥmān Ṣūfī. This is all we intended to say about the fixed stars—with God is success.

CHAPTER FOUR

An Exposition of the Orbs and the Motions of the Sun

[1] When the circumstances and motions of the Sun were observed, it was found to be moving from west to east by its own proper motion such that it makes one revolution in one solar year. However, it does not cut equal arcs on the [zodiacal] orb in equal periods of time but rather moves faster in one half of the [zodiacal] orb and slower in the other half. Considering the uniformity of circumstances that must pertain in celestial matters, this fastness and slowness in speed is possible by either one of two ways.

[2] The first is that the Sun's body moves on the circumference of an orb whose center is eccentric to the center of the World, while it en-