by Beck, in his *Ephemerides Persarum per totum annum*, Augsburg, 1696 (especially chs. iii.–iv., vi.). Even to-day the astrologer's art in casting a horoscope holds an important place in the life of the ignorant and superstitious folk of Persia, and it still survives, though it is gradually disappearing, among the Zoroastrian Parsis of India (cf. Karaka, *History of the Parsis*, London, 1884, i. 160–162).

LITERATURE.—For a translation of the Avesta and the Pahlavi books consult the versions by Darmesteter and West in *SBE*, vols. iv., xxiii.; and v., xviii., xxiv., xxxvii., and by Mills, *ib.* xxxi.; likewise the French translation by Darmesteter, *Le Zend-Avesta*, 3 vols., Paris, 1892–1893. The more important single works on the subject have been given in the course of the article.

A. V. WILLIAMS JACKSON.

SUN, MOON, AND STARS (Japanese).—In the ancient mythology of Japan the sun-goddess plays the most important rôle, while the moon-god, her brother, occupies an insignificant place, and almost nothing is told about stars. The commonly accepted story is that the sun-goddess (Amaterasu, 'the heaven-shining deity') and the moon-god (Tsuki-yomi, 'the ruler of the moonlight night') were born, together with the storm-god (Susa-no-wo, 'the swift-impetuous'), of the couple who were the progenitors of the Japanese archipelago.[1] In this story the creation of these deities is conceived evidently as a generative act, whereas another version makes the emergence of the two deities from the 'white copper' mirrors the work of the male progenitor alone. Perhaps a more interesting version of the story is that the sun and the moon were produced out of the eyes of the progenitor, when he was washing in order to purify himself from the stains with which he had been contaminated on his visit to the infernal world after the death of his consort.[2] Though there are these different versions, the common trait and predominant factor in the story is that the sun-goddess is considered to be the supreme ruler of heaven and earth, and also the progenitrix of the ruling family, who claim to have handed down from the goddess herself the three insignia of the throne (see below). Now the relation between the sun-goddess and the moon-god is based on the natural phenomenon that the two are visible alternately by day and by night. The story is as follows:

> The sun-goddess once commissioned her brother, the moon, to go down from their heavenly abode to earth to see Ukemochi, the female genius of food. When the latter entertained the moon with the food-stuffs taken out of her body, the moon became flushed with anger and slew the goddess of food. The sun-goddess was so displeased with her brother's wantonness that she said to him: 'Thou art a wicked deity. I must not see thee face to face.' Hence the sister and brother appear alternately in heaven.[3]

The intention of the story is evident, but at the same time it shows a characteristic of the sun-goddess as the matron of agriculture, which played a great part in the myths and worship of the goddess.[4] Thus, in contrast to the prominent rôle played by the sun-goddess, the moon plays a very inferior part, and a much smaller part is played by the stars. A star-god is mentioned in the ancient myth, but his rôle is quite ambiguous, while a festival in honour of certain stars (the stellar constellations called the Herdsman and the Weave-maid) was derived from China. All other stories and worship of stars are much later and were introduced chiefly through Buddhist agency, though some of them may have been derived from other sources—Hindu, Persian, or Chinese. The most prominent star-worship is that of the Pole star, together with Ursus Major. These stars, conceived as one deity, are worshipped by the Buddhists as the protector of the country as well as of individual fortune, while the Shintōists identify them with the Taoist 'palace of iridescent subtlety' (Shi-bi-kyū in Sino-Japanese), where the highest deity of Shintō, the 'eternal-ruling' (Minaka-nushi), is believed to reside. But this Shintō worship is of late origin; it was specially emphasized by a Shintō theorizer in the early part of the 19th century.

When Buddhism was introduced into Japan (6th cent.) and questions came up as to the relationship between the indigenous deities and the Buddhist pantheon, the Buddhist teachers tried to discover analogies between them and to explain that the Buddhist deities were the original noumena and the native ones their lateral manifestations. The most striking analogy was found between the sun-goddess and the aspect of Buddha's personality conceived in the sun-myth. The difference in gender concerned the syncretist but little, partly because the Japanese language had no genders and partly because the noumenon and the manifestation may take any sex. The result was an identification of the Japanese sun-goddess with Buddha Vairochana ('the illuminator'), and this conception exercised a wide influence on doctrine and worship during the sway of the syncretic Shintō from the 8th cent. down to the middle of the 19th, when the combination was dissolved by force. Among the theorizers of the syncretism we may cite one, Kanera (1402–81), who explained sun, moon, and stars as corresponding to the three insignia of the throne, *i.e.* the sun to the mirror, the moon to the jewel, and the stars to the sword.[1] This eclectic theory was backed by the popular conception of the 'three illuminating bodies' (*San-kō*) and their worship. People even nowadays regard a simultaneous appearance of the three as an auspicious occasion for worship and as a sign of special blessing to the country—*e.g.*, when on an autumn day the clear sky and the comparatively weak light of the sun cause the new moon and a certain star (Venus) to be visible to the eyes. Naturally, various configurations of the celestial bodies were used for methods of divination and predictions. In these methods Hindu, Persian, and Chinese elements may be detected, and their influence is still a living force among the mass of the people.

LITERATURE.—Besides the works cited in the footnotes, see M. Anesaki, *Japanese Mythology* (=vol. viii. of *The Mythology of All Races*), Boston, 1920.

M. ANESAKI.

SUN, MOON, AND STARS (Muhammadan).—I. *ASTROLOGY*.—1. Name.—Among the Muslims the technical name of astrology is *'ilm* (or *ṣinā'at*) *aḥkām an-nujūm*,[2] 'science (or art) of the decrees of the stars,' *'ilm al-aḥkām*, 'science of the decrees.' Sometimes, though rarely, in place of *aḥkām* its synonym *qaḍāyā* is found. Another name is *an-najāmah* (*nijāmah*) or *'ilm an-najāmah*. On the other hand, the names *'ilm* (*ṣinā'at*) *an-nujūm*, 'science (or art) of the stars,' *'ilm at-tanjīm*, mean astronomy as well as astrology, and they also mean both of these sciences taken together. The word *aḥkām* also signifies 'judgments,' 'judicial decisions'; accordingly the first of the denominations given above was in the Middle Ages translated in the Latin versions of Arabic works by *scientia judiciorum stell-*

[1] See *Nihongi: Chronicles of Japan*, tr. W. G. Aston (*Proc. Japan Soc. of London*, Suppl. to vol. i. [1896]), p. 18 f.; and, for the following stories, pp. 20, 32, etc.

[2] See *Koji-ki, or Records of Ancient Japan*, tr. B. H. Chamberlain (*TASJ*, Suppl. to vol. x. [1883]), pp. 42–44. This version is preserved also in *Nihongi*, p. 32, and, for its connexion with the conception of life and death, see art. LIFE AND DEATH (Japanese).

[3] *Nihongi*, p. 32.

[4] Aston, *Shinto*, London, 1905, p. 282 f., where the ritual to the goddess for harvest is cited.

[1] See art. PHILOSOPHY (Japanese), vol. ix. p. 870.

[2] As in the case of the other branches of scientific literature, so for astrology the Musalmān peoples made use of the Arabic language.

arum, and thence came the name of *astrologia judiciaria* or *astronomia judiciorum*, astrology, as opposed to *astrologia* (*astronomia*) *quadrivialis* (or *doctrinalis*), which is astronomy. Thus in the denomination of astrology among the Musalmāns there is a concept somewhat different from that contained in the Greek term [τέχνη] ἀποτελεσματική, 'science of the fulfilment [of astrological prognostications].' The astrologer is usually called by the same name as the astronomer, viz. *munajjim* (much more rarely *najjām*); sometimes, however, he is called by the special word *aḥkāmī* (plur. *aḥkāmiyyūn*, *aṣḥāb ṣināʿat al-aḥkām*). It was only in the 19th cent. that the distinction between *munajjim*, 'astrologer,' and *falakī*, 'astronomer,' was introduced into Arabic (at least in Egypt and in Syria).

2. Divisions.—The Muhammadans usually arrange the science of astrology under five principal heads:

(*a*) The fundamental principles of astrology, viz. the different divisions of the ecliptic, the properties of the various celestial places and of individual planets, the methods of determining the ascendant and the 12 celestial houses (*buyūt*, 'domus'), the planetary conjunctions, etc.

(*b*) Prognostics of a universal character (*al-aḥkām ʿalā umūr al-ʿālam*), viz. those which refer to the vicissitudes of kingdoms, dynasties, religions, and cities, to wars, epidemics, famines, winds, rains, the prices of goods, etc. This part of astrology, which Ptolemy calls ἀποτελεσματικὴ καθολική, 'universal apotelesmatics,' is usually called by the Arabs *taḥāwīl sinī al-ʿālam*, 'revolutiones annorum mundi,' since a great part of these prognostics is deduced from the planet which has the dignity of 'significator' (ἀφέτης, *dalīl*, *haylāj*) at the moment when the sun enters Aries, *i.e.* at the beginning of each tropic year. This universal part of astrology is subdivided into three sections: (i.) predictions drawn from the various kinds of planetary conjunctions (*qirānāt*, *iqtirānāt*), (ii.) predictions based on the 'revolutiones annorum mundi,' (iii.) predictions relating to the 'mutationes aëris' (*taghayyur al-hawāʾ*), *i.e.* to meteorological phenomena, and which are deduced from the lunar stations, or from the heliacal rising of Sirius, etc.

(*c*) Individual prognostications relating to the vicissitudes of individuals, derived from the planet or other celestial place which may happen to be the 'significator' at the moment of birth, and then from the 'significator' at each revolution of successive tropic years. This part of astrology Ptolemy calls γενεθλιαλογική, and the Arabs *al-mawālīd*, 'nativitates.'

(*d*) *Masāʾil*, 'interrogationes' (ἐρωτήσεις), or that part of astrology which is concerned with replies to questions, *e.g.*, the circumstances of a distant relative, the author of a theft, the hiding-place of a runaway slave, etc. The 'interrogationes' are always connected by the Muhammadan astrologers with the division of the heavens into 12 'domus.' The astrologers who follow the pure tradition of Ptolemy do not admit the 'interrogationes.'

(*e*) *Iḫtiyārāt*, 'electiones,' *i.e.* the choice of the propitious moment for doing any particular thing. The most common method is that of determining such a moment by seeking in which of the 12 celestial 'domus' the moon is found at that particular moment. This was also very probably the method employed by the Greeks; but along with this some Muhammadan astrologers use another method, of Indian origin (but also attributed to Dorotheus), which consists in deducing the fitting moment for action from the place which the moon then occupies in one of the 28 lunar stations or mansions (*manāzil*). The 'electiones' also are not admitted by the astrologers who follow Ptolemy's teaching.

3. Place among the sciences.—The science of the stars, says Ptolemy at the beginning of his *Tetrabiblos*, or *Quadripartitum*, consists of two parts: the first studies the appearances of the motions of the heavenly bodies either with respect to each other or with respect to the earth; the second seeks to deduce, from the physical qualities of those appearances, the changes which take place in the sublunar world. The first part is a science which stands by itself, and can be studied independently of the second; this, on the contrary, cannot do without the first. This conception that astrology is but the sister of astronomy, a branch, that is to say, of the 'science of the stars,' which in its turn is a part of 'mathematics' (*ʿulūm riyāḍiyyah*, *ʿulūm taʿlīmiyyah*, *taʿālīm*), is common to all the Musalmān astrologers and astronomers, and is accepted also by some philosophers (al-Fārābī in his *de Scientiis*, and the Iḫwān aṣ-ṣafāʾ, or 'sincere companions' of the 10th cent. in their *Epistles*), by the author of the *Mafātīḥ al-ʿulūm*, or 'Encyclopædia of the Sciences' (10th cent.), and by the great historian philosopher Ibn Ḫaldūn (*Proleg.* lib. vi. cap. 13; M. G. de Slane's Fr. tr., Paris, 1862–68, iii. 122 f.).

Astrology, however, is classified in a different way by the majority of the philosophers. Musalmān writers commonly divide all science into two great categories: (*a*) sciences which relate to religious law (*ʿulūm sharʿiyyah*), that is to say, in addition to theology and canon law, the learning which serves as an introduction to them, namely, grammar, lexicography, rhetoric, poetry, history, etc.; (*b*) intellectual or philosophic sciences (*ʿulūm ʿaqliyyah* or *ḥikmiyyah*), which the author of the *Mafātīḥ al-ʿulūm*, thinking of their origin, calls *ʿulūm al-ʿajam*, 'foreign sciences.'[1] The intellectual or philosophical sciences in their turn are for the most part divided into the three sections[2] already fixed by the later Greek peripatetics and by the Neo-Platonic expounders of Aristotle (*e.g.*, Ammonius, Simplicius, and Johannes Philoponus), namely: (*a*) metaphysic (*al-ḥikmah al-ilāhiyyah*, θεολογία, τὰ μετὰ τὰ φυσικά); (*b*) natural sciences (*al-ḥikmah aṭ-ṭabīʿiyyah*, 'natural philosophy,' φυσική); (*c*) mathematical sciences (*al-ḥikmah ar-riyāḍiyyah*, μαθηματική). These last correspond to the *Quadrivium* of Boethius, namely, arithmetic, geometry, astronomy, and music; on the other hand, the natural sciences are subdivided into eight fundamental parts, named for the most part after the titles of the corresponding Aristotelian works, namely: *Auscultatio physica*, *Generatio et corruptio*, *Cœlum et mundum*, *Meteoræ*, *Mineralia*, *Vegetalia*, *Animalia*, *de Anima*. Avicenna (*Fī aqsām al-ʿulūm al-ʿaqliyyah*, in *Tisʿ rasāʾil*, Constantinople, 1298 A.H. [=A.D. 1881], p. 71 ff.), Muḥammad al-Akfānī as-Saḫāwī (*Irshād al-qāṣid*, ed. A. Sprenger, Calcutta, 1849; the author died in 749 A.H. [=A.D. 1348]), Ḥājjī Ḫalīfah (in the introduction to his *Lexicon bibliographicum et encyclopædicum*),[3] and others consider astrology as one of the 7 (or 9) *furūʿ*, 'secondary branches' of the natural sciences, placing it, that is to say, beside medicine, physiognomy, interpretation of dreams, alchemy, the science of talismans, etc. This same classification of the natural sciences is found in al-Ghazālī († 505 A.H. [=A.D. 1111]), who, in his *Tahāfut al-*

[1] Each of these two great categories afterwards gives place to the distinction between theoretical (*naẓariyyah*) and practical (*ʿamaliyyah*) science—a distinction which has its origin in Aristotle (E. Zeller, *Die Philosophie der Griechen*³, Tübingen, 1875–81, II. ii. 177).

[2] Other divisions, indicated in the writings of the Iḫwān aṣ-ṣafāʾ, in the *Mafātīḥ al-ʿulūm*, etc., are useless for our present purpose.

[3] Ed. G. Flügel, 8 vols., London, 1835–58.

falāsifah, Cairo, 1319 (1901), p. 63 f., refers to it as common amongst the Musalmān peripatetics, and approves of it.

Averroës, in the *Tahāfut al-tahāfut*, Cairo, 1319 (1901), p. 121, admits, as corresponding to Aristotelian teaching, the eight fundamental parts of the natural sciences; but he denies that the so-called derived branches are sciences. Medicine, he says, is an art (*ṣinā'ah*) and not a science; it has a practical and not a theoretical character; accordingly astrology is included in the same category with divination from the flight of birds and from the movement of quadrupeds (*zajar*), with divination in the form of vaticinations (*kahānah*), with physiognomy and with the interpretation of dreams, all being arts which have as their aim the prediction of the future, but which 'are not sciences either theoretically or practically, however it may be supposed that one may sometimes derive some practical advantage from them.'

A curious classification is found at the beginning of the unedited book *de Interrogationibus* (*Fī'l-masā'il*) of the astrologer Ya'qūb al-Qaṣrānī, who lived in the 3rd cent. A.H. (9th A.D.). According to the catalogue of the Arabic MSS of Berlin (W. Ahlwardt, *Verzeichniss der arab. Handschriften*, Berlin, 1887–99, v. 275, no. 5877), he maintains three degrees (*marātib*) of science: theology, medicine, science of the stars; the last, being based not on observation, but on deduction from analogy, occupies a place between the other two.

4. Sources.[1]—(*a*) *Greek*.—These are represented by the classic (if we may call it so) astrology of the *Tetrabiblos* or *Quadripartitum* of Ptolemy; by the writings of Dorotheus Sidonius (1st cent. A.D.), which go back to the Græco-Egyptian tradition; by the great eclectic compilation of Vettius Valens (2nd cent. A.D.);[2] by the book on the 'decani,' the 'interrogationes,' and the nativities of Antiochus of Athens (2nd or 3rd cent. A.D.), which appears especially to follow the Babylonian tradition; by the Καρπός, or *Centiloquium*,[3] falsely attributed to Ptolemy; by some works ascribed to the mythical Hermes;[4] and by an author whose name (Rīmos?, Zīmos?) is cited by Arabic writers in a form so corrupt as to be unrecognizable. Of another Greek writer, Teucer or Teucrus of Babylon, the Arabs had knowledge through Iranian sources.

(*b*) *Indian*. — The Musalmān writers mention seven or eight Indian astrologers, whose names, however, it has not as yet been possible to identify with the corresponding Sanskrit. The most important is K.n.k.h or K.t.k.h, who, according to some Arabic writers, appears to have come to Baghdād to the court of the khalīf al-Manṣūr, bringing thither astronomical books of India, and, according to others, making known Indian arithmetic. The Arabs attribute to him writings on the *numūdār* (that is, on the method of ascertaining a factitious ascendant of the nativity), on the nativities, and on the conjunctions of the planets; it is therefore plain that he had also treated of the part of Indian astrology called in Sanskrit *horā* or *jātaka*, which arose through Greek influence. This confirms a conjecture of F. Boll (*Sphaera*, Leipzig, 1903, p. 414 f.), who, from the citations contained in the *Introductorium* of Abū Ma'shar (or Albumasar), infers that K.n.k.h had before him materials of distant Greek origin for his representation of the figures arising in the heavens together with the 'decani.' But in general, Musulmān astrologers cite simply 'the Indians' (*al-Hind*), without particular names of authors. We must further add that the influence of Indian astrology made itself felt sometimes through Iranian writings and oral teaching, as is apparent from some Indian words which have passed into Arabic terminology in an Iranian form—*e.g.*, *darījān* (Ind. *drekkāṇa*).

(*c*) *Iranian*.—These are in the Pahlavī language or Middle Age Persian. The writings of Teucrus of Babylon (second half of the 1st cent. A.D.) on the figures arising in the heavens together with the 'decani' reached the Arabs through a Persian version, where the name of the author, on account of the ambiguity of the Pahlavī writing, was afterwards spelt by the Persians and Arabs Tinkalūs (also Tankalūs or Tankalūshā); so that in the *Introductorium* of Abū Ma'shar his teachings were given as 'teachings of the Persians' (*madhhab al-Furs*) and contain also some Persian names of constellations (cf. Boll, p. 415 f.). Another source was Buzurjmihr's commentary on the astrological Ἀνθολογίαι of Vettius Valens; the Pahlavī translation of the Greek title was *vižīdhak*, 'selected,' which became in Arabic *al-bizīdhaj* and was afterwards variously and strangely corrupted by Arabic writers.[1] The Musalmāns also cited as a source of astrological teachings the mythical Zoroaster (Zarādusht in Arabic writings, Zardusht in modern Persian writings), whose name indeed was already frequently found in Greek astrology of the 4th and following centuries. A fourth source is the book on 'nativities' of [al-]Andarzghar, son of Zādānfarrūḫ; but we lack information about this personage, whose name is corrupted into Alendezgod in the Latin version of Alcabitius (al-Qabīṣī), and into Andruçagar in the Latin version of the book of the Jew Ibn 'Ezrā on nativities (which always draws on Arabic sources). Those astrological writings which are ascribed by the Arabs to Jāmāsp the Wise (the trusted counsellor of the mythic king Gushtāsp) seem to be late Muhammadan falsifications.

We do not know exactly when all these works hitherto mentioned were first translated into Arabic, but it is certain that the great majority of them were known in the second half of the 8th cent. A.D., that is, when Musalmān culture began. If the indication placed at the end of the unedited '*Ard miftāḥ an-nujūm* of Hermes (MS in Biblioteca Ambrosiana in Milan) is true, this book would seem to have been translated in the month Dhū 'l-qa'dah, 125 A.H., namely, in September 743 A.D., while the Umayyad khalīfs were still reigning. The first version of the *Tetrabiblos* is due to Abū Yaḥyā al-Baṭrīq, a translator of the time of al-Manṣūr, the second 'Abbāsid khalīf (136–158 A.H. [A.D. 754–775]); Dorotheus and Antiochus are already mentioned in the writings of Mā shā' Allāh (Messahala) in the second half of the 8th cent.; all the other Greek authors mentioned above are amply cited by the astrologers of the 9th century. As has already been said, the writings of the Indian K.n.k.h seem to have been known at Baghdād in the time of the khalīf al-Manṣūr; and about the middle of the 9th cent. we have already several small astrological works of al-Kindī (Alchindus) formed expressly on Indian models. It is almost certain that the Persian books were translated by members of the family

[1] For details see the present writer's Arabic lessons on the origins of astronomy among the Arabs (*'Ilm al-falak, ta'rīḫuhu fī 'l-qurūn al-wusṭā*, Rome, 1911–12), pp. 189–215 (Iranian sources), 216–220 (Greek sources), etc.

[2] Muhammadan astrologers were also acquainted with the *Anthologiæ* of Vettius Valens through an Arabic translation of a Pahlavī version; cf. below, under (*c*).

[3] The Arabic tr. is rather a paraphrase, which attempts to interpret the theories obscurely indicated in the Greek text.

[4] Some of the works attributed to Hermes seem to be Musalmān falsifications—*e.g.*, the book *de Revolutionibus nativitatum*, which has reached us in a Latin translation.

[1] In the Latin version of Albohazen Haly filii Abenragel, *De iudiciis astrorum*, Basel, 1571, the name of the book is *Yndidech* (p. 149, col. b), *Enzirech* (p. 176, col. a), *Endenadeyg Persarum* (p. 347b), *Endemadeyg Persarum* (348b), *Andilarehprosu* (404b).

Nawbaḫt, known by their translations from Pahlavī into Arabic (cf. *Kitāb al-Fihrist*, pp. 244, 274), whose head was astrologer at the court of al-Manṣūr; and in any case the antiquity of Iranian influence in astrology is attested by the fact that in the works of Mā shā' Allāh, according to the Latin translation of John of Seville, technical terms of Iranian origin are freely used: *e.g.*, *alhyleg* (*alhaylāj*), *alcochoden* (*al-kadḫudāh*), *alimbutar* (*al-jānbaḫtān*).

Side by side with the written sources there was, without doubt, the oral tradition of the peoples converted to Islām.[1] Among the Syrians Christianity had almost suffocated astrology, although Bardesanes (154–222) had reconciled Christian dogma with an attenuated form of predestination by means of the stars; all the same we know that at Ḥarrān, the ancient Carrhæ, special astrological traditions flourished along with other pagan sciences. It is further probable that Theophilus, son of Thomas, a Christian of Edessa who was astrologer of the khalīf al-Mahdī (A.D. 775–785), and who has been cited by several Musalmān astrologers as an authority on the subject of 'electiones,' again took up with Syrian oral tradition. In the same manner it is natural that there were absorbed into Musalmān culture the astrological beliefs and practices of the Aramaic centres (tending to paganism) of Mesopotamia and Babylonia, of the Egyptians, etc. Finally, we must not forget the Judaic element which had a notable part in the first ages of Musalmān astrology; in fact, among the principal writers on astrological matters in Arabic in the 2nd and 3rd centuries of the Hijra are the Jews Mā shā' Allāh, Sahl ibn Bishr, Rabban aṭ-Ṭabarī, and Sanad ibn 'Alī.

5. Special character.—The civilized peoples over whom the Arabic domination of the 7th, 8th, and 9th centuries extended, viz. Greeks, Copts, Syrians, Persians, and Indians, had already imagined all the possible fundamental combinations concerning the influence of the stars over mundane events; consequently it was impossible for the Musalmān astrologer to find out anything substantially new. On the other hand, the principal justification of astrology consisted precisely in presenting itself as the jealous preserver of that which an age-long experience had taught the wise of preceding generations. The office of the Musalmān astrologers consequently was reduced to a choosing of what seemed suitable among the many principles and methods of their predecessors, and at times to a harmonizing of elements of very diverse origin, amplifying and completing particular points on which it was easy to give free rein to fancy. All this, as we have said, was done with the widest eclecticism. But, though nothing really original is met with in the field of apotelesmatics properly so called, there is, all the same, a point on which Arabo-Musalmān astrology is far superior to other astrologies, including the Greek, and represents a real progress. This consists of a wide and continued application of spherical astronomy and of exact mathematical processes to the methods of astrological research. Among the Greek astrologers the calculations are very rough; arcs of the ecliptic are substituted for arcs of the equator, right ascensions for oblique ascensions; rough tables, useful for a determined terrestrial latitude, are also employed for different latitudes; the latitudes of the planets are neglected in the calculation of the radiations ('projectiones radiorum,' *maṭāriḥ ash-shu'ā'*). Among the Greeks we seek in vain for a clear exposition of the method of determining mathematically the 12 heavenly 'domus,' which, however, form one of the hinges of the astrological system. Ptolemy himself, teaching minutely in the *Tetrabiblos* how the 'directio' (ἄφεσις) is calculated, completely neglects the latitude of the planets. Characteristic is the fact that Ptolemy, in the *Almagest*, occupies himself with three problems useful only to astrologers (inclination of the shadow of the eclipses with respect to the ecliptic and to the horizon, position of the stars with respect to the sun in consequence of the daily motion of the sphere, appearances and occultations of the planets with respect to the solar rays), and which even in astrology are of very small importance; and, on the other hand, he does not make the slightest allusion to other problems of spherical astronomy which would be of capital importance for apotelesmatics. Musalmān astronomers, on the contrary, teach exact calculations, and often even prepare tables for all the mathematical problems required by astrology: determination of the 12 celestial houses, 'directio,' 'revolutiones annorum,' 'profectio,' 'projectio radiorum.' Thus astrology, among the Musalmāns, becomes an art which demands a solid scientific preparation, and which tends to give an ever greater mathematical complication and exactness to its methods of research among celestial phenomena. *E.g.*, the *mamarr* ('passage [of one planet over another],' *almanar*, or 'supereminentia,' of our astrologers) corresponds exactly from an apotelesmatic point of view to the καθυπερτέρησις of the Greeks; but whilst for the Greeks this takes place when a planet is situated to the west of another, viz. has a lesser longitude, for the Arabs the *mamarr* takes place when a planet in its own epicycle is distant from the apogee of the epicycle less than another planet is distant from the apogee of its own epicycle. Consequently, its calculation in Musalmān astrology is not a light matter, and requires the employment of complete planetary tables. We can understand, therefore, why the theory of the *mamarr* of the planets is not only expounded in several treatises of spherical astronomy, but has also given rise to special monographs. The importance of all this is plain: in the Hellenistic world astrology flourishes while astronomy decays; in the Musalmān world of the Middle Ages astrology becomes a potent ally of mathematical and observational astronomy.

6. Polemic concerning astrology.—From Islām astrology at first had a much less unfavourable reception than from Christianity. The latter had to combat in the teachings of astrology an entire world of pagan ideas and cults; it had to contend against the concept of necessity, which excluded Christian free will. In the 7th and 8th centuries A.D., however, the pagan elements of astrology were completely modified; they were so entirely hidden under a verbal formalism as to be no longer recognizable; and, on the other hand, orthodox Islām, with its doctrine of predestination, which excluded the freedom of human actions, was, at bottom, not very far removed from the εἱμαρμένη of the Stoics and of many astrologers of antiquity. When we consider that the first Musalmān theologians took no heed whatever of the sciences which did not appear to have any relation to the religious content of Islām, we easily understand how astrology had been able to advance unimpeded through its first stages almost up to the end of the 2nd cent. of the Hijra. It is not, therefore, astonishing that Abū Ma'shar, writing his *Introductorium* in 848 A.D., among the ten categories of persons hostile to astrological teaching, makes no mention whatever of opponents influenced by strictly religious reasons,[1] and he makes his defence of astrology to consist (*Introd.* I. 5, fol. b 2 v.–b 3 v.) only in an amplification of the arguments with which Ptolemy (*Tetrab.* I. 3)

[1] Cf. Nallino, *'Ilm al-falak*, pp. 326–332.

[1] *Introductorium*, I. 4 (Augsburg, 1489, fol. a 7 v.–b 2 v.).

had already maintained the material and moral advantages of foreseeing the future, even if this should appear to be adverse to us. The 'philosopher of the Arabs,' al-Kindī, who died a little after 870 A.D., regards astrology as an integral part of philosophy (*ḥikmah*, *falsafah*); he seeks its basis not only in the four mathematical, but also in the physical and metaphysical doctrines;[1] and he opposes it to many popular prejudices. Al-Kindī was perhaps the only one who endeavoured to reduce to a completely rational and systematic form the principles and the methods of astrology.

But matters soon underwent a change. Towards the end of the 2nd cent. of the Hijra the knowledge of Aristotle's teaching grew more definite and profound, and in this there was no place for astrology; hence the philosophers commenced to make war against it. On the other hand, the theologians were not slow to see in the influence attributed to the stars over human actions a menace to the severely monotheistic conception of Islām, more especially when later on there filtered into Musalmān theology an opposition to the idea of necessary causality, and the atomistic doctrine of continued creative acts became more prevalent. Moreover, the daring predictions concerning the duration of Islām[2] became an evident danger to dogma. Thus the polemic against astrology became very acute.[3]

The most ancient confutation which we possess is that of Abu 'l-Qāsim 'Īsā ibn 'Alī,[4] drawn up in the first half of the 10th cent.,[5] and preserved in a work of the Ḥanbalite theologian, Ibn Qayyim al-Jauziyyah, *Miftāḥ dār as-sa'ādah*.[6]

After an exordium in which he admits that the stars may have some influence on such natural phenomena as climate and temperament, but denounces the practice of foretelling the future by their means, he divides his dissertation into three distinct parts. The first has reference to the discordance among astrologers as to their fundamental principles concerning the nature of the influence of the stars, and an exposition follows of several fundamental principles for astrological calculations on which the various writers disagree—*e.g.*, the method of determining the planetary 'termini,' the 'significator' (*dalīl*, ἀφέτης), the 'pars fortunæ,' the male and female zodiacal signs. The second part consists of the examination of many principles which are affirmed by the astrologers, but which are repugnant to good sense (*mustabsha'*). In the third part 'Īsā ibn 'Alī cites some of the arguments adopted by the astrologers in favour of their science, and refutes them.

Contemporary with 'Īsā ibn 'Alī is the famous philosopher al-Fārābī (*q.v.*; † A.D. 950), who, as a profound student of Aristotle, could not but be opposed to astrology. We have a work of his against astrology,[7] which, however, is not so vigorous a confutation as we should have expected from such a philosopher and contains some childish reasonings. This is explained by the fact

[1] Cf. the quotations in M. Steinschneider, *ZDMG* xviii. [1864] 134; and chs. x. and xi. of the anonymous Latin pamphlet *De erroribus philosophorum* (written in the second half of the 13th cent.), ed. P. Mandonnet, *Siger de Brabant*², Louvain, 1908–11, pt. ii. pp. 18–21.

[2] *E.g.*, Theophilus, son of Thomas, the astrologer of the third 'Abbāsid khalīf (see above, § 4), maintained that the reign of Islām would last only 960 years (Ibn Ḥaldūn, *Proleg.*, lib. iii. ch. liv., tr. de Slane, ii. 222 f.). The philosopher al-Kindī calculated that the duration of the kingdom of the Arabs would be 693 years (see O. Loth, 'Al-Kindî als Astrolog,' in *Morgenländische Forschungen, Festschrift an H. L. Fleischer*, Leipzig, 1875, pp. 263–309).

[3] Men like al-Jāḥiẓ († 255 A.H., 869 A.D.) and the famous theologians al-Jubbā'ī († 303 A.H., 915–916 A.D.) and al-Ash'arī († 324 A.H., 936 A.D.) were declared enemies of astrology.

[4] According to Ibn al-Qifṭī, ed. Lippert, p. 244 f., he died on Friday, 28 Rabī' ii., 395 A.H., *i.e.* 28th March, 1001 A.D.; cf. also *Fihrist*, p. 129.

[5] It is, in fact, cited in the preface of the *Libellus isagogicus ad magisterium judiciorum astrorum*, which al-Qabīṣī had written for Saif ad-daulah, prince of Aleppo, who reigned from 333 to 350 A.H. [A.D. 944–967].

[6] Cairo, 1323–25 A.H. [A.D. 1905–07], ii. 156–196.

[7] Al-Fārābī, *Philosophische Abhandlungen*, tr. F. Dieterici, Leyden, 1892, pp. 170–186 (pp. 104–114 of the text published in 1890). Dieterici at some points has not understood the meaning of some technical terms of astrology, so that his version is not always perfect.

that the work is merely a series of notes, published by a disciple just as he found them.

The philosophers contemporary with al-Fārābī did not all share his hostility to astrology; in fact the schools which had been less subject to Aristotelian influence favoured it, as was already the case with al-Kindī.

With reference to this a special place is held by the Iḫwān aṣ-Ṣafā', 'Sincere Companions,' who flourished in al-Baṣrah towards A.D. 950–960, and whose writings set forth the philosophic doctrines of the heretical Bāṭinites, a branch of whom were the Carmaṭians (al-Qarāmiṭah), who towards the end of the 3rd cent. A.H. (9th cent. A.D.) caused political disorders in the 'Irāq, and who founded an independent kingdom in N.E. Arabia which lasted until after A.H. 474 (A.D. 1081–82). The Carmaṭians had reaped great advantage from astrological predictions based on the theory of the great planetary conjunctions.[1] One can therefore understand that the Iḫwān aṣ-Ṣafā' not only admitted, with Aristotle and other Arabic philosophers, that the changes (generation and corruption) of the sublunar world were consequent upon celestial movements but also that the planets foretell the future and have a direct influence upon the will and the moral character. The great encyclopædic work of the Iḫwān is imbued with those astrological ideas, among which the theory of planetary conjunctions occupies the principal place.

Favourable to astrology also are those other philosophers who lead up to Abū Sulaimān Muḥammad ibn Ṭābir ibn Bahrām as-Sijistānī al-Manṭiqī, who, in the second half of the 10th cent., gathered about him at Baghdād a number of learned men for the purpose of discussing various subjects. Notes and summaries of many of these discussions were collected in the *Kitāb al-muqābasāt* of Abū Ḥayyān at-Tawḥīdī, a philosopher, mystic, and jurist († after 400 A.H. [A.D. 1009–1010]), about whose orthodoxy there is some suspicion. A record of a meeting in reference to astrology is preserved almost entire in the work already cited of Ibn Qayyim al-Jauziyyah.[2] Some of those present had attacked astrology, declaring it to be useless, since, after so much study and effort on the part of its supporters, it does not succeed in modifying those events which overwhelm both the wise astrologer and the ignorant man. There then rose up several questioners to refute these accusations, and they set themselves specially to explain how predictions can fail in spite of the truth of astrology, and that, in any case, the efforts of astrologers to discover the truth are always noble. Their defence of practical astrology is somewhat weak, and is probably the last that has been made in the field of philosophy.

Avicenna (*q.v.*; † 428 A.H. [A.D. 1037]) contends against astrology, not only in his great encyclopædia, *ash-Shifā'*, 'The Recovery of the Health [of the Soul],' and in the *an-Najāh*, but also in a special work of which a full résumé was made by Mehren.[3] He demonstrates that astrology has no foundation, and proceeds to show that, even admitting its theoretical truth, it would be impossible for men to acquire a knowledge of it.

Averroës (*q.v.*), or Ibn Rushd († 595 A.H. [A.D. 1198]), is also a decided adversary of astrology, as appears from the severe judgment referred to above (§ 3) and from some passages of his comments on Aristotle. But it would be useless to continue the review of the philosophers, who after the 10th cent. A.D. are all in agreement on this question. It is more interesting to consider the position taken up by the theologians, who—from the motives indicated at the beginning of this section—engaged, towards the end of the 9th cent. A.D., in a relentless war against astrological theories.[4]

We have already seen the attitude of al-Jubbā'ī. We may add here that Ibn Ḥazm († 456 A.H. [A.D. 1064]), who fiercely opposed the scholastic or speculative theology of al-Ash'arī in Spain, gives his ideas on astrology in *Al-Fiṣal fī 'l-milal wa 'l-ahwā' wa 'n-niḥal*.[5] He divides those who believe that the future can be foretold by means of the stars into two classes: (1) misbelievers and polytheists, and (2) persons who are in error. The first are those who maintain that the stars and the

[1] Cf. M. J. de Goeje, *Mémoire sur les Carmathes du Bahraïn et les Fatimides*², Leyden, 1886, pp. 115–129.

[2] ii. 185–193.

[3] A. F. Mehren, 'Vues d'Avicenne sur l'astrologie,' *Muséon*, iii. [Louvain, 1884] 383–403, reprinted in 'Homenaje á D. Francisco Codera,' *Estudios de erudición oriental*, Saragossa, 1904, pp. 235–250.

[4] See also a brief account by I. Goldziher, 'Stellung der alten islamischen Orthodoxie zu den antiken Wissenschaften' (*ABAW*, 1915), pp. 20–25.

[5] Cairo, 1317–21 A.H. (A.D. 1899–1903), v. 37–40.

heavenly spheres are intelligent beings, agents, of eternal duration, and disposing of earthly things either with or without God. The second are those who hold that the stars and the celestial spheres, whilst without intelligence, have been created and established by God as indicators of things which are to take place.

The preserver of Ash'arite dogmatic theology, al-Ghazālī († 505 A.H. [A.D. 1111]), opposes astrology in his *Iḥyā' 'ulūm ad-dīn*, 'The Revival of Religious Sciences.'[1] And the same attitude we find in the books of the famous Ḥanbalite, Ibn Taimiyyah († 728 A.H. [A.D. 1328]).[2]

But the most vigorous and complete confutation of astrology is contained in the *Miftāḥ dār as-sa'ādah* of Ibn Qayyim al-Jauziyyah († 751 A.H. [A.D. 1350]),[3] one of the most noted theologians of the Ḥanbalite school. Only the famous work of Pico della Mirandola, *Adversus astrologiam*, can be compared to the 110 closely printed quarto pages of the confutation written by this Muhammadan theologian, whose impassioned polemics press upon the adversary with an infinity of subtle distinctions which prove the force of his dialectic.

In the theological world perhaps the sole defender of astrology is Faḫr ad-dīn ar-Rāzī († 606 A.H. [A.D. 1210]), cited above. Famous especially for his great commentary on the Qur'ān, he composed also many theological, philosophical, and astrological works, and studied medicine and mathematics. Without doubt his confidence in astrology is due to his cultivation of the sciences, and this confidence already appears in his commentary on the Qur'ān.

No theologian seems to have followed Faḫr ad-dīn ar-Rāzī in his bold interpretations of Qur'ānic passages and of religious traditions. Besides, after the writings of Ibn Qayyim al-Jauziyyah and his predecessors, polemics about astrology could no longer reckon on any novelty of argument. The considerations developed by the great philosopher of history, Ibn Ḫaldūn († 808 A.H. [A.D. 1406]), in his historical *Prolegomena*,[4] are alone deserving of notice.

7. **Astrology in common life.**—The four orthodox schools of jurisprudence and the Shī'ite school were already in existence when the war of the philosophers and theologians against astrology became fierce; accordingly, the anathema launched against it in the name of religion did not occupy much space in Muhammadan law, notwithstanding the fact that this had its chief foundation in religious doctrine. Among some jurists of a rather later age, however, we meet with open hostility to astrology. In Muhammadan law the buying and selling of useless things is forbidden; therefore some jurists[5] teach that one may not sell or buy books of astrology. Another legal prescript does not admit the testimony of misbelievers; therefore some jurists, regarding the astrologer as a misbeliever, deny him the right of acting as a witness.[6] But, before theological anathema smote it, astrology was deeply rooted among all lay classes of society. The courts of the 'Abbāsid khalīfs at Baghdād and of the numerous small dynasties which arose in the Muhammadan world after the 3rd cent. of the Hijra received astrologers with great favour and consulted them on affairs of State as well as on trifling matters of daily life. At the foundation of Baghdād in A.D. 762, and at that of al-Mahdiyyah (in Tunis) in 916, the astrologers, summoned for the purpose, indicate the propitious moment for beginning the work. Many writings on apotelesmatics are dedicated to khalīfs, sultans, and princes. In Turkey, even at the beginning of the 19th cent., one of the chief posts at court was that of *munajjim-bāshī*, or chief astrologer; and the case was similar in Persia, in India, and in Muhammadan central Asia.[1] In the *Thousand and One Nights* not only is the astrologer with his astrolabe mentioned several times (*e.g.*, Nights 28 and 50 of the Egyptian edd.), but there is also a complete dissertation on the elements of astrology (Nights 254–257, in the story of the slave girl Tawaddud). Further, the considerable number of old Arabic astrolabes still existing in the East and in South Europe would alone suffice to prove the great diffusion of astrology throughout the Muhammadan world; and it found strong support among the students of astronomy. Cases of persecution of astrologers by the State are extremely rare. Al-Ḥākim, Fāṭimid khalīf of Egypt, who in 404 A.H. (A.D. 1013–1014) prohibited the study of astrology and banished from Cairo those who cultivated it, was an astrologer himself, and that decree of his is one of many acts of madness committed in the last years of his life.

In the Muhammadan countries into which European civilization has penetrated (which with the Copernican system has destroyed the bases of apotelesmatics) astrology has lost its importance and remains the monopoly of the popular classes, among whom it has degenerated into a form of prediction without any serious mathematical and astronomical basis. On the other hand, in countries where there is little or no European influence (*e.g.*, in many parts of Morocco) apotelesmatics still flourish, but accompanied by only rudimentary astronomical knowledge. To-day in S. Arabia the function of the astrologer is exercised especially by the *qāḍī*,[2] *i.e.* by those whose duty it is to see that canon law is observed!

8. **Influence on European astrology.** — The astrology of the Latin Middle Ages from the beginning of the 12th to the end of the 15th cent. is really Arabic astrology. Its sole sources are Arabic (Albohali, Albohazen, Albumasar, Alcabitius, Alchindus, Almansor, Alphadol, Aomar, Gergis, Hali, Haly Heben Rodan, Messahala, Zahel, and some pseudepigraphical works), or at least translations from Arabic (*e.g.*, the *Tetrabiblos* or *Quadripartitum* of Ptolemy, and the Καρπός or *Centiloquium*); the technical terminology is literal translation or mere corruption of Arabic words. In the 16th cent. the humanists rescued from oblivion the poem of Manilius and the crude compilation of Firmicus Maternus; but this was a mere literary exercise of no importance for the astrology of the 17th century.

In the Byzantine world also Muhammadan astrology leaves deep traces in many versions from the Arabic and from the Persian;[3] so that side by side with the works derived from the classic Greek authors appear those of 'Απομάσαρ (Abū Ma'shar), 'Αχμέτ (Aḥmad ibn Yūsuf ibn ad-Dāyah), Μεσσάλα (Mā shā' Allāh), Σέχλ (Sahl ibn Bishr), and other Arabic writers. Thus there frequently occur in Byzantine astrological writings Arabic and Persian names of planets or technical terms which no longer correspond to those of classical Greek.

1 Cairo, 1302–03 A.H. (A.D. 1885–86), i. 27 f. All this passage is copied without indication of its source in ad-Damīrī, *Ḥayāt al-ḥayawān*, Cairo, 1311 A.H. (A.D. 1893), i. 12 f., *s.v.* 'Asad.'

2 *Majmū'at al-fatāwā*, Cairo, 1326–29 A.H. (A.D. 1908–11), i. 323–336.

3 Ed. Cairo, 1323–25 A.H. (A.D. 1905–07), ii. 132–240.

4 Bk. vi. ch. 26 (tr. M. G. de Slane, iii. 240–249).

5 *E.g.*, al-Bājūrī, *Ḥāshiyah 'alā Ibn Qāsim al-Ghazzī*, Būlāq, 1292 A.H., i. 445.

6 Cf. the quotations in Saḥnūn ibn 'Uthmān al-Wānsharīsī, *Mufīd al-muḥtāj fī sharḥ as-sirāj*, Cairo, 1314 A.H., p. 5.

1 Cf. *e.g.*, F. Bernier, *Evénements particuliers des états du Mogol*, Paris, 1671, p. 96. See also J. T. Reinaud, *Monumens arabes, persans, et turcs*, Paris, 1828, ii. 367 f. For Persia see *Voyages du chevalier Chardin en Perse, et autres lieux de l'Orient*, new ed., Amsterdam, 1735, i. 242, iii. 163–165, 174–183.

2 R. Manzoni, *El Yèmen*, Rome, 1884, p. 209; H. von Maltzan, *Reise nach Südarabien*, Brunswick, 1873, p. 164.

3 The Arabs and the Persians are called indifferently Πέρσαι.

Finally, the Jewish astrological literature of Europe, in which a conspicuous place is occupied by the works of Abrāhām ibn 'Ezrā († 1167), is based exclusively on Arabic sources.

LITERATURE.—There is no work setting forth the content and history of Muhammadan astrology. For biographical and bibliographical notices of individual astrologers reference may be made to H. Suter, *Die Mathematiker und Astronomen der Araber und ihre Werke*, Leipzig, 1900 (completed in 'Nachträge und Berichtigungen zu "Die Math. und Astron.,"' in *Abhandlungen zur Gesch. der mathematischen Wissenschaften*, xiv. [1902] 157-185). The mathematical side of Muhammadan astrology and the explanation of several technical terms are set forth in the present writer's annotations on al-Battānī, *Opus astronomicum*, 3 vols., Milan, 1899-1907. Beyond two or three small pseudepigraphical writings of no importance, printed or lithographed in Cairo, and the dissertation of al-Kindī published by O. Loth (see above, p. 92ᵃ, n. 2), there are no edd. of complete astrological works in the original text; there are, on the other hand, edd. of Middle Age Latin versions (15th-16th cent.), several of which have been cited in the course of the article.

II. *ASTRONOMY.*—1. Name.—The names *'ilm* (or *ṣinā'at*) *an-nujūm*, 'science (or art) of the stars,' *'ilm* (or *ṣinā'at*) *at-tanjīm* denote both astronomy and astrology. For the former science Averroës [1] adopts the expression *ṣinā'at an-nujūm at-ta-'ālīmiyyah*, 'mathematical art of the stars,' which is found also in the original Arabic of the *de Scientiis* of al-Fārābī, where Gerard of Cremona translated it by 'astronomia doctrinalis,' misled by the double signification of the adjective *ta'ālīmī*. The astronomy of observation is designated by Averroës [2] *ṣinā'at an-nujūm at-tajrībiyyah*, 'experimental art of the stars.' Special names of astronomy are *'ilm al-hai'ah*, 'science of the form [of the universe],' and *'ilm al-aflāk*, 'science of the celestial spheres.' [3] The branch of astronomy which deals with the construction and use of instruments for determining the time, especially for the purpose of regulating the times of the religious services in the mosques, is named *'ilm al-mīqāt*, 'the science of the time appointed [for the canon prayers],' and he who cultivates it is called *muwaqqit*.

2. Scope.—The Greek and Muhammadan conception of astronomy does not exactly correspond to the modern conception.

Al-Fārābī says in his treatise *de Scientiis* [4] that astronomy has for its object the study of the celestial bodies and of the earth from these three points of view: (*a*) number, figure, order, and respective position of the spheres and of the celestial bodies; their magnitudes and distances from the earth; immobility of the earth; (*b*) celestial motions and their consequences with regard to the stars themselves (conjunctions and oppositions, eclipses, etc.); (*c*) magnitude of the inhabited part of the earth and its division into zones or climates; determination of geographical co-ordinates; effects of the rotation of the celestial sphere in regard to parts having different latitudes (varying length of the day, right and oblique ascensions of the points of the ecliptic, etc.). This scheme of the content of astronomy is found also in later writers,[5] with the sole difference that the study of the magnitudes and distances of the celestial bodies and spheres comes to be considered under a category (*d*) separate from (*a*).

According to Avicenna, the astronomer studies 'the parts of the universe as far as regards their figure, their respective positions, their magnitudes, and their distances from each other; he further studies the motions of the spheres and of the celestial bodies, the estimate (*taqdīr*) of the globes, of the axes (*l. quṭūb*) and of the circles [ideal] on which those motions take place. All this is contained in the *Almagest*.' [6]

The limits of astronomy are well defined by Ibn Ḫaldūn († A.D. 1406):

Astronomy consists of the study of the celestial bodies and motions as they appear to us; 'it is a most noble science, but it does not give, as is often supposed, the form of the heavens and the disposition of the spheres and of the stars as they are in reality. It only indicates that from those motions there result for the spheres these forms and these dispositions. Now, as is known, it is not strange that from one and the same thing there should result necessarily two different things; therefore, when we say that those motions give as a result [those celestial configurations], we seek to argue the mode of existence of the result by means of the necessary cause; a proceeding which does not at all guarantee the truth. Nevertheless, astronomy is an important science, indeed one of the fundamental parts of the mathematical sciences.' [1]

The diversity of criteria and of purposes by and for which the physicist ('naturalis') studies celestial phenomena, in contrast to the astronomer ('astrologus'), is shown also in a passage of Averroës.[2] This conception of the philosophers is shared by the Muhammadan astronomers, for whom astronomy embraces spherical astronomy (with the theory of instruments), mathematical chronology, spherical trigonometry, and geography as based on mathematics (like that of Ptolemy); and it excludes all that for us would enter into the field of stellar physics and celestial mechanics. This is evident from the summary [3] of the best systematic treatise on Muhammadan astronomy, viz. the unedited *al-Qānūn al-mas'ūdī*, composed in Arabic by al-Bīrūnī († A.D. 1048):

(*a*) General notions and fundamental hypotheses for the geometrical representation of celestial phenomena; (*b*) mathematical chronology, conversion of one era into another, festivals of various peoples; (*c*) spherical trigonometry; (*d*) circles of the celestial sphere and systems of co-ordinates; phenomena of the diurnal motion of the sphere with reference to the earth (amplitudes, solar altitudes, right and oblique ascensions of the points of the ecliptic, etc.); (*e*) form, dimensions, etc., of the earth; problems relating to terrestrial longitudes and latitudes; the direction of Mecca with regard to other places on the earth; geography on a mathematical-astronomical basis; (*f*) theory of the sun; (*g*) theory of the moon; solar and lunar parallaxes; (*h*) syzygies, eclipses, appearance of the new moon; (*i*) fixed stars and lunar stations; (*j*) theories of the five planets; geocentric distances and magnitudes of the celestial bodies and spheres; (*k*) problems of spherical astronomy as subserving astrology (calculation of the twelve celestial 'domus,' of the 'applicationes,' of the 'projectiones radiorum,' of the 'directiones' and 'profectiones,' of the 'revolutiones annorum,' of the *mamarr*, of the planetary conjunctions, of the millenary periods).

Muhammadan astronomical writings, almost always in Arabic, can be classified under four groups:

(*a*) General elementary introductions which represent a perfected form of what the *Isagoge* of Geminus and the *Hypotheses* of Ptolemy were for the Greeks; belonging to this category—to cite only writings translated into European languages and edited—are: the *de Imaginatione Sphæræ* of Thebit (or Thābit) ibn Qurrah († A.D. 901), the compendium of Alfraganus or al-Farghānī († after 861), and the compendium of al-Jaghmīnī († 1344-45); [4] (*b*) systematic treatises corresponding in type to the *Almagest*, but more perfect—*e.g.*, the unedited work of al-Bīrūnī cited above; the Latin translation of the *Almagest* of Geber (or Jābir) ibn Aflaḥ, printed at Nürnberg, 1534, would belong to this category if it had not omitted all the mathematical and astronomical tables; (*c*) treatises of spherical astronomy for the use of calculators and observers; these are called *zīj* (plur. *zījāt, azyāj, ziyajah*); they presuppose a knowledge of the general principles of cosmography and consist essentially of tables for calculation, illustrations of the use of the tables, and indications as to the manner of solving problems of spherical astronomy (for the most part without demonstration); the only treatise of this kind published and translated is that of al-Battānī; [5] of the Persian treatise of Ulūgh Beg only the prolegomena (explaining the use of the tables) and the stellar catalogue have been edited and translated; (*d*) writings on special subjects—*e.g.*, stellar catalogues, treatises on instruments, etc.

---

1 Ibn Rushd, *Metaphysic*, Cairo, n.d. [1902], p. 65, l. 3 from end (ed. and tr. by C. Quirós Rodríguez, Madrid, 1919, bk. iv. § 13).

2 P. 83 (Quirós, bk. iv. § 77).

3 See also above, I. 1.

4 This has reached us only in the Latin version of Gerard of Cremona († 1187), Paris, 1588. The part relating to the mathematical sciences has been translated into German by E. Wiedemann, 'Beitr. zur Gesch. der Naturwissenschaften,' xi. (*Sitzungsberichte der physik.-medizin. Sozietät in Erlangen*, xxxix. [1907] 74-101.

5 *E.g.*, Muḥammad al-Akfānī as-Saḥāwī, *Irshād al-qāṣid*, Calcutta, 1849, p. 84 f.

6 *Risālah fī-aqsām al-'ulūm al-'aqliyyah*, in the *Tis' rasā'il*, Constantinople, 1298 A.H. (1881). The same definition is found in the *Chahār Maqālah*, written in Persian about 1160 by Niẓāmī-i-'Arūḍī-i-Samarqandī (tr. E. G. Browne, Hertford, 1899 [extract from *JRAS*], p. 89).

1 *Prolegomena*, bk. vi. ch. xvi. (tr. de Slane, iii. 145 f.).

2 *Comm. de Cœlo*, bk. ii. ch. 57 (*Aristotelis Opera omnia cum Averrois Cordubensis commentariis*, Venice, 1562, vol. v. fol. 136r.-v.).

3 According to the indexes of the chapters given in the catalogues of the Arabic MSS in Oxford and Berlin.

4 *Sullāķā Haunānāyā*, the course of astronomy of Barhebræus, ed. and tr. F. Nau (*Le Livre de l'ascension de l'esprit sur la forme du ciel et de la terre*, 2 pts., Paris, 1899-1900), although written (in 1279) in Syriac by a Christian bishop, belongs to this category.

5 To which is to be added the Latin translation, made in the 12th cent. by Athelhard of Bath, of Maslamah al-Majrīṭī's recension of the tables of al-Ḫuwārizmī, ed. with an excellent German commentary by H. Suter, 1914.

3. Relation to Islām.—Muhammadan religious ritual bases some of its prescriptions on elements of an astronomical character. The hours within which each of the five daily ritual prayers is valid depend on the latitude of the place and on the epoch of the solar year; further, the legal time for the night prayer is between the end of the evening and the beginning of the morning twilight. The ritual prayer is not valid unless the face is turned in the direction of Mecca; hence the necessity of solving the astronomical-geographical problem of the azimuth of Mecca. The beginning and the end of the month assigned to the fast are determined not by the civil calendar, but by the actual appearance of the new moon; and the beginning of the daily fast is given by the morning twilight. Finally, special ritual prayers are prescribed at eclipses of the sun and moon, for which it is well to be prepared in time. All this presupposes a certain degree of astronomical knowledge; and, although the majority of theologians and jurists are not content with pure calculation for the appearance of the new moon, but require the actual sight of the phenomenon, it is evident that the religious precept must be a real stimulus to scientific study. This explains also why the Muhammadans have undertaken so much research into the complex phenomena of the twilight and of the conditions of visibility of the new moon—phenomena which were almost entirely neglected by the Greek astronomers. On the other hand, many passages of the Qur'ān set forth the benefits which God has vouchsafed to men by means of celestial bodies and motions; at least they invite reflexion on the goodness and providence of God. Astronomy thus becomes an ally of religion.

4. Sources.[1]—(*a*) *Arabian.*—A first element of an exclusively practical character is due to the Arabs before Islām. Like all other peoples who dwell in hot countries and are compelled to prefer night to day for travelling, the Bedawin made use of the stars for guiding their wanderings and for calculating (approximately) the hours of the night; they were thus familiar with the principal appearances of Venus and of Mercury, the places of the rising and setting of the more brilliant stars, and above all the annual course of the moon determined by noting its position in relation to 28 successive groups of stars called for this reason *manāzil al-qamar*, 'lunar stations.' Further, among the sedentary agricultural tribes, the seasons and many meteorological provisions (especially those for rain) were strictly connected with the annual rising of certain fixed stars[2] or else with the cosmic setting of the lunar stations. Hence, even in the 16th and 17th centuries, Arabic writers on astronomy still occupied themselves with the lunar mansions[3] and their *anwā'*, or cosmic settings.

(*b*) *Indian.* — The Muhammadans owe the first scientific elements of astronomy to India. In 154 A.H. (A.D. 771),[4] there came to Baghdād an Indian embassy one learned member of which introduced to the Arabs the *Brāhmasphuṭasiddhānta*, composed in Sanskrit in A.D. 628 by Brahmagupta. From this work (which the Arabs called *as-Sind-hind*) Ibrāhīm ibn Ḥabīb al-Fazārī drew the elements and the methods of calculation for his astronomical tables (*zīj*) adapted to the Muhammadan lunar year. Almost contemporaneously Ya'qūb ibn Ṭāriq composed his *Tarkīb al-aflāk*, 'The Composition of the Celestial Spheres,' which was based on the elements and methods of the *Brāhmasphuṭasiddhānta* and on other data furnished by another Indian scientist (K.n.k.h), who came to Baghdād with a second embassy in 161 A.H. (A.D. 777-778). It seems that almost at the same time there was translated into Arabic under the name *al-Arkand* the *Khaṇḍakhādyaka*, written about A.D. 665 by the same Brahmagupta, but containing elements different from those of his other work. Abū 'l-Ḥasan al-Ahwāzī, a contemporary of al-Fazārī and of Ya'qūb ibn Ṭāriq, probably drawing on oral teachings of learned Indians, introduced to the Arabs the planetary motions according to al-Arjabhad (a corruption of Āryabhaṭa, the name of an Indian astronomer who wrote in A.D. 500). These Indian works had many imitators in the Muhammadan world up to the end of the first half of the 5th cent. of the Hijra (11th cent. A.D.); some astronomers (*e.g.*, Ḥabash, an-Nairīzī, Ibn as-Samḥ) wrote contemporaneously books based on Indian methods and elements and books with Græco-Arabic elements; others (*e.g.*, Muḥammad ibn Isḥāq as-Saraḫsī, Abū 'l-Wafā', al-Bīrūnī, al-Ḫāzinī) adapted elements calculated by the Muhammadan astronomers to great artificial cycles of years constructed in imitation of those of the Indians. For one of the characteristics of the astronomical books of India is their representation of the mean motions of sun, moon, and planets by the number of their revolutions in cycles of millions of years, starting from the supposition that at the beginning of creation sun, moon, and planets were all in conjunction in a given degree of longitude (*e.g.*, at the first point of Aries), taken as the initial point of the celestial sphere, and that at intervals of millions of years they will all be in conjunction again at the same point.[1] Further, many treatises composed by the Arabs gave the roots of the mean motions for the meridian of Uzain (corrupted later into Azīn and Arīn, the Sanskrit Ujjayinī), supposed to be the central meridian of the inhabited earth (90° E. of the first Ptolemaic meridian). From those Indian books the Arabs also derived their first knowledge of trigonometrical sines, of course in the form employed in India, *i.e.* for arcs of 3° 45′ and for the radius of 3438′.

(*c*) *Iranian.*—A few years after the introduction of Indian astronomy, and before the end of the 8th cent. A.D., there was translated into Arabic the Pahlavi work entitled *Zīk i Shatroayār*, 'Astronomical Tables of the King,' a name which became in the Arabic version *Zīj ash-Shāh* or *Zīj ash-Shahriyār*. The original was certainly composed in the last years of the kingdom of the Sāsānids, since the tables were based on the epoch of Yazdagird III. (16th June, A.D. 632); its elements were derived, not from Persian observations, but from Indian books. It appears also that the roots of the mean motions were referred to the meridian of the mythical castle Kangdizh, which Persian epic legend placed in the Far East. The Arabic version met with great favour among the Muhammadans. We know that the astronomer and astrologer Mā Shā' Allāh († at the beginning of the 9th cent. A.D.) made use of it for his calculations, that in the first half of the 9th cent. Muḥammad ibn Mūsā al-Ḫuwārizmī had deduced from it the equations of the planetary motions, whilst he had drawn the mean motions from the *as-Sind-hind* and other elements from Ptolemy, and that Abū Ma'shar († A.D. 886) used it for his astronomical tables. After the 9th cent. A.D. the *Zīj ash-Shāh* rapidly fell into disuse; but a passage of az-Zarqālī (Arzachel) shows that towards the middle of the 11th cent. some astrologers in Spain still calculated the longitude of the fixed stars according to the tables of the Persians.

(*d*) *Greek.*—Last in chronological order is the influence of Greek astronomy. At the end of the 8th cent. or at the beginning of the 9th A.D. a rich patron, of the family of the Barmecids, Yaḥyā ibn Ḫālid († 191 A.H. [A.D. 807]), caused the *Almagest* to be translated for the first time into Arabic. But this book, full of difficulties and obscurities, could not, at first, compete with easier and more practical works of Indian and Persian origin. It acquired influence later, when the mathematical preparation of the Muhammadans was more advanced, and when better translations appeared. In the first half of the 9th cent. also Arabic translations were made of the *Geographia*, the *Tabulæ Manuales*, the *Hypotheses Planetarum*, the *Apparitiones* (φάσεις) *Stellarum fixarum*, and the *Planisphærium* of Ptolemy; the *Tabulæ Manuales* of Theon of Alexandria; the book of Aristarchus on the magnitudes and distances of the sun and moon; the *Isagoge* of Geminus; two tractates of Autolycus; three of Theodosius; and the little work of Hypsicles on the ascensions. To the 9th cent. also probably belongs the Arabic translation of the astronomical tables of Ammonius, of which we still find traces in the 11th cent., when they were remodelled by az-Zarqālī, to pass afterwards into mediæval Latin literature under the names of Humenus, Armanus, etc. Finally, there appear to have been translated in the same century the book of the constellations of Aratus and a book on the magnitudes and distances of the celestial bodies, which, falsely attributed to Ptolemy, is known by the Arabs under the name of *Kitāb al-manshūrāt*.

5. Some astronomical teachings.—We may here refer to some special points, which have an importance for the history of the general ideas of celestial phenomena. The only system received by the Muhammadan peoples was the geocentric. Aristotelian philosophy, the authority of Ptolemy, and the requirements of astrology were insurmountable obstacles to the conception of a heliocentric system, which, in any case, could not have been demonstrated by irrefutable reasons or, in the absence of telescopes, have procured any real advantage to practical astronomy. The lack of telescopes kept Muhammadan astronomers from becoming acquainted with other planets than those already known to the Greeks. The mode, too, of representing their motions is always that of the Greeks, viz. by means of combinations (sometimes very complicated) of eccentrics and epicycles; nor

[1] For details see Nallino, *'Ibn al-falak*, pp. 104–140, 313–323 (for Arabic sources), 149–180 (Indian), 180–188 (Persian), and 216–229 (Greek).

[2] Alois Musil and Antonin Jaussen have found this usage still in vogue among the Bedawin of Moab. Eduard Glaser indicates it for the Yemen.

[3] These correspond only approximately to the *nakṣatras* of the Indians.

[4] So al-Bīrūnī. On the other hand, Ibn al-Qifṭī (a source of less authority) has 156 = 773.

[1] This Indian idea occurs also in some Arabic works which are not astronomical—*e.g.*, Ibn Qutaiba, *Liber poësis et poëtarum*, ed. M. J. de Goeje, Leyden, 1904, p. 503 f.

do the modifications of certain parts of the planetary theories of Ptolemy introduced by some (*e.g.*, Naṣīr ad-dīn and Quṭb ad-dīn ash-Shīrāzī) depart much from this principle. Only among writers who are philosophers rather than astronomers do we meet with theories that supersede those of eccentrics and epicycles.[1] In any case, among them all, the Aristotelian and Ptolemaic doctrine of the circular form of celestial motions reigns supreme, for the elliptic orbit indicated by az-Zarqālī for Mercury[2] is merely a graphical construction on the lamina of the astrolabe, and not a theoretical representation.

(*a*) *Number of the spheres.*—The number of the spheres, *i.e.* of what in the Middle Ages in Europe were called 'heavens,' is eight in Aristotle and Ptolemy, viz. seven for the planets (including the sun and the moon) and one for the fixed stars. This number of eight is preserved by the first Arabic astronomers—*e.g.*, al-Farghānī and al-Battānī, for whom, however, these ideal spheres, created to satisfy the requirements of physics and not those of astronomy properly so called, had no practical importance. Still the number of eight, combined with the Aristotelian theory of solid spheres in which the heavenly bodies are infixed without being able to move themselves, did not easily agree with the other teachings of the Ptolemaic system. Aristotle, who was ignorant of the motion of the precession of the equinoxes, and who consequently held that the fixed stars are really immovable, assigned to the eighth sphere the apparent diurnal motion of the celestial vault from east to west, a motion which the eighth sphere impressed also on all the others. But Ptolemy, accepting from Hipparchus the precession of the equinoxes on account of which the fixed stars have a slow and continued increase of longitude, came implicitly to attribute to the sphere of the fixed stars two motions in opposite directions—one (diurnal) from east to west, and the other from west to east. Ptolemy had no occasion to notice and correct this contradiction, which was soon perceived by the Arabic writers. The contradiction would have been easily eliminated by supposing that the fixed stars moved by the precessional motion within their own sphere, supposed accordingly to be fluid and not solid; and perhaps al-Battānī had in mind the possibility of this hypothesis when he entitled ch. li. of his book[3] thus: 'Of the motion of the fixed stars, whether they move in their sphere, or whether the sphere moves with them.' Another solution of the difficulty would have been to suppose the fixed stars to be infixed in the convexity of the sphere of Saturn, itself naturally subjected, like all the planetary apogees, to the motion of the precession; then the eighth sphere, no longer containing the stars, would only have had the office of impressing the diurnal motion on the spheres below. This solution was actually given by Muhammadan writers, some of whom indeed took advantage of it for reducing the number of the spheres to seven, to conform with the seven heavens of the Qur'ān; but this was never accepted by the astronomers.[4] Therefore, when Ibn al-Haitham († 1039) introduced into pure astronomical teaching the doctrine of the solid spheres of Aristotle, it was necessary for the physical reasons set forth above to add a ninth sphere without stars, impressing on the other spheres diurnal motion. This ninth sphere, accepted by all the later astronomers, was called 'the universal sphere,' 'the greatest sphere,' 'the sphere of the spheres,' 'the smooth sphere' (*al-falak al-atlas*), 'the sphere of the zodiac,' 'the supreme sphere.' In general also the philosophers—*e.g.*, Avicenna and Ibn Ṭufail—accept these nine spheres; Averroës,[1] however, under the influence of Aristotle, cannot bring himself to exceed the number of eight. In the theological camp the nine spheres did not find many opponents, in spite of 'the seven heavens' mentioned in *Qur.* ii. 27; it was held that the specification of the number seven did not imply the negation of a superior number.[2] In fact, several theologians saw in the eighth and ninth spheres respectively the 'seat' (*kursī*) and the 'throne' (*'arsh*) of God mentioned in the Qur'ān.[3]

Doubts were not wanting, however, concerning the unity of the sphere of the fixed stars. Fahr ad-dīn ar-Rāzi[4] informs us that Avicenna, in his book *ash-Shifā'*, declared: 'Up till now it has not been clear to me whether the sphere of the fixed stars be a single sphere or be several spheres, placed one above the other.' And Fahr ad-dīn ar-Rāzi[5] adds that the hypothesis of the single sphere for all the fixed stars rests only on the assumption of the equality of their motions, but that this equality is not at all certain. He further says that, even if the equality of the motions were a certainty, he would not deduce from it the necessity of a single sphere bearing all the stars infixed in it. In face of these criticisms, one comprehends the scepticism of Niẓām ad-dīn al-Ḥasan an-Naisābūrī: 'In conclusion, to none of the ancients or of the moderns is the number of the heavens quite certain, either by the force of reasoning or by the way of tradition.'[6]

(*b*) *Order of the planets.*—The order of the planets followed by almost all the Muhammadan astronomers is identical with that of Ptolemy, although they recognize, together with the Greek astronomers, the lack of absolute proofs in the case of the two inferior planets and the sun. Without telescopes they could not see the transits of Venus and Mercury across the sun or determine the parallaxes of the planets situated above the moon. Some Arabic authors believed that they had perceived transits of Venus or of Mercury across the sun; but what they really saw was solar spots.[7] On the other hand, the postulates of astrology continued in the Muhammadan age to guarantee, from lack of scientific reasons to the contrary, the Ptolemaic series: moon, Mercury, Venus, sun, Mars, Jupiter, Saturn. Spain alone had astronomers who departed from this order. Jābir ibn Aflaḥ (*c.* 1140) held it more probable that Mercury and Venus were above the sun on account of their analogy to the superior planets in having epicycles and eccentrics, stations and retrogradations. Al-Biṭrūjī (*c.* 1200), moved by physical reasons connected with his special system of planetary notions, placed the sun between Mercury and Venus.

(*c*) *Obliquity of the ecliptic.*—The obliquity of the ecliptic with regard to the celestial equator is one of the fundamental elements of astronomical calculation. The Greeks, from Eratosthenes (230 B.C.), had assigned to it the constant value of 23° 51′ 20″; *i.e.*, they held it to be invariable. The astonishment of the Arabic astronomers must have been great when they found by their observations an obliquity sensibly less; at first they could not decide whether the discrepancy was due to a real diminution of the obliquity or to a defect in the ancient observations. Al-Battānī leaves the ques-

[1] Cf. below, § 6.
[2] In the *Libros del saber de astronomía*, iii. 280. In any case, the earth there occupies the centre of the ellipse and not one of the foci.
[3] Ed. Nallino, i. 124.
[4] Cf. Niẓām ad-dīn al-Ḥasan an-Naisābūrī, *Tafsīr* (in marg. to the *Tafsīr* of aṭ-Ṭabarī), 1st ed., i. 205 (comm. on *Qur.* ii. 27); Fahr ad-dīn ar-Rāzī, *Mafātīḥ al-ghaib*, Cairo, 1308–10 A.H., ii. 60 (comm. on *Qur.* ii. 159).

[1] *Metaphys.*, Cairo, n.d. [1902], p. 66 (ed. and tr. Quirós, bk. iv. § 16).
[2] Niẓām ad-dīn al-Ḥasan an-Naisābūrī, *loc. cit.*; Fahr ad-dīn ar-Rāzī, i. 260.
[3] See al-Qazwīnī, *Cosmography*, ed. F. Wüstenfeld, Göttingen, 1848, i. 54; the glosses on *Mawāqif* of 'Aḍud ad-dīn al-Ījī; E. W. Lane, *Arabic-English Lexicon*, 8 vols., London, 1863–93, *s.v.* ''Arsh,' etc.
[4] ii. 59; cf. Avicenna, *Ash-Shifā'*, Teherān, 1303–05 A.H., i. 175 (in the 6th ch. of the 2nd *fann* of the *Ṭabī'iyyāt*).
[5] ii. 59 and i. 259 f. [6] *Loc. cit.* [7] See § 7 below.

tion undecided and declares that he chooses the excellent value found by himself (23° 35′), 'since this was observed by us with our own eyes; the other, on the contrary, was received through the information of others.'[1] Some, less prudent, deduced the theory of libration[2] from the discrepancies as to the obliquity of the ecliptic combined with those relative to the precession of the equinoxes. But the continued series of observations left no doubt by the 13th cent. that the obliquity of the ecliptic was subject to a very slow regular diminution,[3] which therefore came to be admitted by all the astronomers; in Europe, on the other hand, we must come down to Tycho Brahe (1546–1601) to see it affirmed in the midst of opposition which lasted through the greater part of the 17th century. The Muhammadan astronomers had no means of determining whether this diminution was continuous or periodical and within what limits it was contained.[4] Abū 'Alī al-Ḥasan (c. 1260), who had accepted the hypothesis of az-Zarqālī as to libration, believed that the obliquity oscillated between a maximum of 23° 53′ and a minimum of 23° 33′; Faḫr ad-dīn ar-Rāzī[5] admitted a continuous diminution on account of which the ecliptic will coincide one day with the equator and then will depart from it again, so that the Tropic of Cancer will pass to the south and that of Capricorn to the north. Naṣīr ad-dīn aṭ-Ṭūsī († 1274 A.D.) confined himself to setting forth the eight possible hypotheses as to the continuity or the periodicity of the diminution, without giving preference to any.

(*d*) *Precession of the equinoxes.*—The precession of the equinoxes, on account of which the equinoctial points retreat from east to west along the equator and cause a continuous increase in the longitude of the fixed stars (calculated precisely from the point of the vernal equinox or the first point of Aries), is one of the greatest discoveries of Hipparchus, accepted by Ptolemy. It was accepted by all the Muhammadan astronomers, who, from the first half of the 9th cent., assigned it a value much more exact than that of Ptolemy (36″ yearly), viz. 54″ 33‴; later, a continued series of observations indicated other values still more approximate to the true one. There remained a question which celestial mechanics alone has been able to solve with certainty: Is the precession to be regarded as continuous, so that in many thousands of years the retreating equinoctial points will accomplish the entire circuit of the ecliptic, or is it confined within limits so as to be reduced to one oscillation, more or less great, of the equinoctial points? The first hypothesis, which is the true one, is accepted by Ptolemy; the second was followed by some Greek astrologers after the Christian era, who held that the equinoctial points, after having advanced 8° in 640 years, retreated 8° in a similar lapse of time, returning thus to the primitive point. According to them, the precession was 45″ a year. Finally, it is necessary to note that, while some Indian writers are quite ignorant of the precession, others admit it in an oscillatory form with arcs of 54° or 48° (namely, 27° or 24° from the one part and from the other of ζ Piscium), which they imagined by gross mistakes and not for scientific reasons.

(*e*) *Hypothesis of libration or trepidation.*—The great majority of Muhammadan astronomers held that there was a continuous precession, rightly

[1] Ed. Nallino, i. 12.

[2] See below, § (*e*).

[3] This was already the opinion of Ḥāmid al-Ḫujandī, about A.D. 1000.

[4] Only in the second half of the 18th cent. has celestial mechanics been able to establish the fact that it is a question of a very slow oscillation contained within limits of less than 2½°.

[5] *Mafātīḥ al-ghaib*, i. 260, ii. 59 f.

attributing the discrepancies concerning its value to the imperfection of the observations of the Greeks. We know only three writers of the second half of the 9th cent. who, through Indian influence, accepted the idea of the oscillatory precession in the empirical form of the Greek astrologers mentioned above and of the Indians. On the other hand, Thābit ibn Qurrah († 901) suggested that the discrepancies in the estimate of the annual precession were due in reality to an apparent irregularity of that motion, and that they were connected with the discrepancies relative to the obliquity of the ecliptic. In an epistle which is preserved by Ibn Yūnus he says that he had up till then kept his own calculations private, because he regarded them as uncertain and only provisional. It seems that these secret papers formed the tractate which has come down to us only in two unedited Latin translations under the title *De motu octavæ sphæræ* or *De motu accessus et recessus.*[1] In this tractate Thābit notes that, if all the known observations were exact, there would be a slackening and an acceleration in the motion of precession and in the increase and diminution of the obliquity of the ecliptic. In order to explain these apparently irregular variations, he proposes the following hypothesis:

The eighth sphere, viz. that which contains the fixed stars, has a movable ecliptic, the extremities of whose axis rotate about the equinoctial points of an ideally fixed ecliptic inclined 23° 33′ in respect of the equator; the complete rotation on those two small circles, having 4° 18′ 43″ of radius, is accomplished in 4171¼ lunar years. In this period the equinoctial points would seem to accomplish, with a motion not uniform, an oscillation of 21° 30′ (10° 45′ forwards and the same backwards); in a similar time there will take place an unequal variation of the obliquity.

The hypothesis of Thābit was received in its entirety in Europe by Purbachius (1423–62) and by his commentators Reinhold and Nonius. The oscillation of the equinoctial points is called by the Arabs *ḥarakat al-iqbāl wa 'l-idbār*, 'motion of advance and of retreat,' whence the Latin name *motus accessus et recessus*; this was also called in Europe *motus octavæ sphæræ*, in contradistinction to the motion of the ninth sphere, to which was attributed the motion of the continuous precession; finally, since the longitude of the fixed stars underwent the same oscillations of the equinoctial points, it was often called in Europe *trepidatio fixarum*. This does not seem to have had supporters among the Muhammadans of the East after the 11th century. It had greater fortune among the Muhammadans of the extreme West (Spain and Morocco). Towards 1060–70, at Toledo, az-Zarqālī, in order to make his observations agree with those of his predecessors, suggested that the poles of the ecliptic circulated about the equatorial poles, so that the equinoxes advanced by one unequal motion towards the east about 10° and then retreated irregularly by 20°, accomplishing, *i.e.*, an oscillation of 10° forwards and 10° backwards with reference to an equinoctial point ideally fixed. Every arc of 10° would have been passed over in 750 years, so that the complete cycle of the libration would be accomplished in 3000 years. The hypothesis of az-Zarqālī, explicitly denied by Averroës,[2] was accepted by al-Biṭrūjī (*c.* 1200) in Spain and by Abū 'Alī al-Ḥasan (*c.* 1260) in Morocco; it also found great favour among the Jews and Spanish Christians and had an influence on the Hebrews, who, on a basis of Arabic sources, compiled about 1270 the *Tabulæ Alphonsinæ.*[3]

(*f*) *Motion of the solar apogee.* — Ptolemy (followed by all the later Greeks) says that he found the longitude of the solar apogee to be equal to that observed by Hipparchus, and consequently believes that it is immovable at 65° 30′, while the apogees of the five planets move with the motion of the precession. It is a merit of the Arab astronomers of the khalīf al-Ma'mūn (813–833) that they recognized that the solar apogee is subject to the

[1] A suspicion arises, however, that this tractate may rather be by a grandson of Thābit, viz. Ibrāhīm ibn Sinān ibn Thābit, who wrote concerning libration (as al-Bīrūnī and Qāḍīzādeh attest).

[2] *Metaphys.* p. 66 (Quirós, bk. iv. § 15).

[3] It must be noticed that these Hebrews combined the hypothesis of Az-Zarqālī with fantastic elements: viz. they admitted a continuous precession accomplishing the circuit of 360° in 49,000 years (*i.e.* just about 26″ 27‴ a year), which precession was to be always corrected on the basis of an inequality accomplishing its own period in 7000 years. They evidently wished to introduce into the hypothesis of trepidation Judaic elements —a thousand jubilary periods of 49 years and a thousand sabbatical periods of 7 years!

motion of the fixed stars and of the planetary apogees, *i.e.* to the displacement of longitude due to the precession of the equinoxes. But the solar apogee has also another very small proper motion in longitude which, according to Leverrier, is only 11·464″ yearly. This motion must have escaped the Muhammadan astronomers. The determination of the longitude of the apogee is not easy and, in times when telescopes and pendulum-clocks were lacking, could not be effected with absolute certainty in the minutes of arc; on the other hand, there was no term of comparison with ancient observations. One understands, therefore, why the majority of Muhammadan astronomers did not give to the solar apogee any other motion than that of the precession, attributing the small discrepancies to the imperfection of instruments and observations. It seems that Thābit ibn Qurrah, however, had dared to affirm the existence of a *proper* motion. Al-Bīrūnī[1] informs us that Thābit, author of a tractate on the inequality of the solar year, had determined 365 days, 6 hours, 12 minutes, 9 seconds, as being the length of the year which we call anomalistic, *i.e.* the time which the sun takes to return to its own apogee. If, then, the same Thābit (if we may rely upon a piece of information which Regiomontanus and Copernicus seem to have derived from the *De motu octavæ sphæræ* cited above) determined the length of the sidereal year as 365 d., 6 h., 9 m., 12 s., it is plain that he must have attributed to the solar apogee a small proper motion added to that of the precession.[2] Certainly the values found by Thābit are excellent, since, according to the moderns, the anomalistic solar year is 365 d., 6 h., 13 m., 54·9 s., and the sidereal year 365 d., 6 h., 9 m., 10·7 s. It is beyond doubt that az-Zarqālī determined with great exactness ($12\frac{12}{299}''$ every Julian year) the proper motion of the apogee, as distinguished from that due to the precession; and he therefore supposed that the centre of the eccentric of the sun moved over a very small circle, and by this was also settled the variation of the eccentricity of the solar orbit. Among us the proper motion of the apogee was discovered only in the 16th cent. by Kepler and Longomontanus.

(*g*) *Third lunar inequality.*—We need not notice other modifications of special points of Ptolemaic doctrines. It will be enough now to make a reference to a controversy carried on from 1836 to 1871 in the Academy of Sciences of Paris without any definite conclusion being arrived at, viz.: Is the discovery of the variation or third lunar inequality to be ascribed to Abū 'l-Wafā' († 998), as L. A. Sédillot maintained, rather than to Tycho Brahe? There would have been no reason for this dispute if that part of the *Almagest* relative to the movements of the moon had been better studied, and if the analogous discussions in the works of other Arabic astronomers had been examined with care. Carra de Vaux[3] has demonstrated that the hypothetical theory of the variation was nothing else than the πρόσνευσις of Ptolemy, *i.e.* the difference between the true and the mean apogee of the epicycle by which difference the mean anomaly is corrected so as then to calculate the simple equation of the moon. Al-Battānī opportunely calls it 'equation of the anomaly.' It is curious to note that no one has observed that already in 1645 Bullialdus (I. Boulliau) had recognized that the πρόσνευσις corresponded to about half of the 'variation' of Tycho Brahe, and that consequently the tables of Ptolemy for the moon were sufficiently near to the truth.

[1] *Chronology of the Ancient Nations*, Eng. tr., London, 1879, p. 61 f.

[2] The fact that Thābit wrote a tractate to maintain that the solar apogee does move is of no importance, since it is probably merely a confutation of the Ptolemaic immobility.

[3] 'L'Almageste d'Abû 'l-Wéfa al-Bûzdjânî,' in *JA* VIII. xix. [1892] 440–471.

6. **Opposition to Ptolemy.**—The many modifications of the doctrines of the *Almagest* never abandon the geometrical foundation followed by Ptolemy for the representation of the motions of the sun and planets, viz. a combination of eccentric circles and epicycles. This permitted the representation of celestial motions with all the exactness of which astronomical instruments were capable before the discovery of pendulum-clocks and telescopes; it was further obedient to the Aristotelian principle that celestial motions are circular only. Practical astronomy therefore did not feel the need of theories based on different geometrical principles. The difficulty arose only from a physical point of view, since the idea of numerous circular motions round an imaginary point was repugnant to the principles of Aristotelian physics. It was precisely in the name of Aristotelian natural laws that the battle began among the Arabs of Spain in the 12th cent. against the eccentrics and epicycles of Ptolemy; but their opponents were philosophers.[1]

The first of these was Abū Bakr Muḥammad ibn aṣ-Ṣā'igh, known by the name of Ibn Bājah or Avempace († 1139), who is said to have explained the celestial motions by means of eccentrics only, rejecting the epicycles as repugnant to the physics of Aristotle; but we have no particular account of his system.[2] After him we find Abū Bakr ibn Ṭufail (*q.v.*; † 1185–86), famous in Europe for his *Philosophus autodidactus*, who said to al-Biṭrūjī that he had found a theory of those motions quite different from that of Ptolemy rejecting both eccentrics and epicycles, and that he had promised to put it in writing. But it seems that the promise was not fulfilled. The ideas of Ibn Ṭufail probably influenced his friend Averroës (*q.v.*; † 1198), who affirms[3] the physical impossibility of the geometrical hypothesis of Ptolemy. The astronomers, he continues, assign an eccentric to the moon because, since she is eclipsed now more and now less in one and the same point of the zodiac, they suppose that she traverses the cone of shade at different distances with regard to the earth. 'But this may happen also on account of the diversity of her position, if we imagine that the poles of the lunar sphere move around the poles of another sphere. If God shall prolong our life, we will investigate the astronomy of the time of Aristotle, since this seems not to contradict physics; it consists of motions which Aristotle calls *laulab* [*i.e.* spirals]. I believe that this motion consists in this, that the poles of one sphere move about the poles of another; since then the motion [resulting] is according to a line *leulebia* [*i.e.* spiral], just so is the motion of the sun [combined] with the diurnal motion [of the celestial sphere]. Perchance it is possible by means of such a motion to represent the inequalities which take place in the planetary motions.'

In his commentary on the *Metaphysic*, xii. 47,[4] Averroës does not succeed in forming a clear idea of the system of Eudoxus from the scanty allusions of Aristotle and from the commentary of Alexander of Aphrodisias, which is very defective in this part, it not being clear in what manner the 'motus gyrativi'[5] arise from two contrary motions, unless two different poles be supposed.[6] He observes that by this hypothesis one could explain all the appearances of the planets: 'et iste motus, ut mathematici Hispaniæ dicunt, existit in orbe stellato, et vocant ipsum motum processus et reversionis.'[7]

Although Averroës did not complete his exposition,[8] he had guessed a notable part of the hypothesis of Eudoxus (*c.* 409–356 B.C.), which was for the first time reconstructed by G. Schiaparelli in 1875. Averroës, like Eudoxus, allows only spheres concentric with the earth; he admits that the line *laulabī* may be the apparent result of two contrary circular motions—one of the sphere of the planets, and the other, in an opposite direction, of another sphere whose axis is inclined in respect of the axis of the first sphere; finally, the line *laulabī* corresponds to the ἱπποπέδη of Eudoxus, in the form of ∞, which, according to the Greek geometricians, belongs to the category of spiral lines (σπεῖραι), and, according to modern geometricians, would

[1] Cf. L. Gauthier, 'Une Réforme du système astronomique de Ptolémée tentée par les philosophes arabes du xii^e siècle,' in *JA* x. xiv. [1909] 483–510; but this article is insufficient from a mathematical-astronomic point of view.

[2] See Maimonides, *Le Guide des égarés*, ed. and tr. S. Munk, Paris, 1856–66, ii. 185 f.

[3] *Comm. de Cœlo*, ii. 35 (*Aristotelis Opera omnia cum Averrois Cordubensis commentariis*, Venice, 1562, v. fol. 118v.–119r.).

[4] Ed. cit. viii. fol. 331v.–332r.

[5] Thus the Latin translator in the commentary on the *Metaphysic* renders the Arabic adjective *laulabī* 'spiral, in the form of a spiral or of a screw.'

[6] And, in fact, this was the hypothesis of Eudoxus.

[7] *I.e.* the motion of the libration of the fixed stars in the hypothesis of the Spaniard az-Zarqālī (see above, § 5, (*e*)).

[8] Cf. also ed. cit. viii. fol. 329v. (on *Metaphys.* xii. 45).

be a lemniscate described on a spherical superficies instead of on a plane. There naturally occur in the hypothesis of Eudoxus some special conditions, of which Averroës does not seem to have thought; one does not understand, then, how the Arabian philosopher thought to save himself from the greatest objection which could be made to the system of concentric spheres, viz. that by making the distance of the celestial bodies from the earth always equal it did not permit of an explanation of the variation of the diameters of the sun and moon.

Another friend and disciple of Ibn Ṭufail, al-Biṭrūjī (a native of Pedroche to the north of Cordova),[1] attempted a complete system as a substitute for the geometrical hypothesis of Ptolemy,[2] by placing the data of observation of the *Almagest* in agreement with the peripatetic philosophy. He says that, moved by discourses of Ibn Ṭufail to meditate on this question, he had arrived at new theories by a kind of divine revelation. He admits with Ptolemy the nine spheres concentric with the earth; on the other hand, he denies the eccentrics and the epicycles. He finds it to be contrary to natural order that, while the ninth sphere impresses on all the others the diurnal motion of rotation from east to west, the spheres below the ninth should have besides a motion of their own in an opposite direction. In order to remove this contradiction, he conceives a whimsical theory which betrays the inexperience of the author in the field of practical astronomy.

According to him, the movements of the planets and of the fixed stars in longitude take place in reality from east to west, like the diurnal motion of the rotation of the heavens; those movements which astronomers have judged to be from west to east are simply illusory appearances due to the progressive diminution of the angular velocity of the spheres, according as a gradual approach is made from the ninth sphere to the earth.[3] The ninth sphere accomplishes the 360° of circumference in 24 hours and communicates this motion to the spheres below; but the impulse grows weaker from sphere to sphere. That of the fixed stars, which is immediately under the ninth, accomplishes in 24 hours something less than 360°; and this little retardation brings it about that after 36,000 years[4] it has accomplished a whole circuit less than the ninth sphere and appears to be moving very slowly in a direction contrary to it. Under the sphere of the fixed stars comes that of Saturn, considerably slower; it accomplishes in the space of about 30 years[5] a whole circuit less than the ninth sphere. Thus Jupiter loses a whole circuit in 12 years; Mars in two; Venus, the sun, and Mercury in one; and the moon in a little more than 27 days. This, then, is the reason why all the spheres under the ninth appear to move in a direction contrary to it.

For physical reasons, therefore, al-Biṭrūjī believes that the sphere of Venus is to be placed above the sun and that of Mercury below it. There remain to be explained the inequalities of the motions of the sun, moon, and planets. He says that he drew inspiration for this from constructions analogous to that by which az-Zarqālī had imagined the motion of the libration of the fixed stars. While az-Zarqālī made the poles of the ecliptic rotate parallel with the plane of the equator, al-Biṭrūjī, in the case of the planets, made the poles of the planetary spheres move on inclined planes round the poles of the equator or of the ecliptic; from this it results that the planets describe lines *laulabinæ*, *i.e.* spiral, on a spherical superficies. Thus are also explained the stations and retrogradations of the planets. For this part, therefore, we have the partial resuscitation of the hypothesis of Eudoxus. The ideas of al-Biṭrūjī were accepted by a fair number of Christians and Jews in Spain and Provence; and they had also an echo in Italy in the 16th century.

7. Celestial physics.—As is said above,[6] celestial physics, according to Muhammadan and Greek writers, lies outside the field of astronomy; its problems are discussed in books of metaphysics, of physics in an Aristotelian sense, and of theology, or at least in special works, of which the greater part are now either lost or unedited.

Like Ptolemy, the most ancient Arabic astronomers neglect to define the idea of the celestial spheres and limit themselves to considering them in the mathematical aspect of ideal circles representing the movements of the heavenly bodies.

1 Alpetragius of our mediæval writers.

2 Of the book of al-Biṭrūjī there has been published only an obscure Latin tr. (Venice, 1531) made from a Hebrew version. The Latin tr. made in 1217 at Toledo by Michæl Scotus is unedited, as is also the Arabic text.

3 This idea was already maintained by the Iḫwān aṣ-Ṣafā' about the middle of the 10th cent. (see their *Rasā'il*, Bombay, 1305–06 A.H., ii. 22–26) and by Faḫr ad-dīn ar-Rāzī, *Mafātīḥ al-ghaib*, Cairo, 1308 A.H., ii. 60 f. (comm. on *Qur.* ii. 159) and vi. 117 f. (on *Qur.* xxi. 34). But they admit Ptolemy's eccentrics and epicycles.

4 This is the period of time in which, according to Ptolemy, the fixed stars accomplish the circumference, proceeding towards the east.

5 The duration of the heliocentric sidereal revolution of Saturn is a little less than 29½ years; it is, in the Ptolemaic hypothesis, the revolution of the centre of the epicycle of Saturn in the zodiac.

6 See § 1.

The Aristotelian conception of solid spheres was introduced for the first time[1] into a purely astronomical treatise by Ibn al-Haitham; and he, in his unedited compendium of astronomy, gives the definition which was accepted afterwards by all the other writers of elementary treatises: 'A celestial sphere (*falak*, plur. *aflāk*) is a body completely spherical, bounded by two parallel spherical superficies having the same centre.'[2] In this, as he himself says, he drew his inspiration from the *Hypotheses Planetarum* of Ptolemy; in fact, as we see from a passage of Naṣīr ad-dīn at-Ṭūsī, he followed the *Hypotheses* also in expounding how the celestial motions can be represented, and also by supposing simple equatorial zones of those complete spheres, so that the spheres of the epicycles become, as it were, tambourines (*duff*) rotating on their own axes, and the other spheres like armils.[3] This second form of representation was soon abandoned, as contrary to the principles of natural philosophy.

Muhammadan writers agree with Aristotle in holding that the spheres and the celestial bodies are a simple unique substance, different from the four elements of the sublunar world, and forming a fifth element. The solidity also of the spheres, by reason of which the stars remain infixed within them, and by which the stars are carried round, is accepted by almost all,[4] except a few theologians who, to support a strictly literal meaning of a passage of the Qur'ān,[5] maintain that the stars move within the spheres like fish swimming in water. The ideas of the majority of writers after the 4th cent. of the Hijra are those set forth in the dogmatic theology of al-Baiḍāwī († 1286) as follows:

'The spheres are transparent; since if they were coloured, our eyes could not possibly see that which is within them. They are neither hot nor cold; since otherwise the heat and cold would dominate in the elements of the sublunar world on account of their contiguity to it. They are neither light nor heavy; since otherwise in their nature there would be a tendency to rectilinear motion.[6] They are neither moist nor dry; otherwise the facility or difficulty of taking certain forms or of attaching themselves would be manifested in rectilinear motion. They are not capable of quantitative motion; since, if the convexity of the external superficies were to increase, it would be necessary that there should be a void above it, which is absurd; and the same is to be said regarding concavity, since if this were to increase it would be necessary that one sphere should enter into another or that between the two there should be a void.'[7]

So also it is proved by Aristotelian reasonings that the motion of the spheres must be circular.

The greater number of Muhammadan philosophers accept the peripatetic doctrine that the spheres and the stars are living beings, rational, operating by their own will; that the spheres have souls which exist in their bodies as our souls in our bodies; and that, as our bodies move under the impulse of our souls towards the ends we have in view, so also do the spheres, which have as their end the serving of God. This doctrine is for the most part repudiated by the theologians: al-Ghazālī († 1111) does not deny the possibility of it, but he affirms that we are incapable of knowing it; on the other hand, Ibn Ḥazm († 1064), Ibn Qayyim

1 This follows from the preface itself of Ibn al-Haitham and from the attestation of Muḥammad al-Akfānī as-Saḥāwī, *Irshād al-qāṣid*, p. 85.

2 Only the spheres of the epicycles are full, *i.e.* are true globes.

3 These two forms of hypothesis are always found side by side for every planet, in bk. ii. of the *Hypotheses*, published for the first time (1907) in German according to the Arabic version which takes the place of the lost Greek text (in Ptolemy, *Opera astronomica minora*, ed. Heiberg, p. 113 ff.).

4 The ancient Arab astronomers—*e.g.*, al-Battānī (i. 124)—leave the question uncertain.

5 xxi. 34.

6 According to the Aristotelian theory (*de Cœlo*, i. 8 f.), heavy bodies tend in a straight line towards the centre of the world, light bodies tend to withdraw in a straight line from the centre.

7 *Maṭāli' al-anwār*, Constantinople, 1305 A.H., p. 262.

al-Jauziyyah († 1350), and many others absolutely deny life and intelligence to the heavenly bodies. The philosophers of the peripatetic school and several theologians (*e.g.*, al-Baiḍāwī) hold that the movers of the celestial souls and consequently of the spheres are pure intelligences. Concerning their origin al-Fārābī, Avicenna, and their followers maintain a Neo-Platonic emanatory theory: from the first principle emanates the first intelligence, and from this are derived all the nine spheres by means of successive triads always composed of intelligence, soul, and body, until one arrives at the final or active intelligence from which is derived all the material of the sublunar world. This theory is vigorously opposed by al-Ghazālī and the other theologians.

The question of the marks on the moon is either neglected or only hinted at in the works hitherto published. The idea that the moon had valleys and mountains like the earth—an idea set forth by several Syriac writers—did not harmonize with the Aristotelian conception of the nature of the heavenly bodies and so could not be accepted by Muhammadan writers.

Observation of the solar spots is almost impossible to the naked eye; Faḫr ad-dīn ar-Rāzī, however, explicitly affirms: 'There are those who believe that there exist on the surface of the sun spots, in the same manner as there are marks on the surface of the moon.'[1] These spots were actually seen on some occasions, but were erroneously believed to be transits of Mercury and Venus across the sun.

The comets and the other meteors (in an Aristotelian sense) were the subjects of observations and of numerous monographs. But, judging from the little that we know about them, Muhammadan writers followed in this matter the theories set forth by Aristotle in his books on meteorology.[2]

8. Conclusion.—The importance of Muhammadan astronomy in the history of science has been variously judged; sometimes Muhammadan astronomers have received excessive praise, sometimes unjust criticism, as if they had done nothing but preserve and transmit to Europe Greek science, improving it only in minor details. This harsh verdict is due not only to very imperfect knowledge of the Arabic writings on astronomy (of which the greater part is still unedited), but also to the fact that no account has been taken of the special conditions of astronomy in the glorious period of Muhammadan culture. The system invented by the Greek geometricians, and completed by Ptolemy, for representing all the celestial motions had mathematically all the precision that could be desired or attained by the use of the best instruments; it produced no sensible discrepancy between theory and the result of observation. The elliptic orbits of Kepler would not have given the theory greater perfection than it received from the complicated system of eccentrics and epicycles; the latter indeed had the advantage of preserving the Pythagorean and Aristotelian principle, which denied any but circular movement in the heavens. One must not forget that even in the heliocentric system of Copernicus the motions of the planets were still explained by means of combinations of epicycles — combinations which were in several cases less perfect than those employed by the Ptolemaic astronomy. To change the method of geometrical representation would therefore have been whimsical—a mathematical trick, which no datum of observation would have justified; and, in fact, those Arabs who wished to eliminate the eccentrics and the epicycles[1] were philosophers rather than astronomers, and they propounded their hypotheses from data based only on Aristotelian physics.

It is thus easy to understand how it was that, *e.g.*, the astronomers of the khalīf al-Ma'mūn and their successors saw no necessity for drawing from their observations of the movement of Venus[2] the final conclusion that Venus revolved round the sun. From the point of view of such phenomena as could be observed without telescopes, this second hypothesis had no higher value than that which made Venus revolve round the earth. In a word, celestial appearances gave no cause to shake the foundations of the geocentric system, which agreed very well with every religious notion, and which was supported by the authority of both Aristotle and Ptolemy, reinforced by a very potent element in Hellenistic and mediæval culture, viz. astrology. Giovanni Schiaparelli, in one of his monographs on Greek astronomy,[3] has set forth clearly the decisive influence which astrology, brought into Greece by the Chaldæan Berosus (3rd cent. B.C.) and consequently received with great favour by the Stoics and Neo-Pythagoreans, had in the abandonment of the heliocentric system of Aristarchus. Astrological doctrine, based on the immobility of the earth in the centre of the world, was irreconcilable with any system which made the earth revolve round the sun or round any other body; astrology was thus a very powerful additional obstacle to the abandonment of the geocentric idea. Further, we must not forget that it was only in the 17th cent. that European physics reached clear proofs of the diurnal rotation of the earth and justified elliptic orbits and the heliocentric system, and that the really irrefutable argument for the revolution of the earth round the sun was furnished only in 1728 by the discovery of the aberration of the fixed stars.

An essential condition of all astronomical progress is to have at disposal a long series of methodical observations; and in this matter Muhammadan astronomers were obliged to begin, so to say, from the foundation. Ptolemy was the last Greek observer; but not even all the observations which he says he made are true. In several cases of capital importance—*e.g.*, regarding the obliquity of the ecliptic and the longitude of the solar apogee —he gave as agreeing with his own observations data found about 270 years before his time by Hipparchus, thus causing certain elements to be believed constant which are really variable. In other cases—*e.g.*, regarding the precession of the equinoxes — his observations are very rough. Theon of Alexandria (4th cent. A.D.) and Proclus (5th cent.) do no more than accept Ptolemy's elements, in some ways aggravating his errors; accordingly, during the seven centuries from Ptolemy to the first flourishing of Arabo-Muhammadan astronomy, we have not even one observation which is of use to the science. The first task, therefore, of the Arabic astronomers was to revise all the Ptolemaic elements of the celestial motions; it was a time not to form new theories but to collect the indispensable elements of fact by means of continuous observations more accurate than those of the Greeks. This task was accomplished by the Muhammadan astronomers in a marvellous manner;

[1] *Mafātīḥ al-ghaib*, i. 259, on *Qur.* ii. 27.

[2] On falling stars see present writer's art. in *Rivista degli Studi Orientali*, viii. [1920] 375–388.

[1] See above, § 6.

[2] They found (contrary to Ptolemy) that Venus has the same longitude of apogee, the same eccentricity, and the same equation of centre as the sun; and so the true longitude of the centre of the epicycle of Venus is always equal to the true longitude of the sun. This was the same as to suppose that the orbit of Venus is an epicycle whose centre is always the true place of the sun and runs over the solar orbit; in other words, it was equivalent to making Venus a satellite of the sun.

[3] *Origine del sistema planetario eliocentrico presso i Greci*, Milan, 1898, § 55.

indeed, we must come down to the time of Tycho Brahe (1546–1601) to find observers and observations comparable to those of the Muhammadan Middle Ages. Further, by founding trigonometry in a modern sense and developing it to a high degree they furnished astronomical science with an excellent instrument for its work.

The influence of Muhammadan astronomy in Europe is so far-reaching that to treat of it at length would be to give the history of some centuries of European astronomy. From the 12th cent. to the end of the 15th the compendiums used in the schools were translated from Arabic or were based on Arabic writings; the astronomical tables and the processes of calculation were derived from Arabic works, among which must be classed (from the point of view not of their language but of their contents) the celebrated tables of Alfonso which were still used by many in the 16th century. Spherical trigonometry in Europe started from Arabic treatises; the famous Regiomontanus himself (1436–76) borrows more than appears on the surface from al-Battānī. Through the influence of these Arabic sources the ancient Latin technical terminology was greatly modified, and not only do Arabic astronomical terms enter into European languages, but Latin words acquire new significations by imitation of corresponding Arabic words. The words 'degree,' 'minute,' 'equation' (in its astronomical sense), 'equation of the centre,' 'argument' (of a table), and some others, owe their technical signification to ridiculously literal translations of Arabic writings. We cannot enumerate all that European astronomy owes to Muhammadan observers; it will be enough to recall that they rendered inestimable services even to writers of the 17th cent.—*e.g.*, Halley—precisely because they offered the only certain means of checking elements determinable only by a comparison with observations separated by long intervals of time. The books of Regiomontanus, Purbachius, Copernicus, Tycho Brahe, Riccioli, etc., cite the observations which were known to them of their Oriental predecessors. The theory and practice of instruments in Europe has also Arabic sources. Finally, we must not forget the influence exercised by the Arabs in the way of example. They infused into the Christians and Jews of Spain a passion for continued observations and an idea of the perfectibility of astronomical science; from Spain this passion and idea spread through the rest of Europe, preparing the way for modern astronomy.

The conditions of the Byzantine mediæval world were not favourable to the development of the sciences. Nevertheless, Muhammadan culture, which left many traces in Byzantine astrology, had also its part in astronomical studies. In 1323 an anonymous Greek introduced the Persian astronomical tables of Shams ad-dīn al-Buhārī (Σάμψ Μπουχαρής), which were at once widely used; in 1346 George Chrysococces made a new redaction of them, preserving at the same time many Arabic-Persian technical terms; and finally, about 1361, Theodore Meliteniotes reproduced these methods and these Persian tables in the third and last book of his Ἀστρονομικὴ Τρίβιβλος, after having set forth in the first and second books the methods and the tables according to Ptolemy and Theon of Alexandria. Thus there was created at Byzantium also a new astronomical terminology different from that of the classic Greek; and sometimes even Greek proper names appeared transformed by their passage through Arabic-Persian sources, as Θαούνης in place of Θέων.

LITERATURE.—There is no satisfactory exposition of the astronomy of the Muhammadan peoples in the Middle Ages; the general histories of astronomy—*e.g.*, those of F. Hoefer, J. H. von Mädler, R. Wolf (the best of all), and Arthur Berry—are inadequate, antiquated, and often erroneous. J. B. J. Delambre, *Hist. de l'astronomie du moyen âge*, Paris, 1819, pp. 1–211, and 513–530, is not a history but an analysis (of very unequal value) of various works of Muhammadan authors; the part devoted to the unedited book of Ibn Yūnus (pp. 76–156) is especially noteworthy, but it has the usual defect of Delambre—instead of the analyzed processes of the author, it substitutes a series of formulæ found by Delambre himself. Useful, but to be used with great caution, is L. A. Sédillot, *Matériaux pour servir à l'hist. comparée des sciences mathématiques chez les Grecs et les Orientaux*, 2 vols., Paris, 1845–49; see also his *Mémoire sur les instruments astronomiques des Arabes*, do. 1841 (*MAIBL*, *Savants étrangers*, i.). The present writer's Arabic book quoted above, p. 90[a], n. 1, concerns only the earliest period (summary of H. Suter, in *Bibliotheca Mathematica*, III. xii. [1912] 277–282). Many historical notices concerning the development of astronomical theories are to be found in the present writer's commentary on al-Battānī, *Opus astronomicum*, 3 vols., Milan, 1899–1907; short notices are to be found here and there in E. Wiedemann, 'Beiträge zur Geschichte der Naturwissenschaften,' nos. iii.–xxxviii. (in the *Sitzungsberichte der physikal.-medizinischen Sozietät in Erlangen*, 1904–1914) and in other small pamphlets by the same author. For biographical and bibliographical notices concerning individual writers see the excellent book of H. Suter, *Die Mathematiker und Astronomen der Araber und ihre Werke*, Leipzig, 1900, and 'Nachträge und Berichtigungen zu Die Math. und Astron.,' in *Abhandl. zur Gesch. der mathemat. Wissenschaften*, xiv. [1902] 157–185. For edd. and tr. of original texts see above, II. 2.

CARLO ALFONSO NALLINO.

SUN, MOON, AND STARS (Teutonic and Balto-Slavic). — 1. *TEUTONIC.*—**1.** Archæological evidence.—The world-wide symbol of the sun-wheel occurs in the earliest Scandinavian rock-markings. Rude representations of horses and ships, which may have solar significance, are also found. In 1902 a curious object, apparently connected with the sun-cult, was discovered near Trundholm in Sweden. It is a representation of a disk, having gilding on one side and spiral ornamentation on the other, with a horse in front of it, both horse and disk being drawn on a waggon.

2. Solar myths.—Sun and moon, day and night, summer and winter, are personified in the poems of the older Edda. The Valkyrie Sigrdrifa invokes Day and the sons of Day, Night and her kinswoman.[1] Various passages from *Grimnismál*, *Vafþrúðnismál*, and *Völuspá* are summarized by Snorri:[2]

> 'Night, who was of Jotun race, married Delling, who was of Aesir race, and their son was named Day.' 'Then Allfather took Night and her son Day and set them up in heaven and gave them two steeds and two chariots and they were to drive round the earth every twenty-four hours.' The earth is bedewed by the foam which falls each morning from the bit of Hrimfaxi, the horse of Night. Day's steed is called Skinfaxi and he lights up the whole world with his mane. 'Then said Gangleri: "Who steers the course of the sun and of the moon?"' Mundilföri had a son Mani and a daughter Sol, whom the gods set up in heaven. 'They let Sol drive the steeds which drew the chariot of that sun which the gods made to light the world, from the sparks which flew out of Muspellheim [*i.e.* the world of fire and heat]. . . . These steeds are called All-Swift and Early-Awake, but under the withers of the horses, the gods set two wind-bellows to cool them, but in some old records that is called "isarnkol" [*i.e.* iron-coolness]. Mani steers the course of the Moon and rules over waxing and waning.'

The belief in the chariot and horses of the sun is very wide-spread; in Scandinavia, judging by the archæological evidence, it must have existed in very early times. We may have a reference to the same idea in Tacitus:

> 'Beyond the Suiones is another sea, sluggish and almost stagnant, by which the whole globe is imagined to be girt about and enclosed, from this circumstance that the last light of the setting sun continues so vivid till its rising as to obscure the stars. Popular belief adds, that the sound of his emerging from the ocean is also heard, and the forms of horses and the rays streaming from his head are beheld.'[3]

Like most other primitive people, the Scandinavians were struck by the phenomena of the eclipses, which they thought were caused by wolves.

> 'He who pursues her [*i.e.* the sun] is called Skoll; he frightens her and he will catch her; but he who is called Hati

[1] *Sigrdrifumál*, 2. [2] *Gylfaginning*, x.–xii.
[3] *Germ.* 45. Unfortunately the text is uncertain; some editors read *deorum* for *equorum* in the last sentence.