ISLAM AND THE RISE OF THE SEVENTEENTH CENTURY SCIENCE*

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The rise of the Abbaside Caliphate in the middle of the eighth century marked the opening of a period of scientific activity important not only in the history of Islam but also in all history. This era of intense scientific work, sometimes called the Golden Age, was not very long-lasting, however, and the leadership of Islam in science was lost after the eleventh century. This was not only the result of the rise of scientific interest in Western Europe, but was also due to a decline of scientific interest in Islam.

Speaking of the eleventh century, Sachau says that it was the turning point in the history of the spirit of Islam, and adds, "But for Al Ash'arî and Al Ghazâlî the Arabs might have been a nation of Galileos, Keplers, and Newtons."[1]

This statement is rather representative of the general attitude of scholars when they speak of the decline or stagnation of science and its causes in Islam. It involves the assumption that science would have advanced in lines roughly equivalent to those in Europe, had scientific interest and progress in Islam continued with its initial intensity, an assumption which would, on the whole, appear quite reasonable.

Another assumption generally implied by the study of the causes of the stagnation or decline of science in Islam is that, left to itself, science would progress more or less automatically, and that its decline would have to be brought about by definite forces, would have to be imposed by outside factors. It is not by any means clear, however,

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Bu yazı, 1958 Haziranının üçüncü haftasında Pisa ve Vinci'de toplanan Milletlerarası İlim Tarihi Simpozyomunda sunulan tebliğimi tesbit etmektedir. Bu Simpozyoma Türk Tarih Kurumunun ve Dil ve Tarih-Coğrafya Fakültesinin temsilcisi, ve İtalya İlim Tarihi Cemiyetinin davetlisi olarak katıldım.

[1] Al Bîrûnî, *The Chronology of Ancient Nations*, tr. Ed. Sachau, 1879, Preface, p. 10.

that the progress of science in Europe, leading to the rise of the seventeenth century science, is less in need of explanation than is its failure to achieve a similar progress in Islam.

Examples of stagnation of science are seen in other societies: in India, China, Egypt, and among the Greeks themselves. Generally speaking, therefore, the stagnation of science should perhaps be considered to be as natural as its progress.

Speaking of Islam, or medieval science in general, there is, for one thing, the question of the degree of readiness of science as left by the Greeks for new and important advances. It is by no means clear that Greek science still possessed an inherent ability for easy and rapid growth, that it had not reached a stage with a tendency toward stagnation. There were additional factors arising in the Middle Ages, and it can reasonably be claimed that medieval science, at any rate, does not seem to have been in a circumstance particularly suitable for rapid change and for fundamental advances.

It may be said that medieval science, seems to constitute a case favorable to the torch theory of progress. Thus although Islam did not produce Galileos and Keplers, she prepared the groundwork for the ultimate emergence of the new scientific era in Europe. Islam largely played its part by enhancing the dignity of Greek science and also by enriching it materially, but perhaps she thereby used her force in large measure. And when the torch of science went to another society which was eager to cultivate it, the very passage to a new environment with its fresh possibilities of development for science may be claimed to have constituted a change favorable to its progress.

The intervening Islamic efforts may ideed have been indispensable. The importance of the legacy of Islam finds its expression in the term "The Renaissance of the Twelfth Century". But there is also the question of possible Islamic contributions during the era extending form the thirteenth to the sixteenth or seventeenth century. Although the decisive achievements were materialized in Europe and Islam failed to reach this same stage, Islamic contributions seem not to have come to an end with the close of the period of translations from Arabic into Latin. It is the purpose of this paper to give examples of such possible contributions, our attention being concentrated on Eastern Islam.

Contacts of Europe with Islam were sharply reduced with the close of the translation period, but some fruitful contacts undoubtedly continued to take place. Christianity was a recognized religion in Islam, and Christians were given a definite legal status by the Moslems. There were places of pilgrimage too within Islamic territory, and there always were Christians travelling in Islam. Such travels were facilitated, moreover, by the existence of Christian communities within Islam.

The time of the Mongols, or more specifically, the Ilkhans, and the Ottoman era, especially the reign of Muḥammed the Conqueror, marked periods of increased contacts. The Christian and Jewish communities within Islam too were, doubtless, instrumental in furthering cultural contacts between Islam and Europe. By the middle of the fifteenth century a considerable part of the Balkans came under Ottoman rule, and it is reasonable to think that these circumstances too increased cultural relations between the two realms.

The map of America by Pîrî Reis,[2] an admiral of Suleyman the Magnificent, is a clear witness of the existence of fruitful cultural relations. The Ottomans had learned how to make cannons also from the Europeans. It should be true, however, that due to the prevalence of a more philosophical variety of scientific interest in Europe, the Christian World would be expected to have had a more searching curiosity and a more open eye for new things in science as compared with Islam in these later centuries.

It has been claimed that the ideas of Ibn al Nafîs influenced the discovery of the circulation of blood in Europe. This is probable, as translation from Ibn al Nafîs into Latin was made in the sixteenth century, and it was after this that the new ideas on the subject made their appearance in Europe. But the evidence at our disposal in favor of such an influence is by no means conclusive.[3] It is quite possible too that the trocart whose invention is attributed

[2] See, e. g., *Pirî Reis Haritası*, Istanbul 1935.

[3] See, e. g., H. Butterfield, *The Origins of Modern Science*, 1952, p. 32-33; Abdul-Karim Chéhadé, *Ibn an-Nafîs et la Découverte de la Circulation Pulmonaire*, 1955, p. 47 ff.; Charles O'Malley, *A Latin Translation of Ibn Nafis (1547) Related to the Problem of the Circulation of the Blood, Actes du VIII*[e] *Congrès International d'Histoire des Sciences* vol. 2, p. 716-720; *Histoire Générale des Sciences*, vol. 1: *La Science Antique et Médiévale*, ed. René Taton, 1957, p. 470.

to Sanctorius (1561-1636) and sometimes to certain contemporaries of his [4] was not unrelated to the similar instruments used by Sabunjuoghlu Sharafuddîn, fifteenth century Turkish physician. [5] It is of interest in this connection that Sanctorius had been to Hungary and Croatia. [6]

A sizable book of Naṣîr al Dîn's (d. 1274) on Euclid's postulates was published in Arabic in the end of the sixteenth century in Rome, and about the middle of the following century his ideas on this subject became available in Latin translation. This is said to have influenced the work of Girolamo Saccheri, in the eighteenth century. [7]

There is also the recent discovery that the lunar theory of Ibn Shâṭir of the fourteenth century was identical with that of Copernicus except for trivial differences in parameters, but it cannot be ascertained whether any Islamic influence is involved in this case.[8] But the field of astronomy would seem to be of special importance, as far as possible later influences of Islam on Europe are concerned.

In fact, Eastern Islam was the scene of rather substantial activity in astronomy in the course of the later centuries. This work was especially concentrated in the Marâgha and the Samarqand Observatories, falling in the second half of the thirteenth and the first half of the fifteenth centuries respectively. In these two centers there was a revival of scientific work which, though short-lived, is somewhat reminiscent of the Golden Age. The major incentive for scientific work during these later centuries in Eastern Islam seems to have come from astrology.

Indeed, in Islam, the activity of observatory buildnig and systematic observation reached its peak after the twelfth century, i. e., after

[4] Ernst Heinrich, *Sanctorius und die Erfindung des Trokars, Archiv für die Geschichte der Naturwissenschaften und der Technik*, 1913, p. 160-162.

[5] A. Süheyl (Ünver), *Sur un Manuscrit médical illustré du XVe siècle, Extrait des Comptes rendus du IXe Congrès International d'Histoire de la Médecine*, 1932, p. 5.

[6] H. E. Siegerist, *The Great Doctors*, 1933, p. 151.

[7] H. Suter, *Die Mathematiker und Astronomen der Araber und Ihre Werke*, 1900, p. 151; G. Sarton, *Introduction to the History of Science*, vol. 2, p. 1003; *Histoire Générale des Sciences*, vol. 1, p. 456.

[8] Victor Roberts, *The Solar and Lunar Theory of Ibn ash-Shâtir, A Pre-Copernican Copernican Method, Isis*, vol, 48, 1957, p. 428, 430-32.

the decline of science had started, and this astronomical work was aimed to be conducted on a rigorously mathematical level. Europe was quite active in philosophical speculations on astronomical theory, a tradition which was a continuation of the Islamic trend in Spain and the Maghrib. In the field of mathematical and observational work, however, European achievements were not impressive at all up to the time of Peurbach and Regiomontanus. Astronomy in Eastern Islam was clearly in advance of Europe up to the fifteenth century, and after this too it took Europe some time before it could rightly feel above any profitable contacts with Islam. It is of interest that up to the fifteenth century astrology was held at bay in Europe as a result of its prohibition by the Church.

It seems probable that the sudden rise in the level of astronomical work in Europe with Peurbach and Regiomontanus was the result of contacts with Eastern Islam. That the upper planets follow the sun in their motions on their epicyles and the lower planets with the motions of the centers of their epicycles was of course known to Ptolemy and was clearly stated by him. But with the fifteenth century these connections between the motions of the planets and that of the sun began to receive special emphasis, and this tradition has been deemed to be of special importance in the genesis of the Copernican system.

Peurbach speaks of such relations between solar and planetary motions, but does not refer to Mercury in this connection;[9] Regiomontanus completes the list by also referring to Mercury as having the same characteristics as Venus.[10] It is of interest that these details seem to have their parallels among the astronomers of Islam connected with the Marâgha Observatory and those who commented on the work done in that institution, as well as the astronomers of the succeeding generations.

The motion of the apogee of the sun had been discovered by the astronomers of Al Mamûn already in the ninth century but had remained controversial. [11] With the Marâgha astronomers the doubts

[9] E. Zinner, *Entstehung und Ausbreitung der Coppernicanishen Lehre, Sitzungsberichte der phys.-med. Sozietät*, Erlangen 1943, vol. 74, p. 97.

[10] E. Zinner, *ibid.* p. 129 ff.

[11] Karl Kohl, *Über den Aufbau der Welt Nach Ibn al Haytam, Stizungsber. der phys.-med. Sozietät* Erlangen 1922/23, vol. 54-55, p. 155; Francis Carmody, *The Astronomical Works of Thâbit, Isis*, vol. 45, p. 239 ff.

on this point are seen to have disappeared; they generally accepted the motions of the apogees of all the five planets and the sun to be equal to that of the fixed stars resulting from the precession of the equinoxes.[12] Such a common motion between the planets and the sun was undoubtedly conducive to the placing of emphasis on the parallelisms between the planetary motions and that of the sun.

This displacement common to all the spheres made the theory of solid spherical shells very well suited to the explanation of stellar motions; and, in turn, this theory which served to explain the motions required by the Ptolemaic system in a spirit of Aristotelian ideas, must also have facilitated the continued acceptance of the equation of the motion of the apogees with that of the fixed stars. It is of interest that the system of solid spherical shells, which was widely in use in Marâgha circles as well as with the later astronomers of Islam,[13] was adopted by Peurbach.[14]

The apogees were all on the deferents *(ḥâmil)*, but Mercury had an additional apogee on its additional sphere, the *mudîr* which enveloped the deferent. The motion of the *mudîr* apogee of Mercury was equal to the motions of the apogees of the sun and the other planets, but as far as the motions of the apogees of the deferents were concerned Mercury formed an exception.

The fact that, compared with the other planets, an additional sphere was assigned to Mercury is one of the special characteristics of Mercury which are mentioned, and this may be considered the main feature differentiating Mercury from the other planets. For all other comparisons pertaining to other details such as the relations of apogees

[12] See, e.g., Quṭb al Dîn al Shîrâzî, *Nihâya al Idrâk fî'l Hay'a*, MS., Bursa Hüseyin Çelebi, No. 747, p. 67b, 52a, 77b; Ḥasan ibn Muḥammed al Nishâbûrî, *Kashf al Ḥaqâiq*, ms., Bursa, Haraccıoğlu, No. 1163, p. 101b, Ayasofya, No. 2696, p. 81a; Wabkanwî, *Zîj* ..., Ayasofya, No. 2694, p. 50a, 51b, 52a. See also the relevant tables of the *zîjs* of the period.

[13] The system seems to have originated with Ibn al Haytham (Kohl, p. 144-45), but a prototype of it wherein each planet was treated as an independent system in itself was apparently devised earlier by Al Nayrîzî (Muḥammad 'Abd al Ḥalîm, Annotations to Qâḍîzâda's Commentary of Chaghmînî's *Mulakhkhkhaṣ*, Delhi 1325 H., p. 31).

[14] Dreyer, *A History of Astronomy from Thales to Kepler*, p. 289; Zinner, *ibid.*, fig. 10, p. 41.

and perigees result from or are represented by the difference of the system of spheres assigned to it.[15]

Some astronomers, especially Quṭb al Dîn al Shîrâzî claimed that the correspondence of the centers of the epicycles of the lower planets with the sun was only approximate, as maximum morning and evening elongations were not equal in these planets.[16] Quṭb al Dîn also states that although in its motion in latitude and longitude Mercury resembles Venus, Venus was deemed to correspond with the upper planets and not with Mercury.[17]

Consequently, the parallelisms between the upper planets and Venus are seen to have been emphasized, at least by one school of astronomers. [18] It would appear probable therefore that Peurbach was influenced by such Islamic views. Of course it is necessary, however, to make comparisons of details.

The tendency of emphasizing the similarities between Venus and Mercury, i. e., of grouping the upper and the lower planets separately, is also found, among the Islamic astronomes of this period. These astronomers had corresponding preferences in the factual realm; they believed, e. g., that the correspondence between the sun and the centers of the epicycles of the lower planets was exact. One of the representatives of this school seems to have been Al Chaghmînî whose *Mulakhkhaṣ* was very poupular, as can be seen from various commentaries written on it during the first half of the fifteenth century especially. [19]

Thus, the corresponding European tradition associated with Regiomontanus may also be due to an Islamic influence. And the times of Quṭb al Dîn, Peurbach, and Regiomontanus were quite fovorable for the passage of ideas from Islam to Europe.

The Ilkhans, e. g., were in rather active relationship with Western Europe, and this was not limted to diplomatic relations.[20] Speaking

[15] Quṭb al Dîn, *ibid.*, p. 68a; M. 'Abd al Ḥalîm p. 89 and note 6.

[16] Quṭb al Dîn, p. 68a.

[17] E. g., Quṭb al Dîn, p. 67b, 66b.

[18] Quṭb al Dîn, p. 77a; M. 'Abd al Ḥalîm, p. 89.

[19] It was commented, e. g., by Birjandî in addition to the above-mentioned Qâḍîzâda and M. 'Abd al Ḥalîm (see below, note 24).

[20] T. F. Carter, *The Invention of Printing in China*, 1931, p. 126-32

of the time of Ghâzân Khân, i. e., the beginning of the fourteenth century, Rashîd al Dîn says, "There were gathered under the *padishah* of Islam, philosophers, astronomers, scholars, historians, of all religions, of all sects, people of Cathay, of Machin, of India, of Kashmir, of Tibet, of the Uyghur and other Turkish nations, Arabs and Franks".[21]

The Ilkhan ruler Arghûn was studying the course to be followed by his Genoese envoy Buscarelli di Ghizalfi in his journey to Rome, France, and England from a map prepared by Quṭb al Dîn. [22]

The question of the distances of the stellar bodies would seem to constitute another item of interest to our subject. It is known that Copernicus was at least extremely pleased to see that with his system the question of planetary distances could be answered in an unambiguous manner, and it has been suggested that preoccupation with the difficulties connected with the question of planetary distances was an important factor in leading him to his new system. [23]

It is of interest that increased preoccupation with the distances of Mercury and Venus as compared with that of the sun is seen in the later centuries in Islam. There are references to alleged observations of these two planets as black spots on the face of the sun and to speculations as to the possibility of making such observations, especially in Eastern Islam. [24] Regiomontanus seems to have heard of them; for

[21] Rashîd al Dîn, *Jâmi' al Tawârîkh*, ed. and tr. Quatremère, vol. 1, Paris 1836, p. 38, 39; Carter, p. 128. There is mention of a Byzantine scholar who, at the end of the thirteenth century, went to Persia, apparently to the land of the Ilkhans, and studied astronomy there; he is said to have brought back with him to Trebizonde several books on astronomy which were translated into Greek (R. Guillard, *Essai sur Nicéphore Grégoras, l'Homme et l'oeuvre*, Paris 1926, p. 72; M. F. Köprülü, *Maraga Rasathanesi*, *Belleten*, vol. 6, 1942, p. 225). Greek activity of a similar nature about the time of Muḥammed the Conqueror was of greater importance, for at that time it also meant contact between Europe and Islam with the Byzantines as intermediaries.

[22] Sarton, *Introduction..*, vol. 2, p. 1018; Zeki Velidi Togan, *Türk Yurdu*, vol. 26, 1942, p. 45-48.

[23] Benjamin Ginsburg, *The Scientific Value of the Copernican Induction*, *Osiris*, vol. 1, p. 307 ff.

[24] Thus Ibn Sînâ, Muḥammad Ṣâliḥ ibn Muḥammad al Baghdâdî, and Muḥammad ibn Abî Bakr al Ḥakîm are said to have made such observations of Venus, while Ibn Bâjja is said to have seen both Mercury and Venus under such circumstances (Birjandî, Annotations to Qâḍîzâda's Commentary of the *Mulakhkhaṣ* of Chaghmînî, Istanbul 1290 H., p. 16, 40).

he expresses his belief in their impossibility, as he thought the sun's surface to be one hundred times as large as that of Venus.[25]

Parallax was conceived, at least theoretically, as a means of determining distances, but in general distances were assumed known and parallaxes calculated from them. As the solar parallax was generally thought to be of the order of 2 to 4 minutes, it was natural to think that planets nearer than the sun too should have perceptible parallaxes. In fact, Jâbir ibn Ḥayyân is said to have expressed this belief.[26] During the later centuries it is sometimes said that parallaxes are detectable up to the sphere of Mars but that Mars has no perceptible parallax.[27] It is also stated that it is uncertain whether Mercury and Venus have any parallaxas and therefore whether they are below the sun or above it. It is explained that parallaxes are measured with the parallactic ruler which is set up in the meridian, and that as these planets are not visible at their culmination their parallaxes cannot be measured.[28]

Ghiyâth al Dîn al Kâshî, the first director of the Samarqand Observatory, is said to have thought of a new method for measuring the parallaxes of the lower planets and to have used it for Venus. As these planets are not visible at their culmination, he is said to have proceeded as follows, in Samarqand. He found the latitude and longitude of Venus for a given time shortly before sunrise or shortly after sunset and calculated its true altitude from these values of latitude and longitude; he then found its azimuth from this altitude and fixing a parallactic ruler at this azimuth he measured the apparent altitude of Venus. From this he deduced its parallax.[29]

Two of the methods, for measuring the parallaxes of comets, attributed to Regiomontanus are based on measurements of elevation and azimuth at two positions making acute angles with respect to the

[25] E. Zinner, *Leben und Wirken des Johannes Müller von Königsberg Genannt Regiomontanus, Schriftenreihe zur Bayerischen Landesgeschichte*, vol. 31, 1938, p. 62.

[26] Sarton, *ibid.*, vol. 2, p. 206.

[27] E. g., *Al Risâla al Mughnîya and Zubda al Hay'a*, attributed to Naṣîr al Dîn (Ms. Ayasofya Museum Library, No. 2670, p. 92a, 263b-264a); Al Wabkanwî, *Zîj*... (Ayasofya 2694), p. 2a.

[28] Birjandî-Chaghmînî, *ibid.*, p. 15-16; M. 'Abd al Ḥalîm, *ibid.*, p. 22-23.

[29] Birjandî, p. 40.

meridian;[30] the measurement of elevation at directions outside of the meridian reminds one of Ghiyâth al Dîn, and it is possible that the latter's method had inspired Regiomontanus.

A. von Braunmühl has pointed to parallelisms between the trigonometries of Naṣîr al Dîn and Regiomontanus.[31] Zinner refers in this connection also to the work done in Ulugh Bey's circles, but he says that Regiomontanus could not have received any influence from Naṣîr al Dîn or Ulugh Bey as the relevant books had not been translated into Latin.[32] Although, on the other hand, D. E. Smith speaks of Regiomontanus' indebtedness to Naṣîr al Dîn,[33] his source, i. e., A. von Braunmühl, is non-committal in this respect.

Zinner's criterion would seem to be too strict. For influence of sufficient importance may be received by other ways, e. g., by oral transmission. It may be remarked in these connections that Regiomontanus himself saw with scientific missions in Hungry,[34] a region which was in close relations with the Ottomans.

Very little is known concerning similar activities on determinations of parallax in Islam, but the astronomers of the Istanbul Observatory may have done work of this nature in connection with the comet of 1577.[35] In Europe such work on comets is found from the fifteenth century on, and this is said to have led to similar work by Tycho Brahe.[36]

In the field of instruments the torquetum seems to represent one of the earlier examples of influence from Eastern Islam after the close of the period of translations from Arabic into Latin. This instrument was used in Europe up to the seventeenth century especially. It was

[30] M. Delambre *Histoire de l'Astronomie du Moyen Age*, 1819, p. 340-43; See also, Zinner *Leben und Wirken...*, p. 156.

[31] A. von Braunmühl, *Nassir Eddin Tûsî und Regiomontan, Nova Acta, Abhandl. der Kaiserl. Leop.-Carol. Deutschen Akademie der Naturwisseschaften*, vol. 71, No. 2, 1897, p. 33ff.; *Vorlesungen über Geschichte der Trigonometrie*, part 1, Leipzig 1900, p. 199 ff. See also, Delambre, *ibid.*, p. 333.

[32] *Leben und Wirken...*, p. 107.

[33] D. E. Smith, *History of Mathematics*, vol. 2, 1925, p. 610, note.

[34] See, e. g., Zinner, *Leben und Wirken*, p. 103, 105 ff.

[35] A. Sayılı, *'Alâ al Dîn al Manṣûr's Poems on the Istanbul Observatory, Belleten*, vol. 20, 1956, p. 446.

[36] Delambre, *ibid.*, p. 340-43; *Histoire de l'Astronomie Moderne*, vol. 1, 1821, p. 196 ff., 233 ff.

given the name Türkengerät or Turketum at its first appearance toward the end of the thirteenth century, but with the fifteenth century the name was changed to torquetum, derived from *torquere*.[37] The name of this instrument indicates that it was learned from Turkish cirles,[38] so that, as Henry Michel suggests, its being traced back to Jâbir ibn Aflaḥ is probably not correct;[39] this was a tradition going back to Regiomontanus. But the question of the origin of the turketum has not been ascertained.

An instrument similar to the torquetum occurs in 'Abd al Mun'im al-'Âmilî's book on astronomical instruments composed about the middle of the sixteenth century.[40] Its principal part consisted of two rings for the measurement of azimuths and altitudes, but a device similar to that in the armillary sphere was added to it with the help of which an ecliptic system with alidade was added to the principal framework. Al 'Âmilî treats this instrument as a variety of the theodolite or azimuthal quadrant; he mentions it under the same heading and without giving it any special name.[41]

Chr. Pühler, writing in 1563, refers to "a new torquetum", and this is identified as the theodolite by Fritz Schmidt.[42] This expression shows that the simpler theodolite was introduced into Europe at a much later date than the turketum. For this instrument too must have been learned frcm Islam where it figured among the principal observatory instruments, but Pühler does not refer to such an origin.[43]

[37] Zinner, *Leben und Wirken*, p. 114. See also, H. Michel, *Introduction à l'Etude d'une Collection d'Instruments Anciens de Mathématiques*, Anvers 1939, p. 68.

[38] A. Sayılı, *The Wâjidiyya Madrasa of Kütahya, A Turkish Medieval Observatory?*, *Belleten*, vol. 12, 1948, p. 675.

[39] H. Michel, *Le Rectangulus de Wallingford précédé d'une Note sur Torquetum*, *Ciel et Terre* 1944, No. 11-12, p. 1 (offprint).

[40] Ms., British Museum, Pers. Add. 7702 (see, H. J. Seemann, *Die Instrumente der Sternwarte zu Marâgha nach den Mitteilungen von Al 'Urḍî*, *Sitzbr. der phys.-med. Sozietät*, Erlangen 1928, vol. 60, p. 121.

[41] P. 32. I have studied this manuscript from a photographic copy belonging to Dr. sevim Tekeli, History of Science Assistant, Ankara University.

[42] Fritz Schmidt, *Geschichte der geodätischen Instrumente und Verfahren im Altertum und Mittelalter*, 1935, p. 304.

[43] Chr. Pühler, *Ein Kurtze und Grundliche Anlaytung zu dem Rechten Verstand Geometriae*, 1563, chapter 55 (p. 88 ff.). A photographic copy of this text became accessible to me thanks to the courtesy of Professor B. Spuler.

My attention was drawn by Professor Willy Hartner to the existence of interesting similarities between the instruments of Tycho Brahe and those used by his contemporary Taqî al Dîn in the Istanbul Observatory while we were looking through the illustrated Topkapı Museum Library manuscript (Hazine, 452) on the latter astronomer's instruments (Istanbul Congress of the Orientalists, 1951). A detailed and substantial comparison of the instruments of these two astronomers was made by my former student Dr. Sevim Tekeli in her Ph. D. thesis prepared under my direction. Her conclusions may be summarized as follows:

Among the instruments common to both, the mural quadrant and the azimuthal quadrant had long been in use in Islam but were new in Europe. The wooden quadrant, with its special features, although a rare instrument, was constructed by both astronomers. Both astronomers had the armillary sphere and the parallactic ruler, both Ptolemaic instruments well known and used in Islam and Europe by earlier astronomers. In addition, both astronomers had two instruments of their own invention.[44]

The analysis of the significance of this similarity will depend upon further detailed work, but it seems to be the result of influences operating in both directions.

Small and portable quadrants of the same type as the "wooden quadrant" were much in use in medieval times, but the large and fixed variety appears only after the Middle Ages and is rare. As its construction by Tycho Brahe was of a considerably earlier date than that of Taqî al Dîn, it may represent a European influence on the Ottomans. Both astronomers had an elaborate mechanical clock working with a train of cog-wheels, and this common feature too is probably indicative of European influence, for it seems quite certain that the geared clock was developed in the West. It is of interest in this connection that at the end of the century an organ which contained a clock and automatic devices was sent from England to Istanbul as a present, and its constructor Thomas Dallam visited Istanbul on this occasion.[45]

[44] Sevim Tekeli, *Nasiruddin-i Tûsî, Taqiyuddin ve Tycho Brahe'nin Rasad Aletlerinin Mukayesesi* (in Turkish, not published), 1956, p. 7-9.

[45] See, e. g., Harold Bowen, *British Contributions to Turkish Studies*, 1945, p. 14-15.

Tycho Brahe's famous mural quadrant was of the same type as the giant meridian arc of Ulugh Bey, and this therefore points again to influences from Samarqand Observatory circles. The Ottoman capital may have served as an intermediary, for the Samarqand meridian instrument was still famous in Istanbul in the seventeenth century when Greaves visited that city.[46]

There should be little doubt indeed that the parallelism between the instruments of these two astronomers again shows the existence of Islamic influence on Europe. It is very likely that there was no direct influence proceeding from Taqî al Dîn to Tycho Brahe. For one thing, there is practically no time interval separating the construction of the bulk of their instruments. Moreover, a similar comparison between Tycho Brahe's instruments and those of the thirteenth centrury Marâgha would not be very different in result, and the same would very likely be true for the Samarqand Observatory, were the instruments of that institution known with certainty.

Tycho Brahe probably did not receive Islamic influence directly but only through intermediaries, especially those of erarlier date. At any rate, he speaks of Turks as warlike people not much interested in the sciences and in astronomy. [47] Tycho Brahe was intersted in having the latitude of Alexandria checked, and near the end of the sixteenth century he offered to assist the Venetians with instruments and advice for such an undertaking. [48] He hoped that the Venetians would materialize this plan through their ambassador at the Ottoman capital; the project is said to have failed due to lack of instruments. [49]

Similar activities were undertaken during the first half of the seventeenth century for longitude measurements involving simultaneous eclipse observations on the eastern and western coasts of the Mediterranean. The purpose of these was the determination of the difference of longitude between the two ends of that sea.

[46] Johannis Gravii, *Binae Tabulae Geographicae una Nassir Eddini Persae, Altera Ulug Beigi Ta ari*, London 1652, p. 9-10.

[47] *Tycho Brahe's Description of His Instruments and Scientific Work*, tr. and ed. H. Raeder, E. Strömgen, and B. Strömgen, 1946, p. 122.

[48] Dreyer, *Tycho Brahe*, 1890, p. 262-63.

[49] G. Bigourdan, *Histoire de l'Astronomie d'Observation et des Observatoires en France*, Paris 1918, p. 32.

These led to important achievements in that they resulted in diminishing the length of the Mediterranean considerably, but the part played by Islamic astronomers in this work seems to have been very little, if any. There is a statement by a person charged with these undertakings to the effect that no local astronomers capable of doing such work were to be found, and that though in the past the Arabs had been masters in astronomy there was no more any trace of that knowledge among them. [50]

Greaves, who was an orientalist as well as an astronomer and mathematician, visited certain parts of Turkey in 1638, and he says that he conversed in Istanbul with "some Turkish astronomers of no mean parts and skill". [51] Again, speaking of large instruments with which good observations could be made, Greaves says, 'the ancients have not many such large instruments, and in our time there are but a few, excepting Tycho Brahe and some of the Arabians'.[52]

The observations of Greaves should undoubtedly be more realistic and reliable. At any rate, the seventeenth century itself lies outside the present subject. The Istanbul Observatory founded in 1575, e. g., had a staff of sixteen astronomers, and this indicates that men of this profession were quite available at the time eventhough it is likely that not all of these sixteen men were first-rate or even full-fledged astronomers. [53]

In Europe, the increased momentum in astronomical work in the fifteenth century was accompanied with a policy of attaching greater importance to systematic observations. Observatories of some importance began to be built, and greater dignity was accorded to astrology. These new conditions too are reminiscent of the Islamic tradition, especially of that of Eastern Islam. Moreover, as in Islam, astrology seems to have served to encourage the pursuit of serious astronomical work.

Astrology in these centuries in Europe seems to have emphasized the necessity of reliable observations and precise astronomical calcul-

[50] Bigourdan, p. 36-37.

[51] H. Bowen, p. 16.

[52] *Miscellaneous Works of John Greaves*, publisched by Thomas Birch, London 1737, vol. 2, p. 368.

[53] Sayılı, *'Alâ al Dîn al Manṣûr's Poems*, p. 440, 443, 477-78.

ations, and failures of astrology were attributed to the insufficiency of precise measurements and to shortcomings of astronomical theory. This too is reminiscent of Islam and may therefore have been the result of Islamic influences. It is true that such excuses need not necessarily depend on Islamic precedents, but it was only in Islam and especially in Eastern Islam during the later centuries that such ideas became instrumental in the foundation of elaborate observatories.

Some kind of an appeal for systematic observations was made by Roger Bacon and Theodoricus of Freiberg. The former at least seems to have received his inspiration from the example of the Marâgha Observatory or from Mongol circles in general, and the same may be true for Theodoricus. Later on we find Regiomontanus [54] and Tycho Brahe, [55] e. g., stating that the reason why many astrological predictions were not satisfactory was that precise and exact knowledge of the positions of the stars was not available.

Tycho Brahe was remarkable for his method of pursuing his observations regularly and for not being satisfied with occasional observations at selected times. It is interesting to see therefore that in Islam regular daily observations of the sun and the moon were made by the astronomers of Al Mamûn. And especially during the later centuries there was an insistence on observation programs of not less than thirty years so as to cover a complete period of Saturn, suggesting that the same method was perhaps extended to the planets. Certain statements of Quṭb al Dîn sugget that work on determinations of apogees and perigees may have resulted in increasing the frequency and length of observations. It is possible therefore that Tycho's method was not entirely new when compared with that prevalent in Islam. [56]

Both Tycho Brahe and Taqî al Dîn had a small observatory appended to their main observatory. Moreover, Tycho Brahe's observ-

[54] Zinner, *Leben und Wirken*, p. 20, 38.

[55] *Tycho Brahe's Description of His Instruments*, p. 117.

[56] Sayılı, *The Introductory Section of Ḥabash's Astronomical Tables...*, *Dil ve Tarih-Coğrafya Fakültesi Dergisi*, vol. 13, No. 4, 1955, p. 143, note 4; *'Alâ al Dîn al Manṣûr's Poems*, p. 436-7. Quṭb al Dîn, *ibid.*, p. 51b, 68b. My attention was drawn by Professor O. Neugebauer to the importance of making such a comparison of methods of observation with Tycho Brahe.

atory contained a chemical laboratory, and this may have been the case with the Marâgha Observatory too; at least, Hulâgû, the founder of the Marâgha Observatory, is said to have had an array of alchemists for whom he spent enormous sums just as he did for his astronomers.[57] These similarities too may not be due to chance.

It is possible to find a few other examples of a similar nature, and though it is difficult to give conclusive proofs for each individual case, the cumulative impression gained leaves less room for doubt. Although scientific work and interest had suffered a clearly noticeable decline in Islam and although it is clear that under the prevailing circumstances the birth of the European seventeenth century science could not have occurred there, the claim can reasonably be made nevertheless that the positive contributions of Islam to the emergence of the seventeenth century science continued after the period of translations from Arabic had come to an end. There are reasons to believe, moreover, that this contribution of Islam was not trivial or negligible but was of some importance.

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[57] Rashîd al Dîn, *ibid.*, p. 400-403.