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Suhayl is an annual journal (biennial between 2016-2021) published at the end of the year in English and Arabic in paper and electronic formats. Suhayl publishes original scholarly articles on the history of the natural and exact sciences in the Islamic and Islamicate world and their relationship with other cultural traditions. Its objective is to make available to the scientific community the latest developments in the field and, in particular, unpublished original sources. The journal is aimed at all experts interested in ancient, medieval and pre-modern science, from an interdisciplinary perspective.

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A Universal Sundial Made for Sultan Mehmet II, in the Context of Astronomical Instrumentation in late-15th Century Istanbul

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Abstract: In this study we present a previously-unknown astronomical and mathematical instrument. This is a sundial for all latitudes made in 1477 and dedicated to the Ottoman Sultan Mehmet II who is known for his interest in astronomy. It is a unique example of a type of instrument previously known only from Arabic astronomical texts some two centuries earlier. This sundial, which enables the user to measure time from the solar altitude throughout the year, is conceived for all inhabited latitudes (as in classical geography, this would be from the equator to about 45°). By necessity, therefore, it is based on an approximate but practical formula for timekeeping.

In Islamic civilization sundials have a history of over 1,000 years, but this has yet to be documented on the basis of surviving sundials and texts – of these, universal sundials form a small but significant part. The immediate source of the design for this particular universal sundial can be identified as an Egyptian treatise on astronomical instruments from the late 13th century; however, the device itself was much earlier, maybe originating as far back as Baghdad *ca*. 900. The formula was known already to the earliest Muslim astronomer al-Fazārī in Baghdad *ca*. 750. This sundial is a mathematical device as well an astronomical one, in the sense that it was not really intended to be used as a *practical* time-telling device. It is so small that it would be difficult to measure time with it under any circumstances; the same is true of many hand-held astronomical instruments. It may

King, David A. & Charette, François (2024). «Astronomical instruments from late-15th-century Istanbul, introducing a universal sundial made for Sultan Mehmet II». *Suhayl. International Journal for the History of the Exact and Natural Sciences in Islamic Civilisation*, 21, December 2024, pp. 7–208. ISSN: 1576-9372. DOI: 10.1344/SUHAYL2024.21.1.

be «universal» but one could hardly travel about with it. Nevertheless, at some time it was brought from Istanbul to Bucharest, either whilst the latter was still under Ottoman control or even thereafter. In fact, it is simply an intriguing object embodying mathematical quantities associated with an elegant astronomical formula for timekeeping, and a testimony to part of the essence of the transmission of ideas from Antiquity to the early Muslim world, thence to Mamluk Egypt and on to the early Ottoman world. And similar devices appear in Renaissance Europe. This «new» sundial reveals how little we knew previously about the astronomical interests of Mehmet II and their level of sophistication; it invites a new look at the relevant sources. This study deals with materials not yet incorporated into the current history of Ottoman astronomy. It casts light on astronomy and dialling in 15th-century Istanbul and it adds substantially to our knowledge of Mehmet II's interest in astronomy.

Key words: Mehmet II; Istanbul; Ottoman; Aḥmar; universal sundial; latitudes; climates; al-Marrākushī; Najm al-Dīn al-Miṣrī; Habermel; Regiomontanus; Bessarion; Piero della Francesca; world-map; rectazimuthal; Ḥabash; Nasṭūlus; al-Bīrūnī; al-Ṣūfī; al-Khalīlī; universal auxiliary tables; astrolabe; alidade; sundial; Muslim prayer-times; Byzantine astronomy.

Resum: En aquest estudi presentem un instrument astronòmic i matemàtic fins ara desconegut. Es tracta d'un rellotge de sol per a totes les latituds fet el 1477 i dedicat al sultà otomà Mehmet II, conegut pel seu interès en l'astronomia. És un exemple únic d'un tipus d'instrument conegut prèviament només a partir de textos astronòmics àrabs uns dos segles anteriors. Aquest rellotge de sol, que permet a l'usuari mesurar el temps a partir de l'altura solar al llarg de l'any, està concebut per a totes les latituds habitades (en la geografia clàssica, des de l'equador fins a aproximadament 45°). Per necessitat, per tant, es basa en una fórmula aproximada però pràctica per a la mesura del temps.

A la civilització islàmica, els rellotges de sol tenen una història de més de 1.000 anys, però encara ha de documentar-se a partir dels rellotges de sol i els textos que han sobreviscut; d'aquests, els rellotges de sol universals formen una part petita però significativa. La font immediata del disseny d'aquest rellotge de sol universal en particular es pot identificar com un tractat egipci sobre instruments astronòmics de finals del segle xiii; no obstant això, el dispositiu en sí mateix era molt més antic, potser originari de Bagdad cap al 900. La fórmula ja era coneguda pel primer astrònom musulmà al-Fazārī a Bagdad cap al 750. Aquest rellotge de sol és un dispositiu matemàtic a més d'astronòmic, en el sentit que no es va concebre realment per a ser utilitzat com a dispositiu pràctic per a la mesura del temps. És tan petit que seria difícil mesurar el temps amb ell en qualsevol circumstància; el mateix passa amb molts instruments astronòmics manuals. Pot ser «universal», però difícilment es podria viatjar. No obstant això, en algun moment va ser portat

d'Istanbul a Bucarest, ja sigui mentre aquesta última encara estava sota control otomà o després. De fet, és un objecte intrigant que encarna quantitats matemàtiques associades amb una fórmula astronòmica elegant per a la mesura del temps, i un testimoni de part de l'essència de la transmissió d'idees des de l'Antiguitat fins al món musulmà primerenc, després cap a l'Egipte mameluc i finalment cap al món otomà primerenc. Dispositius similars apareixen a l'Europa del Renaixement. Aquest «nou» rellotge de sol revela com de poc sabíem anteriorment sobre els interessos astronòmics de Mehmet II i el seu nivell de sofisticació; convida a una nova mirada a les fonts pertinents. Aquest estudi tracta de materials encara no incorporats a la història de l'astronomia otomana. Aporta llum a l'astronomia i la gnomònica a l'Istanbul del segle XV i incrementa substancialment el nostre coneixement de l'interès de Mehmet II en l'astronomia.

MOTS CLAU: Mehmet II; Istanbul; Otomà; Aḥmar; rellotge de sol universal; latituds; climes; al-Bīrūnī; al-Marrākushī; Najm al-Dīn al-Miṣrī; Habermel; Regiomontanus; Bessarion; Piero della Francesca; mapamundi; rectoazimutal; Ḥabash; Nasṭūlus; al-Bīrūnī; al-Ṣūfī; al-Khalīlī; astrolabi; alidada; rellotge de sol; hores de pregària.

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Part A. The instrument

1. Introductory remarks

We present here the first description of an instrument made for and dedicated to the Ottoman Sultan Mehmet II in 1477, almost 25 years after he had conquered the tired old city of Constantinople.[1] Fatih Mehmet, «The Conqueror», attracted scholars from all over the Muslim world to his Court, from al-Andalus to Central Asia, so that learning and science might flourish in a cosmopolitan milieu. It is known that the Sultan had an interest in astronomy, but until now scholars have not identified any written works or instruments specifically associated with him. This «new» instrument will take specialists of many disciplines by surprise, as it did the two authors.[2]

At the outset we stress that we shall be dealing only with the practical side of Ottoman astronomy in the 15th century and thereby do not discuss theoretical astronomy, which has been investigated by colleagues.[3] We shall only occasionally mention subjects such as astronomical handbooks with tables (*zīj*es); computation of annual ephemerides (*taqwīm*) with horoscopes (*ṭāliʿ*); and models to help understand the apparent motions of the imaginary spheres (*falak*, *haya'a*). Most of our discussion will be focused on علم الالات, *ʿilm al-ālāt*, the subject of astronomical instrumentation, serving علم الميقات, *ʿilm al-mīqāt*, the science of time-keeping by the sun and stars and the regulation of the prayer-times, which, one could argue, was the most significant branch of science as far as the majority of the population was concerned. It is the only aspect of the traditional rational/mathematical sciences that is still of importance to practising Muslims today.

1. In Ottoman Turkish, Arabic Muḥammad becomes Mehmet, and Bā (< Abū) Yazīd becomes Bayezid. In this paper, we have used the modern Turkish forms of the names of the Ottoman sultans and Muslim dynasties, and the transliterated forms for other Arabic names and terms, rendered according to the standard scholarly conventions. Some discrepancies are inevitable.

2. A brief, illustrated description of the instrument was presented to the International Congress «Channels of Transmission of Astronomical Knowledge in the Ottoman World (14th-18th centuries)» (https://ottomanastronomy.org/), held in Istanbul, 21-24 November 2023 (by video link). A summary of parts 1-5 of the present paper is to appear in the *Proceedings* of the Congress.

3. See, for example, numerous works by Jamil Ragep, Robert Morrison, Scott G. Trigg, Ahmet Tunç Şen, Hasan Umut, and others. For reliable popular surveys, see Salim Aydüz. On the recensions for Istanbul of astronomical tables (*zīj*es) from Cairo, Samarqand and Shirwan, see İhsanoğlu *et al*. and the forthcoming *zīj* survey by Benno van Dalen.

The instrument falls squarely within the disciplines of astronomical timekeeping and the regulation of the times of prayer on the one side, and astronomical instrumentation on the other. The first author has attempted to survey these two disciplines using primary sources.[4] In the present paper, we focus on astronomical treatises and tables and instruments from the early Ottoman period, especially the 15th century. The materials discussed provide a context for this instrument which cannot or should not be considered out of the context of the history of Ottoman astronomy.

The «new» instrument is made of brass, surrounded with a rim of silver inlay, of which part remains. It is rectangular in shape, measuring roughly 20 cm by 15 cm. The markings on the sundial are of a very special variety consisting of a series of snail-shell-shaped spirals. In medieval scientific Arabic, the device is called *ḥalazūn*, meaning snail or snail-shell. This appellation refers to the spiral markings for the hours. The original gnomon which fitted in the hole at the centre of the instrument is missing and has been replaced.

The instrument is a universal sundial, the sole known surviving example of a universal «spiral» sundial. Most sundials were designed for a specific latitude and the markings laid out according to a rather complicated procedure. This sundial is special because it is universal, serving the climates of classical geography, that is, all reasonable, inhabited latitudes, understood as being between the equator and about latitude 48 degrees. The markings are laid out according to a simple trigonometric formula for timekeeping by the sun (independent of terrestrial latitude) which was used for centuries alongside the accurate one.

The only Arabic source in which the *ḥalazūn* is clearly mentioned and illustrated is a substantial Egyptian work that was available in Istanbul in Mehmet II's times. We refer to the encyclopedia of al-Marrākushī (*ca*. 1280) containing an overview of the principal instruments known in his time. This provides the key to our understanding of the *ḥalazūn*.

Ottoman astronomers had no need to reinvent the wheel. They were happy to draw from the Central Asian astronomical tradition – mainly Samarqand, theoretical astronomy and planetary tables – and from the Egyptian and Syrian traditions – mainly spherical astronomy and astronomical timekeeping. Thus, for ex-

4. DAK, *Synchrony with the Heavens*, 2 vols., 2004-05. The first volume deals with astronomical timekeeping (*'ilm al-mīqāt*), and the second one with non-observational instruments. This work will be referred to simply as «*Synchrony*», and the two volumes by 'A' and 'B'.

ample, the astronomer ʿAlī Qūshjī came from Samarqand to the Court of Mehmet II in 1472,[5] and Taqī al-Dīn came from Nablus in Palestine a century later to direct the Istanbul Observatory.[6]

It is less well known that there was also a healthy tradition of practical astronomy in 14th- and early-15th-century Ottoman Anatolia and Thrace. This was certainly partly inspired by the visit to Sivas of the great late-13th-century Iranian scholar Quṭb al-Dīn al-Shīrāzī, who, although he only spent about 10 years there, authored three substantial books on theoretical astronomy, dedicating them to local dignitaries.[7] We also know of some serious timekeeping tables for 14th-century (?) Konya, of the same kind as those used in Cairo, Damascus and Jerusalem, and another very unusual set, apparently of Iranian inspiration, copied in Sivas in 1371 – see §6.5.

Already a dozen years after the conquest of Constantinople, the universal auxiliary tables for solving the problems of spherical astronomy for any latitude compiled by the mid-14th-century Damascus astronomer Shams al-Dīn al-Khalīlī[8] were copied in Edirne, the previous Ottoman capital. These represented the most remarkable achievement in spherical astronomy of any Muslim astronomer, and it is significant that they were available at least in Edirne, if not for widespread use. See again §6.5.

Furthermore, we present some other remarkable instruments, including the intriguing spherical astrolabe with a rete, signed enigmatically and simply by «Mūsà» at the end of the reign of Mehmet II, not dedicated to any ruler but clearly made by, or for, a court adherent. Then we have three astrolabes presented to Bayezid II. These were, until recently, mainly unknown to the scholarly community, in which there is still a tendency to favour historical texts over objects. Here we attempt to show how important a single instrument can be, and a group of instruments from the same milieu and timeframe even more so.

5. On ʿAlī Qūshjī, see the copiously documented book Umut, *Theoretical Astronomy in the Early Modern Ottoman Empire*.

6. See the article «Taḳī al-Dīn» in *Enc. Islam*, 2nd edn., and numerous articles by Sevim Tekeli (n. 151), and, more recently, the article «Taqī al-Dīn» by İhsan Fazlıoğlu in *BEA*. A new study is Avner Ben-Zaken, «The Revolving Universe and the Revolving Clocks» (2011).

7. On al-Shīrāzī see the article in *BEA* by Jamil Ragep.

8. On al-Khalīlī, see the article in *BEA*, and on his tables see *Synchrony*, A, pp. 359-401; also https://muslimheritage.com/al-khalili-astronomy/.

2. Description of the instrument

> Scientific instruments dating from antiquity and the middle ages are of unique historical value since they supply evidence quite different from that available in texts. In many cases as we know that the evidence of the artifacts directly contradicts that which had been presumed from written sources. With the exception of a few special classes such early instruments are also remarkably rare and, on the whole, badly published and inadequately indexed ... (Derek de Solla Price, «An International Catalogue of Scientific Instruments made before 1500» (1967), p. 41).

> Each medieval instrument can tell us something that contributes to the overall picture. The time is ripe for further study of related groups of instruments, with the aim of learning about the workshops in which they were constructed, why they were made, and how they were used. ... Medieval instruments constitute a veritable goldmine of historical sources still to be exploited. (DAK, «Making instruments talk – Some medieval astronomical instruments and their secrets» (1995), available at www.academia.edu/34695170/).

2.1 Provenance, form and size

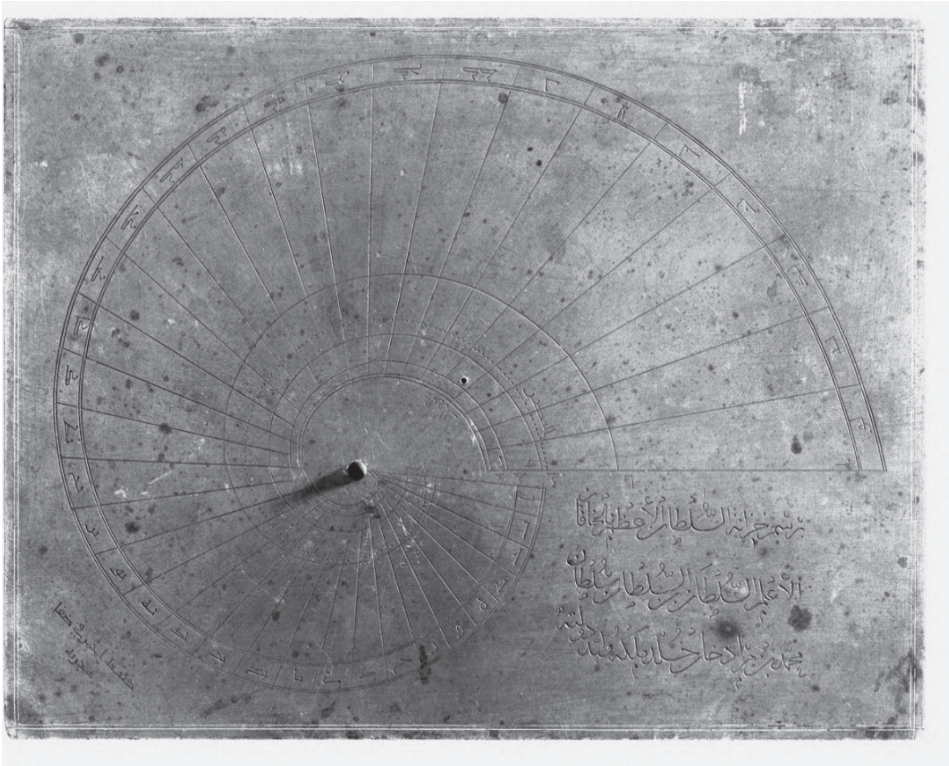
This is the only known scientific instrument made for and dedicated to the Ottoman Sultan Mehmet II, better known as Fatih Mehmet, «The Conqueror». It is also the sole surviving example of a universal «spiral» sundial in Islamic astronomy.

The instrument is now in a European private collection. According to the owner it was acquired at a pawn shop in Bucharest,[9] where it was deposited by a Romanian lady. It had been in her father's collection in the 1960s. The provinces of Moldavia and/or Wallachia (*Evlāk / Kara-Eflāk*) remained under Ottoman control until about 150 years ago,[10] but there remained a sizeable Turkish minority in Romania even during the 20th century.[11] A certificate issued by

9. See https://bucharest-guide.ro/en/golden-falcon/ ... (under «jewelry»).

10. Article «Eflāk» in *Enc. Islam*, 2nd edn., by N. Beldiceanu.

11. «Islam in Romania», *Wikipedia*, https://en.wikipedia.org/w/index.php?title=Islam_in_Romania&oldid=1231770078 (accessed July 30, 2024); Kemal Kerpat, «Romania and the Ottoman Empire: A Historiographical Review», *Turkish Studies Association Bulletin* 24/1 (Spring 2000): 129-135, https://www.jstor.org/stable/43384752; Florin Anghel, «Romania Between Istanbul And Ankara: The Beginning of the Alliance in the first decade of the Kemalist Republic», *Ankara Üniversitesi Dil ve Tarih-Coğrafya*



Figures 1.1a-c: The front of the universal sundial, the dedication in the lower right of the spiral horary markings. All images courtesy of the owner.