II. BÖLÜM / CHAPTER II

MATEMATİK BİLİMLER

MATHEMATICAL SCIENCES

2. Uluslararası Prof. Dr. Fuat Sezgin İslâm Bilim Tarihi Sempozyumu Bildiriler Kitabı

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A Little Known Paper by Professor Fuat Sezgin on the Meridian Instrument of Ibn al-Haytham

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ABSTRACT

When Fuat Sezgin came to Istanbul in 1943, he became a student of mathematics and engineering, only changing to Oriental Studies after meeting Hellmut Ritter. We will analyze a paper which Fuat Sezgin published in 1986 and which is a witness of his mathematical abilities. The paper includes an edition of a mathematically difficult text by Ibn al-Haytham which Sezgin reconstructed from a unique Arabic manuscript written with very few diacritical marks. In this treatise, Ibn al-Haytham discusses the theoretical and practical aspects of an instrument which he produced for determining the meridian with utmost accuracy.

Keywords: Fuat Sezgin, Ibn al-Haytham, meridian, astronomy, astronomical instrument

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1. Professor Fuat Sezgin as a Mathematician

When Fuat Sezgin first came to Istanbul in 1942, he was a student of mathematics and engineering. He changed to Oriental Studies only after meeting his teacher, the German orientalist Helmut Ritter (1892-1971). However, Ritter told him to continue his studies in mathematics (Güldütuna 2020). We will see below that Professor Sezgin did not forget mathematics for the rest of his career. Our source is a paper which he published in 1986 in Arabic in the journal *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften*, vol. 3, pp. 7-43, under the title *Tariqat ibn al-Haytham fi ma`rifat khatt nisf al-nahar* [Ibn al-Haytham's method for the determination of the meridian line]. In this paper, Professor Sezgin published for the first time two Arabic texts by Ibn al-Haytham on the determination of the meridian line. Sezgin's paper had not been translated into other languages and therefore has remained unknown to the international research community. We will briefly analyze the paper here; an English translation of Sezgin's editions of Ibn al-Haytham's two texts has appeared in the same journal *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* in 2022 (Hogendijk 2023, pp. 149-184).

The meridian line is the line on the horizontal plane which runs from true north to true south. The precise determination of the meridian line is of fundamental importance in medieval as well as modern astronomy. Ibn al-Haytham wrote two texts on the subject. The first text is available in two manuscripts (Sezgin 1974, p. 368 no. 21). The second text is available in a unique Arabic manuscript in the State Library in Berlin, Or. 2970 ff. 46b-59a (Sezgin 1978, p. 260 no. 23),

In the first text, Ibn al-Haytham shows how craftsmen can find the meridian if they observe the shadow of the sun at one moment in the morning or afternoon, and if some extra information is available, namely the geographical latitude and the declination of the sun. The text is very brief and practical, and it includes a geometrical figure. Ibn al-Haytham did not provide a geometrical proof because the craftsmen for whom he wrote the text would not be interested in it. Professor E.S. Kennedy published a brief English summary and analysis of this first text (Kennedy 1989).

2. Summary of Ibn al-Haytham's Second Text: On Finding the Meridian with Utmost Exactness

The second text by Ibn al-Haytham is five times longer and much more challenging from a mathematical point of view. It is entitled *fI istikhraj khatt nisf al-nahar `ala ghayat al-tahqiq* [on the determination of the meridian line with utmost exactness]. In this text, Ibn al-Haytham deals with the theory and practice of a new instrument for finding the meridian line. We will now summarize the contents of the text, based on Professor Sezgin's Arabic edition (Sezgin 1986, pp. 20-43).

Ibn al-Haytham begins with a long theoretical introduction. He first informs the reader that the astronomers of his time usually determined the meridian line by the so-called Indian method.

This method boils down to the following. Place a vertical object, the gnomon, on the horizontal plane and observe the shadow cast by the sun, in the morning and in the afternoon. Choose a suitable moment in the morning, find the shadow, and wait until the shadow has exactly the same length in the afternoon. Then, bisect the angle between the two equally long morning and afternoon shadows. The bisecting line is the meridian.

The Indian method is based on the following principle. If the sun has the same altitude at two moments of time, before noon and after noon, the two positions of the sun at these two moments are symmetrical with respect to the meridian plane, that is, the vertical plane through the meridian line.

Ibn al-Haytham says that the Indian method ignores the fact that the sun has a proper motion. According to modern astronomy, the earth moves around the sun. However, the effect is that the apparent position of the sun changes with respect to the fixed stars as seen from the earth, which is what Ibn al-Haytham considered the proper motion of the sun.

If we assume two positions of the sun, in the morning and in the afternoon, in such a way that the shadows of the sun make equal angles with the meridian, then in winter and spring, the sun will appear a bit higher in the afternoon than in the morning; in summer and fall, it will be a bit lower. As a result, the altitudes of the two positions are not the same and the two shadows are not equally long. As such, Ibn al-Haytham concludes that the method is not accurate. Ibn al-Haytham was of course aware of the fact that the effect is minimal, only a fraction of a degree, but he thought that such aspects are important if one wants to determine the meridian with utmost exactness as stated in the title of the treatise.

Ibn al-Haytham says that there is another error because the sun is not a point, but rather a small circle in the sky. As a result, the shadow of the tip of the gnomon will be blurred. This is easy to see by experiment: the photo in Figure 1 shows the shadow of a knife with a sharp point, held vertically as a gnomon; the width of the tile is 20 centimeters.

Figure 1: Photo showing the blurred shadow of a gnomon with sharp tip

To avoid these two types of errors, Ibn al-Haytham proposed that we do not work during daytime, but during the night, and that we use a fixed star instead of the sun. A fixed star does not have a proper motion like the sun, and its apparent size is much smaller than the apparent size of the sun. Thus, if we observe the fixed star two times when it has the same altitude, before and after culmination, take the direction (that is, its azimuth) of the star at the two moments, and bisect the angle between the two directions, we will obtain the meridian as the bisecting line, in a very precise way. While Ibn al-Haytham discusses refraction, he shows that it does not affect this method.

Ibn al-Haytham then describes an instrument which allows us to do all these things: we can use it to observe a star in a certain altitude before and after culmination, determine the directions of the star at the two moments, bisect the angle, and thus find the meridian. No medieval instruments of this type have been preserved. Accordingly, such an instrument was unknown until Professor Sezgin's paper appeared.

3. The Style of Ibn al-Haytham's Text on Finding the Meridian with Utmost Exactness.

In most of his texts on geometry and astronomy, Ibn al-Haytham presents geometrical figures, just as in his first short text on the meridian. However, in his second longer text, he did not provide any geometrical figure at all. Instead, he asks the readers to visualize the complicated geometrical situation in their own imaginations. In addition, Ibn al-Haytham does not divide his second text into chapters or paragraphs. This makes the text extremely difficult to understand. It would appear that Ibn al-Haytham wrote the text for mathematically trained philosophers. He used the same method in a few other works, such as Book IV of his Optics.

The Berlin manuscript is written with few diacritical points, so words are often ambiguous and can only be understood by a reader who is familiar with the mathematical contents. Thus, Professor Sezgin had to overcome substantial difficulties, which were also of a mathematical nature. I will now illustrate these difficulties in an example. It is not necessary to know Arabic in order to understand my arguments.

Figure 2 shows a passage (f. 47b lines 8-17) in the Berlin manuscript.

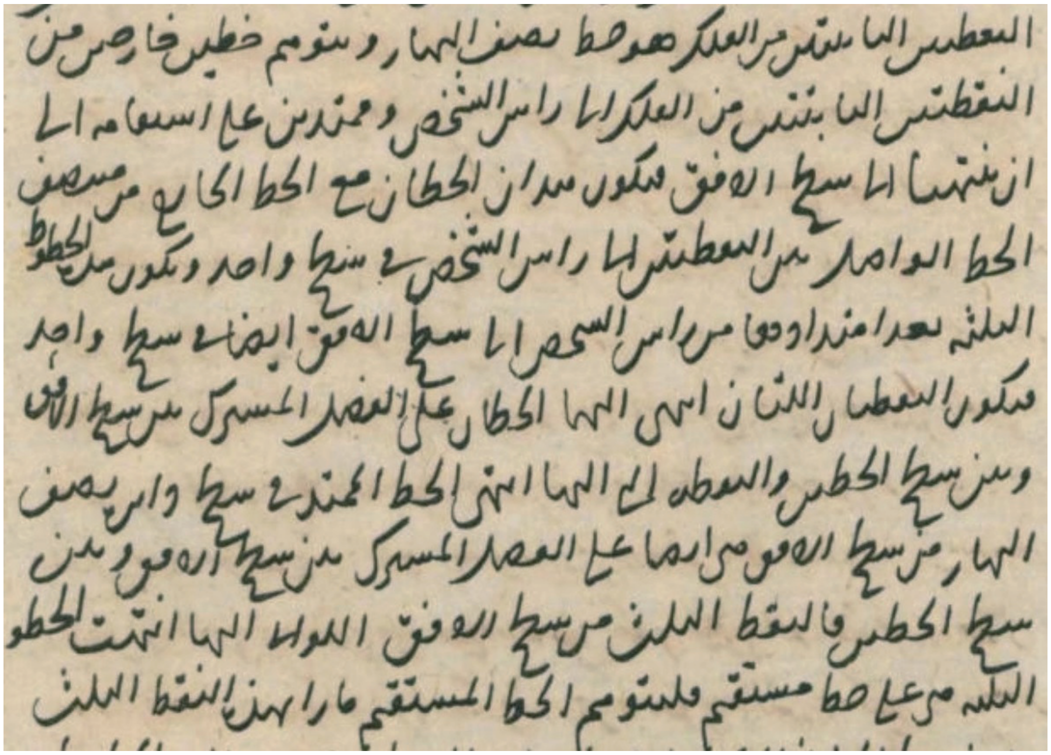

Figure 2: A passage in the Berlin manuscript of Ibn al-Haytham's text

Professor Sezgin added missing diacritical marks and interpunction, as well as introduced a division into the paragraphs. In his edition, the passage reads as follows (see Figure 3): (Sezgin 1986 p. 22 lines 11-18):

ونتوهم خطين خارجين من النقطتين الثابتتين من الفلك إلى رأس الشخص وممتدين
على استقامة إلى أن ينتهيا إلى سطح الأفق فيكون هذان الخطان مع الخط الخارج من
منتصف الخط الواصل بين النقطتين إلى رأس الشخص في سطح واحد. وتكون هذه
الخطوط الثلاثة بعد امتدادها من رأس الشخص إلى سطح الأفق أيضاً في سطح واحد.
فتكون النقطتان اللتان انتهى إليهما الخطان على الفصل المشترك بين سطح الأفق وبين
سطح الخطين، والنقطة التي إليها انتهى الخط الممتد في سطح دائرة نصف النهار من سطح
الأفق هي أيضاً على الفصل المشترك بين سطح الأفق وبين سطح الخطين. فالنقط الثلاث
من سطح الأفق، اللواتي إليها انتهت الخطوط الثلاثة، هي على خط مستقيم.

Figure 3: The passage in Ibn al-Haytham's text as reconstructed by Professor Fuat Sezgin

The following translation of the passage provides an idea of the complexity of the argument. As mentioned above, Ibn al-Haytham does not include any geometrical figures and expects the reader to visualize everything by himself. Ibn al-Haytham discusses two fixed points on the celestial sphere. These two fixed points will be the two positions of the star which is observed by the instrument, before and after culmination. Ibn al-Haytham says:

> "We imagine two lines drawn from the two fixed points on the sphere to the tip of the gnomon, which are extended rectilinearly until they end at the plane of the horizon. Then, these two lines are in one and the same plane together with the line drawn to the tip of the gnomon, from the midpoint of the line joining the two fixed points on the sphere. So these three lines are also on the same plane after being extended rectilinearly beyond the tip of the gnomon. Therefore, the two points at which the two lines end are on the intersection between the plane of the horizon and the plane of the two lines. However, the point on the plane of the horizon, which is the endpoint of the line extended on the plane of the meridian circle, is also on the intersection between the plane of the horizon and the plane of the two lines. Therefore, the three points on the plane of the horizon, at which the three lines end, are on one straight line."

The text is easier to follow with Figure 4, a geometrical figure which Ibn al-Haytham does not provide.

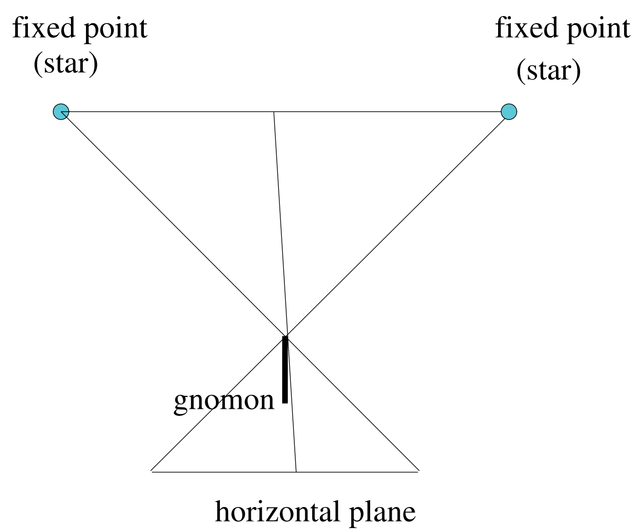

Figure 4: Geometrical figure illustrating the passage reconstructed by Professor Fuat Sezgin

In order to make sense of the Arabic manuscript and to identify the ambiguous words, it is absolutely necessary to understand the mathematics. Excellent scholars in Arabic with a specialization in the humanities usually make mistakes when editing a mathematical text. The fact that Professor Sezgin's edition is flawless shows that he had taken the advice of his teacher Ritter to heart. His successful reconstruction of Ibn al-Haytham's text bears witness to his mathematical abilities.

4. Notes on Ibn al-Haytham's Instrument for Finding the Meridian

After finishing the work on his edition of the two texts by Ibn al-Haytham, Professor Sezgin immediately turned to his many other projects. Thus, he included neither a translation nor a detailed commentary in his article. Because he wanted people to see the instrument of Ibn al-Haytham, he commissioned a company to rebuild the instrument. Figure 5 (taken from Sezgin 1986 p. 14) illustrates the preliminary drawing used for this reconstruction. The reconstructed instrument consists of a vertical wooden bar which can rotate around a vertical axis, and on top of that, a horizontal copper plate on which an alidade with a tube rotates around the same vertical axis. The tube is used for viewing the stars. For a description with photos, see Sezgin 2010 vol. 2, p. 146.

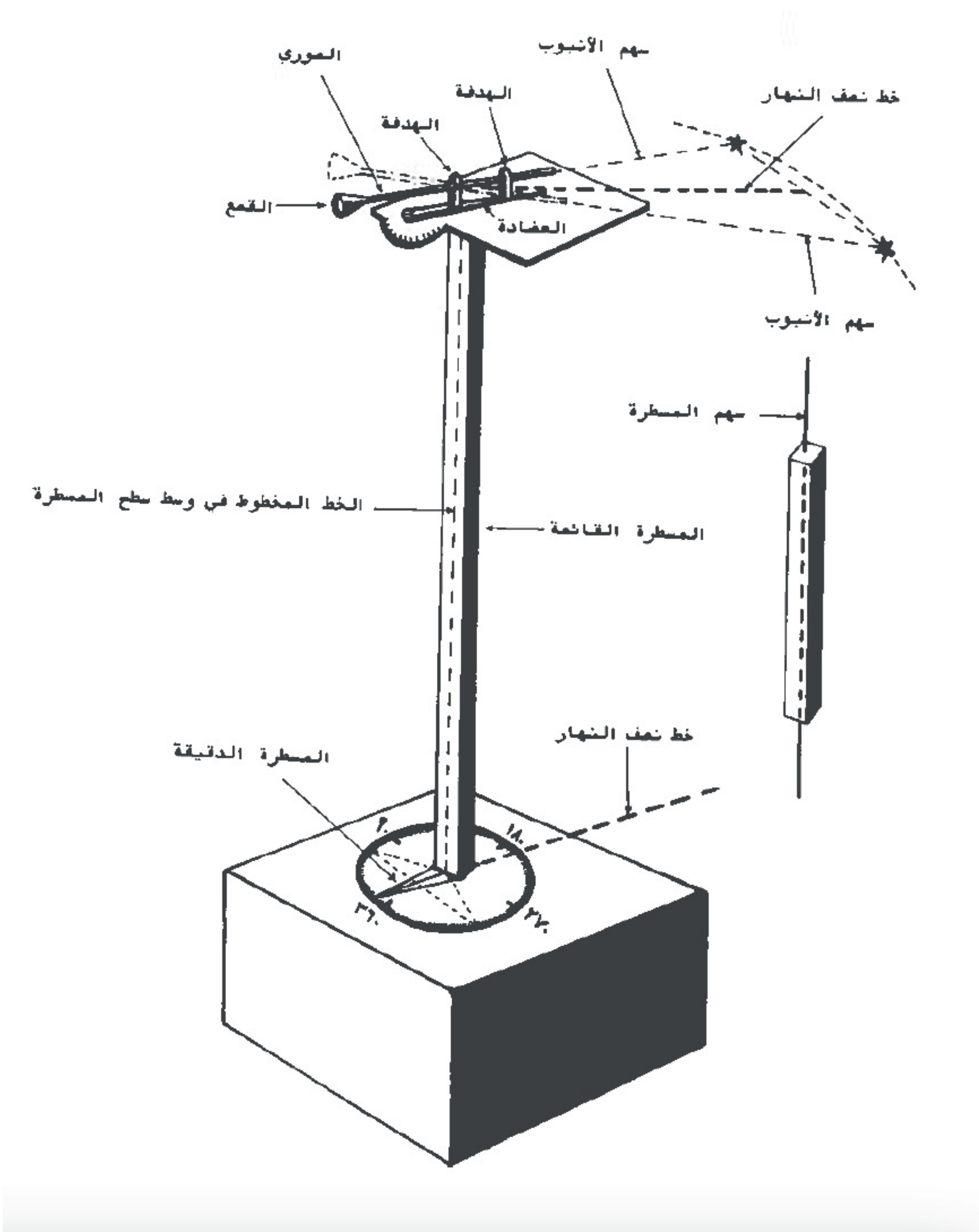

Figure 5: Preliminary drawing of the reconstructed instrument

The comparison between this preliminary reconstruction and Professor Sezgin's edition of Ibn al-Haytham's text raises some interesting issues. Since the tube in the preliminary drawing is always horizontal, the instrument can only be used to gaze upon stars on the horizon.

However, in Professor Sezgin's edition (Sezgin 1986 p. 29 lines 17-22), Ibn al-Haytham says:

> "When the instrument has been mounted according to this description, then one should wait for the night. When the night has become dark and the sky is clear, one should pay attention to a fixed star East of the meridian, and let it be at a moderate altitude above the horizon. Then the bar is rotated, and the observer

> holds his eye at the edge of the plate, and turns the bar right and left until he sees the star together with the surface of the plate. Then he puts his eye near the circumference of the funnel at the end of the tube, and he moves the alidade up and down until he sees the star in a direction parallel to the tube."

Here, Ibn al-Haytham says explicitly that the stars which could be used to find the meridian should be above the horizon. He prescribes that the alidade should be moved up and down with the tube, which suggests that the plate is vertical, not horizontal.

Thus Ibn al-Haytham's own instructions, according to the edition by Professor Sezgin, suggest an alternative reconstruction of the instrument, in which the copper plate at the top should be mounted vertically, not horizontally, so that stars above the horizon can also be sighted. See Figure 6 below for a representation of such an instrument.

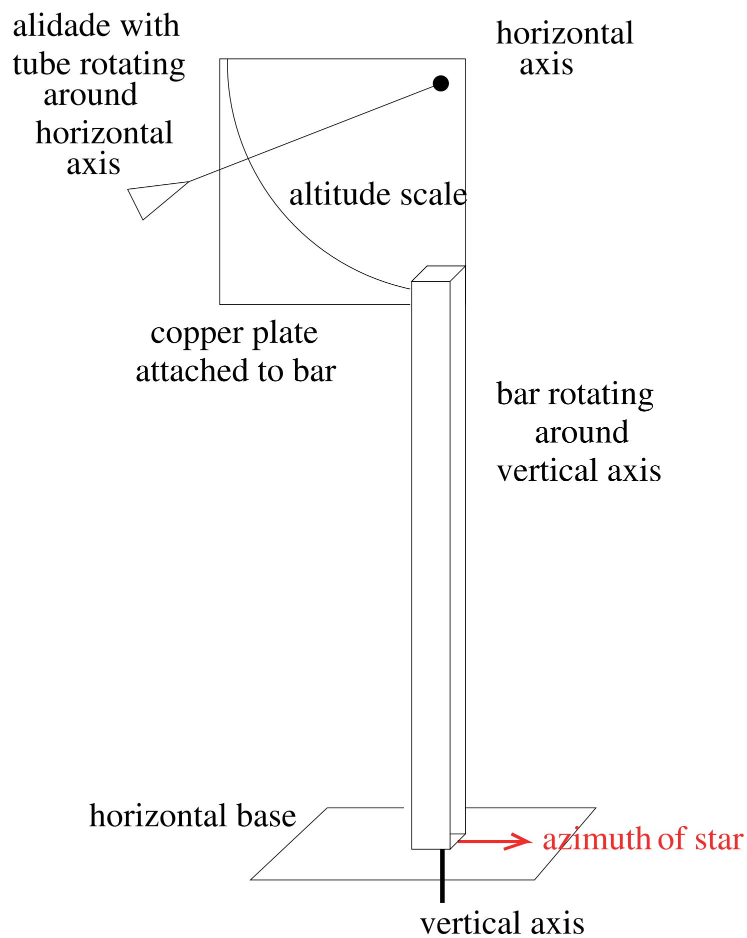

Figure 6: Alternative reconstruction of the instrument, suggested by Ibn al-Haytham's text in the edition by Professor Sezgin

Such different interpretations are of course not surprising. They are in agreement with the approach of Professor Sezgin, who always emphasized that research in the scientific tradition of Islamic civilization has not been finished, and that new insights can always be found.

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