THE HISTORY OF DETERMINING TIME AT NIGHT USING NOCTURLAB INSTRUMENTS

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Abstract

At night, determining time is a little more complicated because the Sun cannot be observed directly. However, there is a unique instrument for knowing the time at night by reference to the position of the stars in the sky, namely the nocturlab. This article will discuss the history of determining the time at night with nocturlab. The method used in this research is qualitative to get an overview of Nocturlab in the past. This research shows that the Nocturlab instrument has a long development history; even though it is now a more sophisticated tool for determining time, this tool remains an essential part of astronomy and determining time in human civilization.

Keywords: *Time determination; Nocturlab; Astronomy*

Abstrak

Pada waktu malam hari penentuan waktu sedikit lebih rumit dikarenakan matahari tidak dapat diamati secara langsung. Meskipun demikian terdapat instrumen khusus untuk dapat mengetahui waktu di malam hari dengan acuan posisi bintang di langit yaitu nocturlab. Dalam tulisan ini akan membahas mengenai sejarah penentuan waktu di malam hari dengan nocturlab. Metode yang digunakan dalam penelitian ini ialah metode kualitatif, yaitu untuk mendapatkan gambaran mengenai nocturlab pada masa lalu. Hasil dari penelitian ini bahwa instrumen nocturlab ini memiliki sejarah yang panjang dalam perkembangannya, meskipun saat ini sudah alat yang lebih canggih dalam menentukan waktu alat ini tetap menjadi bagian penting dari sejarah astronomi dan penentuan waktu dalam peradaban manusia.

Kata Kunci: *Penentuan Waktu; Nocturlab; Instrumen Astronomi*

A. Introduction

In ancient times, determining time at night was a little more complicated than deciding time during the day. Time can be easily known because the Sun is above the horizon, it can be easily observed its position or look at the shadows of an object to determine its time. Unlike the case at night, celestial objects at night cannot cast a shadow on an object so that its position can be observed. So, a particular instrument is needed to know the time of the night. One of the astronomical instruments of its time that could be used to determine a time at night practically was the nocturlab.

Nocturlab[1] It is a simple navigation tool that was first discovered in the 16th century to estimate the time at night; by aiming at the stars, you can estimate the time within 10-15 minutes.[2] This instrument has two rotatable dials with pointers and a hole in the center. One of the areas of the dial is the month of the year so that the date can be set. The pole star is visible through the hole and located (α and β Stars) of the Big Dipper, a pointer to Polweiser. Then, the time can be read on the second dial area.[3]

This paper aims to trace the history of the development of the nocturlab as an instrument for determining the time at night. Apart from that, it also reveals the chronology of the development of the use of the Nocturlab instrument as a tool for determining the time at night. The answer to this question allows in-depth research to understand and explore the vital role of the nocturlab instrument in science development at that time.

This paper argues that the nocturlab is a crucial tool in human exploration and astronomy history. Although determining time can now be done quickly and modernly, the Nocturlab instrument is the initial step that forms the basis of human knowledge about time. Thus, this instrument has an essential role in developing navigation and understanding of astronomy in the past and present.

[1] Günther Oestmann, "The History of the Nocturlab," *Bulletin of The Scientific Instrument Society*, 2001.

[2] "Nocturlab or Night Dial," bbc.co.uk, n.d.

[3] "Nocturlab (Instrument)," Memim Encyclopedia, n.d.

B. Method

The research method used to complete this research is qualitative research.[4] In this article, we will pay more attention to the urgency of the Nocturlab, starting from the instrument's concept and mechanism and its use at that time. The data collection method used in this paper is documentation, namely by collecting data sourced from articles containing historical data. The primary data source that the author uses comes from the article *"On The History of The Nocturlab"* by Günther Oestmann.[5]. Meanwhile, the secondary data comes from books, journals, and several museum findings on the Nocturlab instrument. The analysis used in this research is a descriptive analysis, where each process will carry out data collection from the sources mentioned. Then, the existing data will be compiled and processed to get an idea of the past Nocturlab development.[6]

C. Discussion

C.1. The Definition of Time

Time is a condition that can be observed and measured using tools such as machine clocks, electric clocks, or natural conditions. Essential concepts that must be known in determining time include the Sun's and Earth's movement. Time is based on the Earth's rotation on its axis. The differences are due to differences in the celestial objects used as the basis for the calculations.[7]

The Sun has a close relationship with the circulation of the Earth, especially in the rotation and revolution of the Earth towards the Sun, including the movement that depicts the Sun as a star; in fact, it is in a stationary position (not moving). The Earth and the planets move in a regular motion from west to east. When viewed from Earth, the Sun moves from east

[4] A. Muri Yusuf, *Metode Penelitian: Kuantitatif, Kualitatif dan Penelitian Gabungan* (Jakarta: Kencana,2017), 328.

[5] Günther Oestmann, "The History of the Nocturlab," *Bulletin of the Scientific Instrument Society*, 2001, https://www.researchgate.net/publication/267035472_On_the_History_of_the_Nocturlab.

[6] Sugiyono, *Metode Penelitian Kualitatif, Kuantitatif dan R&D* (Bandung: CV. Alfabeta, 2013), 147

[7] Denis Savoie, *Sundials Design, Construction, and Use* (Chichester: Praxis Publishing, 2009), 25.

to west daily. This movement is what we know as the apparent daily movement of the Sun.[8]

The basis for measuring time is the rotation of the Earth about its axis. Due to the Earth's rotation, the Sun appears to rise from the east and set in the west.[9] The primary object of calculating accurate solar time is the apparent motion of the Sun as seen by the observer due to the irregular rotation of the Earth.

C.2. The Various of Time

Time is a moment determined based on the position of the Sun in the sky. Time can also be interpreted as time specified by the globe. Humans divide time-based on the regular Earth, Moon, and Sun cycles.[10] Perbedaan antara satu tempat dengan tempat yang lain bisa diketahui dengan menggunakan jam Matahari.[11] The various types of time include solar time (dynamical time and universal time), middle or local time, and regional time.

C.2.1. The Solar Time

Solar time (actual time) is time-based on the Sun's proper (actual) circulation, namely when the Sun reaches the culmination point determined at 12.00 particular time. One place to another, according to the direction of west and east, has different times even in one city, especially in different cities.[12]

C.2.2. The Middle Time

Local time is the average time according to the longitude of a place. As many longitudes as there are places on the Earth's surface, there are also as many intermediate times as there are. This time is also called Local Mean Time (LMT).[13] The time that uses the WIB/WITA/WIT rule is time that is based on

[8] Muh. Hadi Bashori, *Penanggalan Islam* (Jakarta: PT. Elex Media Komputindo, 2013), 43.

[9] Rahmatiah, "Urgensi Pengaruh Rotasi Dan Revolusi Bumi Terhadap Waktu Salat," *El-Falaky: Jurnal IlmuFalak* 1 (2017), 63.

[10] Muhammad Ilyas, *A Modern Guide to Astronomical Calculations of Islamic Calendar, Times, & Qibla* (Kuala Lumpur: Berita Publishing, n.d.), 56.

[11] M. Maftuh, "Jam Bencet Alat Peraga IPA untuk Memahami Keterkaitan Rotasi Bumi dengan Jam Istiwa,"*Unnes Science Education Journal* 1 (2012), 35.

[12] Slamet Hambali, *IlmuFalak 1* (Semarang: Program Pascasarjana IAIN Walisongo, 2011), 81.

[13] Muhyiddin Khazin, *Ilmu Falak Dalam Teori Dan Praktik* (Yogyakarta: Buana Pustaka, 2008), 69.

middle time, that is, time that is based on the circulation of an imaginary Sun which seems to have a stable or even journey, never too fast and not too slow, namely 24 fixed hours in one day.[14]

C.2.3. The Regional Time

Regional time is intermediate time based on a specific longitude.[15] People in determining time are guided by meridians that pass approximately in the middle of a particular area, so areas within one area are called unitary time areas. Regional time is the official time used in government institutions and bodies' reports, news, announcements, and regulations.[16] Regional time is adjusted according to regional longitude based on the meridian, which passes approximately in the middle of the area concerned.

C.3. Definition of Nocturlab

Nocturlab is a classic astronomical instrument commonly used to determine the time of night star observations. Linguistically, Nocturlab comes from the Greek "noctur" and "labio". Noctur means night, while labion means scout or measurer.[17]

Nocturlab, sometimes also called Night Watch or Star Clock (Nachtuhr, Sternenuhr), uses the North Star and nearby conspicuous stars, especially the 'Guardians' of the constellation of the Great Bear (α and ß Ursae maioris, Dubhe and Merak) to tell the time. The extension of the connection line directly points to the North Star. Sometimes also used is the brightest star of the Little Bear (ß Ursae minoris; Kochab). It consists of three concentric plates mounted together but can be quickly rotated. The outer disk is divided counterclockwise into twelve equal parts representing the months, divided into five-day periods. Suppose the instrument is designed for use with several stars. In that case, the calendar disk is mounted and movable on the base disk, because the date on

[14] Mishbahus Surur and Zaenal Arifin, "Mengenal Equation of Time, Mean Time, Universal Time/ Greenwich Mean Time dan Local Mean Time untuk Kepentingan Ibadah," *Yudisia: Jurnal Pemikiran Hukum dan Hukum Islam* 5 (2014), 130.

[15] Slamet Hambali, *Ilmu Falak 1 (Penentuan Awal Waktu Salat dan Arah Kiblat Seluruh Dunia)*, 100.

[16] Hambali, *IlmuFalak 1*, 71.

[17] M. Khalid 'Aini, *Al-Usturlab* (ebook, n.d.), 1.

which the venerable star to be used for timekeeping has the same perpendicular position as the Sun must lie on the instrument's axis of symmetry, namely the meridian. The base disc or calendar disc is equipped with a handle so the instrument can be held easily.[18]

The central disk circle is divided into twenty-four equal parts, each equal to one hour. To make it easier to read the clock at night, 24 teeth were cut (the 12-hour mark was longer or had a different shape) so that the hour could be known by touch. The inner plate has an alidade, which projects beyond the outer edge of the calendar plate. The rivet in the center that holds all the pieces together is drilled and serves as a sighting hole for the North Star.[19]

To use the Nocturlab, the 12-hour mark on the center dial is set to coincide with the respective date. The instrument is held at arm's length, and the pole star is positioned in the hole in the center. Now, the alidade is turned until its beveled edge coincides with the Guard, and the number of hours can be read directly or (in the dark) by counting the number of teeth between the 12-hour mark and the edge of the alidade. Please note that the 12-hour mark set on each date indicates midnight. If you count the hours clockwise, you get the hours after midnight; if you count counterclockwise, you get the hours before midnight. Since the North Star is currently at a distance of about 1˚ from the Celestial Pole, a specific error is inevitable, but with a well-executed Nocturlab instrument, it can be measured within 5-10 minutes.[20]

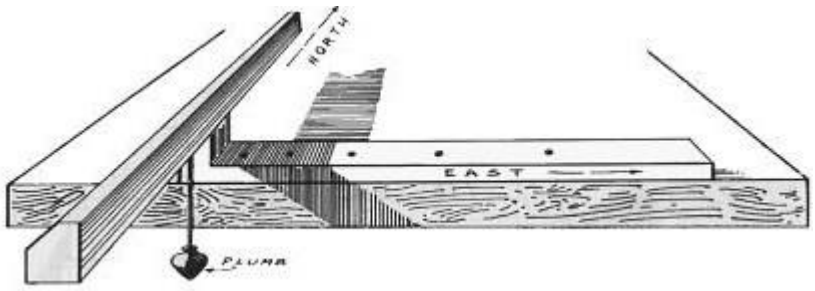
C.4. The History and the Development of Time Determination

In ancient times, before the discovery of time measuring devices, humans observed the shadows cast by trees to find out the time. When the shadows of the trees begin to move longer, humans start to come out of their homes to hunt, namely in the morning. Then, humans observe the shadows begin to shorten; they begin to return to their place of residence, namely daylight. After noon, the shadows will continue to lengthen until the Sun sets.[21] From this

[18] Oestmann, "The History of the Nocturlab", 5.
[19] Oestmann, 5.
[20] Oestmann, "The History of the Nocturlab."
[21] Siti Thutmainul Qulub, *Ilmu Falak dari Sejarah ke Teori dan Aplikasi* (Depok: Rajawali Pers, 2017), 132.

phenomenon, humans created the first scientific instrument used to determine time, namely the sundial.

A sundial is the world's oldest clock, usually called a sundial.[22] At the beginning of the 20th century, archaeologists discovered a sundial estimated to have been made around 370 BC. This sundial was the first sundial discovered. As time progressed, archaeologists began to find other sundials that were older, and most of these sundials were found in the Egyptian area.[23] One of the oldest sundials found in Egypt is thought to have been made around 1500 BC and was used by Thutmosis III.[24]



The sundial is made of stone in the form of a flat bar about 12 inches long with a perpendicular plane shaped like a "T" at one end. When the Sun shines on the sundial, the shadow from the "T" shaped area will fall on the flat bar below it, showing the measure of time. To be able to use the sundial, the "T" shaped area must be directed east in the morning and west in the afternoon. This sundial is also equipped with a pendulum, which is used as a tool to measure the alignment of the sundial when it is placed.[25]

Another sundial found in Egypt is thought to have been made around 660-330 BC. This sundial can show the time throughout the day without changing the sundial's position in the afternoon, like the first sundial. Apart from having a flat sundial, this sundial has a sloping and terraced plane resembling a ladder on both sides. The shadow that falls on the inclined plane

[22] John M Echols and Hasan Shadily, *Kamus Inggris Indonesia*, 25th edition (Jakarta: Gramedia, 2003), 586.

[23] R Newton Mayyal and Margaret W Mayyal Mayyal, *Sundials Their Construction and Use* (Cambridge: Sky Pub Corp, 1994), 3.

[24] Rene R. J. Rohr, *Sundial, History, Theory and Practice* (New York: Dover Publication Inc, 1996), 5.

[25] Rohr, 4.

can also show time. With this shape, this sundial can be placed without first knowing the meridian lines. To use this sundial, all you need to do is put it in a flat position and then move it until the time shown by the image on the inclined plane is the same as the time indicated by the shadow on the flat plane above it.[26]

In the classical Greek period, several sundial designs began to be developed. Aristarcus of Samos (3rd century BC) is said to have designed a sundial called the "hemisperium". This sundial is made of concave stone, and in the middle of it is a vertical gnomon in the form of a stick that points toward the zenith.[27]

In subsequent developments, the hemisperium was modified by Berosus, an astronomer who lived at the time of Alexander the Great. (356-323 BC). The hemispheric modified by Berosus is called the hemicycle, which people sometimes call the "dial of Berosus." The front part, or part of the hemispheric that faces south, was cut because the shadow from the gnomon never touched that part, so that part was considered useless. This sundial no longer uses a vertical gnomon but has been replaced by a horizontal gnomon. With these modifications, the hemicycle was easier to read and lighter to carry, so researchers at that time stated that the hemicycle was a significant improvement over the hemispheric.[28]

At the end of the 10th century, Arab astronomers made a significant discovery that became the forerunner to the birth of the modern sundial. They realized that using a gnomon parallel to the Earth's axis, a sundial could show the same time on one day of the year. This type of sundial was made by an astronomer named Ibn Al-Shātir for the Umayyad mosque in Damascus in 1371 AD. This is the oldest sundial (which uses a gnomon parallel to the Earth's poles) that still exists.[29]

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[26] Lawrence E. Jones, *Sundial and Geometry* (Glastonbury: North American Sundial Society, 2005), 4.

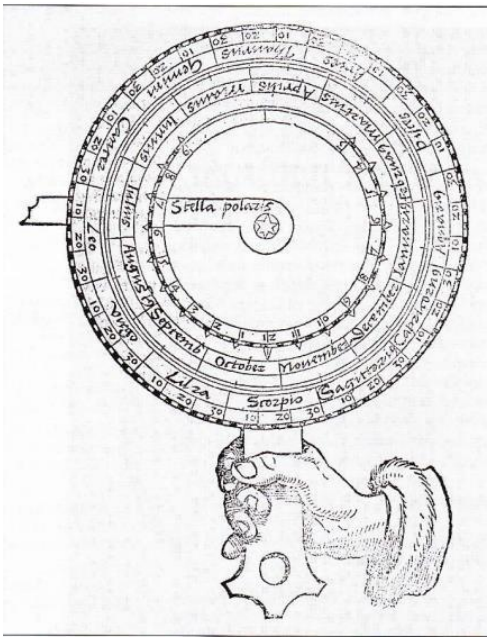
[27] Rohr, *Sundial, History, Theory, and Practice*, 5.

[28] Rohr, 8.

[29] Jones, *Sundial and Geometry*, 6.

C.5. The History and the Development of Nocturlab Instrument

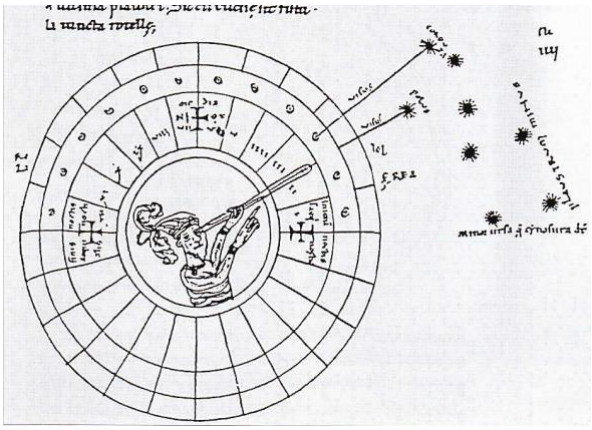
Judging from history, historians have yet to learn who the first inventor of nocturlab was. However, some literature discussing Nocturlab states that nocturlab comes from Europe. In a series of papers (1917/52, 1959), Henri Michel dates the discovery back to the 10th century BC in China. Michel assumed that the outlines of a flat jade disk with three deep grooves cut at a distance of 120° from each other and with three series of serrations between these teeth closely matched the positions of several prominent circumpolar stars around 1000 BC. He postulated that the prismatic jade tube and disc were used together and formed an astronomical instrument for telling the time at night. However, the reality is that the star's position is not as close as Michel stated. Moreover, he was not a sinologist and textual evidence contradicted his speculations. At first glance, Michel's claims seem exciting and admirable but have recently been refuted by modern sinological research.[30]



In the first half of the 9th century, the forerunners of the nocturlab instrument were introduced in Italy. The head of the Verona cathedral scriptorium, Pacificus (d. 844), claimed to be the disc inventor with a viewing tube. He described the rhyme, and the observation tube was depicted several

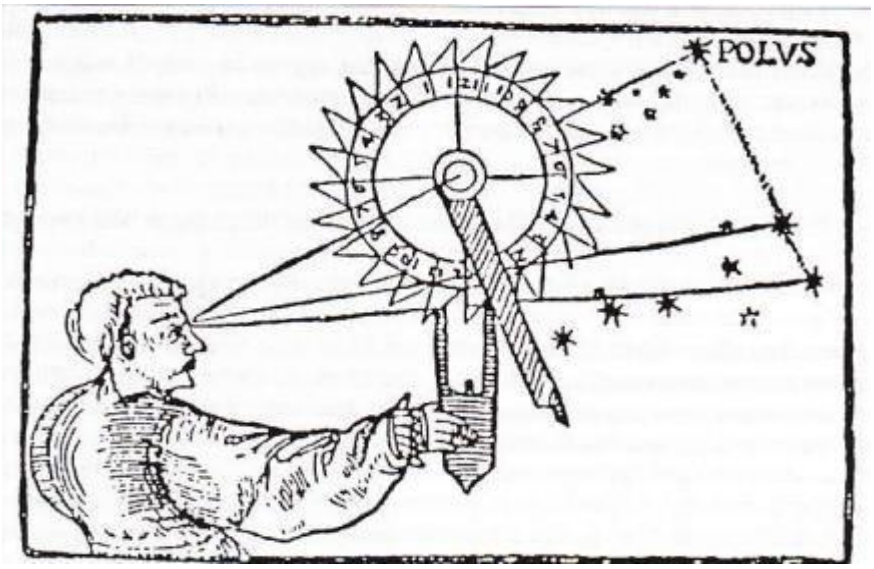
[30] Oestmann, “The History of the Nocturlab", 6.

times in manuscripts dating from the 11th and 12th centuries. In the 19th century, these statements led to exaggerated claims about the alleged invention of the medieval telescope. See Figure 4.



In contrast to the astrolabe, ancient manuscripts discussing nocturnes are rarely found. In his paper, Oesman states that nothing in the development of Islam regarding this type of instrument is known. Eighteen manuscripts from the 15th and 16th centuries discuss the construction or use of nocturlab instruments (or both). Most of these texts are part of collections of astronomical texts or tables. A comprehensive examination of the telephone call manuscript may reveal more of the text.

There is no list of extant nocturlab instruments available. A rather superficial census based solely on examining printed catalogs and inventory lists of German, British, and American collections revealed that 74 Nocturlabs up to 1800 can be found. Of these, 25 are made of wood (mostly boxwood). Many night creatures can be discovered with other instruments (astronomy summaries and quadrants).



A description of the first print (Fig. 5) appears to be included in Peter Apian's Cosmographicus liber.[31] This book was enlarged by Gemma Frisius in 1529. By 1609, it had gone through 30 editions and several translations, undoubtedly contributing to the instrument's spread. Nocturlabs also appear in the Apian Instrumentbuch of 1533, combined with universal dials of the Regiomontanus type and called Horometers, wooden pieces to be glued to wood or cardboard were an addition as a replacement for expensive instruments made of wood and metal. These instruments are worn out in everyday use; only a few survive.

In the 17th century, the Nocturlab was used by sailors for height correction and time calculation, as written by Georges Fournier in his Hydrographie, printed in Paris in 1643. It was also a valuable instrument for calculating the time of High Water in any place where the steady state (i.e., the time interval that elapses between the meridian passage time of the Full Moon or New Moon and the time of the following High Water) is known. A single nautical textbook hardly omits a description of the Nocturlab. However, contrary to the apparent widespread use of the instrument, the method of determining latitude by observing the North Star disappeared from textbooks at the end of the 17th century.[32]

[31] Peter Apian, *Cosmographicus Liber Petri Apiani Mathematici Studios Collectus* (Landshutae: Impensis P. Apiani, 1524), 239.

[32] Oestmann, "The History of the Nocturlab", 32.

Although observing the North Star at night was more accessible than directly observing the Sun with a Quadrant or Cross-Staff, the development of the Back-Staff and Davis Quadrants made it possible to observe the Sun without the danger of blinding. There was also a need to rework the correction tables occasionally because of the effects of precession. However, the Nocturlab instrument was still used until the 18th century; this is proven by the large number of instruments that still exist. There was a gap between the learned authors of nautical treatises, who often emphasized precise and mathematically sound methods for determining geographic position, and the standard user, who preferred simple instruments and non-mathematical procedures.[33]

C.6. Nocturlab Analysis in Hisab Rukyat

Nocturlab, as a classical instrument in the development of astronomy, is still very rarely used in the discourse of rukyat reckoning in this case because it relates to determining at night it does not require a specific time, however in the development of the Islamic world, which is related to Islamic worship the reference used is certain celestial phenomena such as the disappearance of the light of dusk and the appearance of the light of dawn.

The beginning of Isha and dawn is marked by the disappearance of the syafaq light on the western horizon, and the appearance of dawn is marked by reddish white light spreading on the eastern horizon. These two phenomena are closely related to the height of the Sun, which ranges from 15 to 20 degrees below the horizon.[34] In this case, the position of the Sun constantly changes every year due to the apparent annual movement of the Sun. Meanwhile, determining time at night with the Nocturlab instrument utilizes the position relative to the fixed stars around the pole star. So, it is impossible to decide on the start of Isha and Fajr practically using the Nocturlab instrument. However, there is still the possibility of efforts to develop this instrument to predict the time of dawn.

[33] Oestmann.

[34] Imam Qusthalaani, "Kajian Fajar dan Syafaq Perspektif Fikih dan Astronomi," *Mahkamah: Jurnal Kajian Hukum Islam* 3, no. 1 (2018): 9.

On the other hand, the noctrurlab instrument has advantages and disadvantages, including the fact that this tool functions as a calculation and observation instrument. Nocturlab, in its function as a calculation tool, does not require other tools, such as knowing the time; it can immediately be determined on a specific date because it has been adjusted to the date correction on the second plate. However, there are several areas for improvement in Nocturlab, which is made with real-time as a reference, so it still requires time conversion to know the regional time.

The alidade operation between the nocturlab was designed to project the southern sky, and the northern sky is different. In the south of the sky, the alidade rotates from left to right (clockwise), while in the northern sky, the alidade rotates from right to left (counterclockwise).

D. Conclusion

Determining the time at night using the nocturlab instrument is an ancient astronomical practice. This instrument measures time by selecting the relative position of stars in the night sky. The following is a brief history of timing with the Nocturlab instrument:

1. Ancient Times: The earliest investigations into observing the sky at night date back to ancient civilizations. They developed simple instruments to track stars and planets at night.
2. European Middle Ages: Nocturlab was also known and used in Europe during the Middle Ages. European astronomers and navigators used Nocturlab for ocean navigation and monks to determine worship times.
3. Development of modern technology: although these instruments are still used in specific historical and cultural contexts, their use has decreased significantly with modern technology, such as mechanical watches and digital devices. Modern tools have replaced many of Nocturlab's traditional functions in terms of timing.

Although the nocturlab's role in modern astronomy has diminished, it remains an integral part of the history of astronomy and timekeeping in human civilization.

Nocturlab is an instrument used to understand celestial bodies' movement at night and accurately determine time in ancient cultures.

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