From Bagdad to Barcelona via Franeker up to Zaragoza

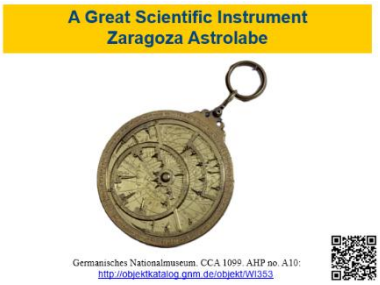


Inhoud

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Website:	https://www.fransvanschooten.nl/astrolabe.htm#Zaragoza2026
Presentation:	https://www.fransvanschooten.nl/astrolabe/2026_09_21_IbnAlSamh.pdf
Handout:	https://www.fransvanschooten.nl/astrolabe/2026_09_21_handout.pdf

From Bagdad to Barcelona: the education of astrologers using astrolabes



Hello, my name is Henk Hietbrink. I am a retired mathematics teacher and an independent researcher.

My talk is about the education of astrologers who used astrolabes to determine important astronomical and astrological events.

Let me start with the astrolabe. Today, we would use a computer and spherical trigonometry to solve many of the problems that could be solved with an astrolabe. But in the tenth and eleventh centuries, astronomers, astrologers, and mathematicians used this remarkable instrument instead.



The title of this slide, *From Baghdad to Barcelona*, comes from an important book about the transmission of Islamic exact sciences and, in particular, the history of astrolabes.

My question is: What did someone have to learn to become a competent user of an astrolabe? My question is: What did someone have to learn to become a competent user of an astrolabe?

This question takes us from the history of the instrument to the history of mathematical education.

From Bagdad to Barcelona Via Franeker: we are proud of our University



My hometown is Franeker, a small city in the north of the Netherlands, in the province of Friesland.

Friesland is rather proud of being different. Our native language is Frisian, not Dutch. Road signs are bilingual, newspapers are published in Frisian, and by law, Frisian can even be used in court.

Franeker also has a long academic tradition. In 1585, only ten years after the University of Leiden was founded, the University of Franeker was established to educate Protestant ministers. It was the second university founded in the Dutch Republic during the revolt against Spanish rule.

The Dutch won. The Netherlands became an independent kingdom and I became an independent researcher.

Eise Eisinga Planetarium in Franeker

Franeker has another reason to be proud of its heritage: the Eise Eisinga Planetarium.



Eise Eisinga, an entrepreneur and amateur astronomer, built this remarkable model of the solar system on the ceiling of his living room between 1774 and 1781. It took him seven years to complete his 25-square-metre, real-life planetarium.

Almost 250 years later, the clockwork is still running accurately. It shows the angular positions of the Sun, Moon and the five planets known in Eisinga's time.

Last month, there was a solar eclipse. That day, looking up at the ceiling, I could see that the Moon was exactly between the Earth and the Sun.

For me, it is a beautiful example of how astronomical knowledge can be embodied in a mathematical instrument.

But an astrolabe is different.

It does not simply show you the answer. The user has to operate it.



Frisian Astrolabe

[astrolabe photo from Fries Museum]

https://ariederuiter.nl/zwk/astrolabe_pibo-gualtheri.html

The Eise Eisinga Planetarium also exhibits a replica of a seventeenth-century astrolabe made by the Frisian craftsman Pybe Wouters, or, in Latin, Pibo Gualtheri. He engraved it in 1606, when he was 26 years old. Pybe was born around 1580 and died around 1640.

In Friesland, we are proud of this astrolabe. Do you recognize the tulip inside the ecliptic circle?

But there is more.

In the same century, the Franeker professor Adriaan Metius wrote extensively about mathematics, mathematical geography, and mathematical instruments such as the astrolabe. He also wrote about their use and about the mathematics behind them, including spherical trigonometry and stereographic projection.

You will meet him in about thirty minutes.

So in Franeker, we are proud of our past:
our university, our astrolabe, and our planetarium.

From Bagdad to Barcelona via Istanbul, Frankfurt, Franeker and Zaragoza



The people of Zaragoza can be proud of their university, their scientists, and their astrolabe too.

Have you heard of the eleventh-century Zaragoza Astrolabe?

This astrolabe was actually made in Zaragoza by Ahmad ibn Muhammad al-Naqqash in the year 472 of the Hijra era, corresponding to 1079/1080 AD. Today, you can see this astrolabe in the Germanisches Nationalmuseum in Nuremberg.

Old astrolabes are usually rather small, only ten to twelve centimetres in diameter.

The next slides show some astrolabes in more detail.

[replica]



But I have a question for you, people of Zaragoza: do you have a replica in your city?

There are replicas in Frankfurt and in Istanbul, at the Museum of the History of Science and Technology in Islam.

Why not have one here in Zaragoza?

A replica could commemorate Zaragoza's thousand-year scientific heritage and, more importantly, introduce that heritage to today's children, and to their parents. Zaragoza deserves its astrolabe.

Maybe a several-metre-wide astrolabe, standing in a square in the historic city centre: moving automatically, showing the time as a sundial during the day, and showing the stars at night.

From Bagdad to Barcelona via Oxford



[photo from Oxford]

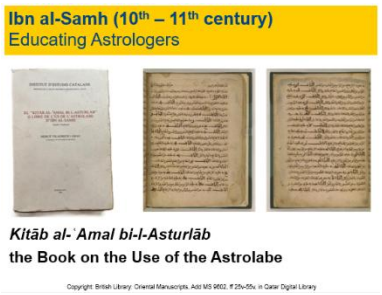
Do you recognize the star map on the astrolabe? You can see it on the right.

Perhaps you have held a star map in your hands. Such a map helps you recognize stars in different directions. But it does not allow you to measure the angular distances between the stars and the horizon.

The astrolabe has a better map. We call it the rete. Thanks to the clever use of stereographic projection, the rete allows us to perform measurements. We can measure angular distances.

This is not just a map. It is a mathematical instrument.

Ibn al-Samh: Educating Astrologers how to use the Astrolabe



Ibn al-Samh was a mathematician, astronomer and astrologer. Ibn al-Samh lived in tenth- and early eleventh-century Córdoba. He died in 1035 AD.

Ibn al-Samh wrote a book for astrologers on how to operate the astrolabe. One of his treatises is called *Kitāb al-ʿAmal bi-l-Asturlāb*, that is, the Book on the Use of the Astrolabe.

The Arabic text has been preserved in only one manuscript. It is now in the British Library in London, under the number Add. 9602, and is available in digital form in the Qatar Digital Library.
https://www.qdl.qa/en/archive/81055/vdc_100023486831.0x000002

The Arabic text was translated into Catalan by Mercè Viladrich. Her thesis was published in 1986. For me, it is an honour to translate her work into English. The book will be published by the Institute for the History of Arabic-Islamic Sciences in Frankfurt, together with the Arabic edition, which has not been published before.

Before the advent of digital computers, the astrolabe was an analogue device for telling time and representing the positions of the stars, both past and future.

An astronomer could use it to measure time during the night.

An astrologer could use it to draw horoscopes.

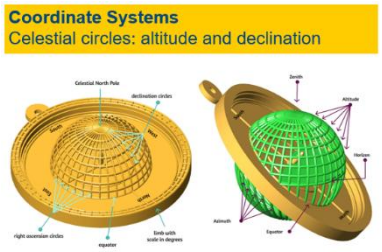
[Oxford]

Do you remember the star map (the rete) rotating over the plate?
Let's have a closer look.



Coordinate Systems: Celestial circles

[my 3D print version of two spheres]



We can describe the position of a star relative to the celestial equator.

The angle between the equator and the star is its declination.

On the left, you see an astrolabe with a sphere showing circles of declination. The equator is one of the most important circles on the astrolabe.

Polaris is the North Star. In our hemisphere, it is visible throughout the night. Its position is very close to the celestial north pole.

In general, stars appear to rise and set during the night. Europe, they seem to turn in circles around the North Star. The North Star is at the centre of these circles, and it is also the centre, or pin, of the astrolabe.

But Polaris is not directly overhead. In Europe, its altitude is somewhere around 40 or 50 degrees, depending on where you are.

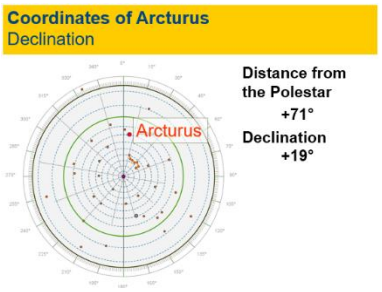
Now it gets complicated: We can describe the position of a star in two different ways. We have already described it relative to the celestial equator. Now we describe its position relative to our horizon.

We measure the angle between the horizon and the star. This is its altitude.

We also measure its direction along the horizon, starting from north. This is its azimuth.

During the night, the altitude and azimuth of a star change continuously as the star rises and sets. But its declination remains constant. Here is an example.

Coordinates of Arcturus



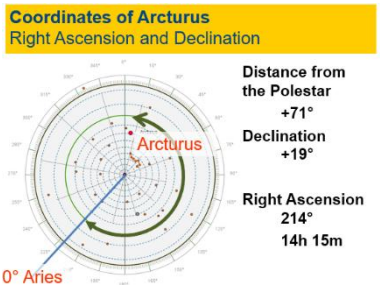
You have seen a few antique starmaps.

This slide shows the modern starmap of my digital astrolabe.

At the centre, you find Polaris, the North Star. The concentric circles are circles of declination: 10°, 20°, 30°, and so on.

Do you see that the circles are not evenly spaced? The gaps between them become wider. This is a consequence of the mathematics of the projection method.

Perhaps you recognize the Great Bear, or Ursa Major.



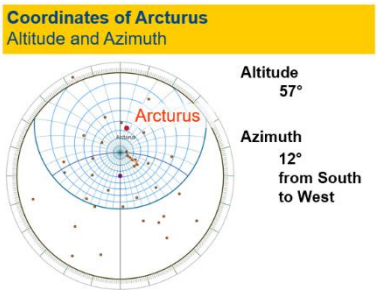
At the top, you see the star Arcturus.

Its polar distance is 71°.

Its declination is 19°.

Its right ascension, measured from 0° Aries, is 214° .

[Altitude]

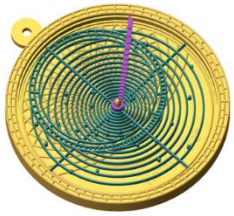


The slide now shows the other part of the astrolabe: the plate with altitude circles.

The altitude of Arcturus is 57° and its azumuth is 12° from South towards West.

Plate and Rete

Plate and Rete
Plate shows altitude + Rete shows declination



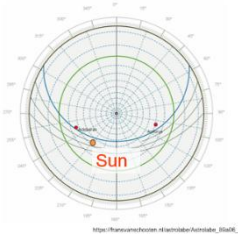
[Two GeoGebra animations]

So, we have two coordinate systems, and the astrolabe brings them together.

Let's see how this works.

https://www.fransvanschooten.nl/astrolabe/Astrolabe_89a06_k21_declination.gif

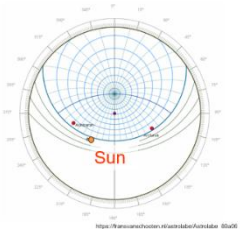
Rete shows declination
Animation Franeker 2 july: Sunrise and Sunset



We start with the rete. You can see the Sun and two stars moving around the celestial north pole. The animation shows what happens in the heavens on my birthday, 2 July. That day, the Sun has a declination of 23°.

https://www.fransvanschooten.nl/astrolabe/Astrolabe_89a06_k21_altitude.gif

Plate shows Altitude
Animation Franeker 2 july: Sunrise and Sunset



Now I add part of the plate, with its altitude and azimuth lines.

Watch the Sun.

It rises at 0° altitude, climbs to 10°, 20°, 30°, 40°, and reaches 50°. Then it descends again (40°, 30°, 20°, 10°) and finally sets.

So the rete shows us the celestial position, while the plate shows us the position relative to the horizon.

And now we can ask the important question:

How does the astrolabe convert one coordinate system into the other?

What shall we teach to whom?



[Ali Nesin Math Village]

Of course, I could give a lecture on spherical trigonometry, stereographic projection and geometry, and even explain how to construct an astrolabe.

But explaining the mathematics behind the conversion from one coordinate system to another takes a lot of time.

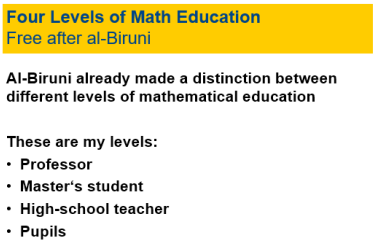
In Türkiye, I had the opportunity to teach for a whole week at the Ali Nesin Mathematics Village, in the summers of 2023 and 2024. There, I had time to go much deeper.

Today, I have only 30 minutes. So let us focus on didactics.

If we remember al-Qabisi, who was cited by Jan, many people who used the astrolabe did not know the mathematical and astronomical theories that were behind the instrument.

The real question is: Do you need to understand the mathematics behind the conversion in order to operate an astrolabe?

Four Levels of Math Education



[classification]

- Professor
- Master‘s student
- High-school teacher
- Pupils

Al-Biruni and al-Qabisi made a distinction between different levels of mathematical education.

We can make a similar modern classification as follows.

At the top is the professor, who knows the mathematical theory, can provide the proofs, and may even develop new ones.

Next comes the master’s student. The student is expected to understand and apply the theorems and to follow their proofs, but not necessarily to develop new proofs.

Then comes the high-school teacher (that’s me at school). As a teacher, I do not need to reproduce every proof from memory. My job is to make mathematics understandable, prepare pupils for examinations, and, perhaps most importantly, deal with the pupils.

And finally, we have the pupils. Most pupils learn by following the instructions they are given. And then there are always a few who ask questions and challenge the teacher. But the majority has more on their minds.

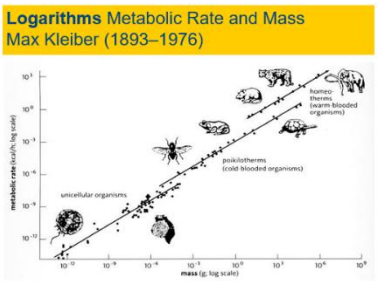
So where does Ibn al-Samh place the astrologer?

As a pupil, I believe.

And you may wonder: how can that be? The astrolabe is such an advanced mathematical instrument.

Logarithms

[double log graph:
Max Kleiber: mass and metabolic rate]



From a didactical point of view, learning to use an astrolabe is rather like working with a graph with logarithmic scales.

My pupils could put every animal in the right place on this graph. They could even estimate values in between, once they learned the rule: halfway between 1 and 10 on a logarithmic scale is about 3.

So the scale goes: 1, 3, 10, 30, 100, 300, ...

My fellow mathematics teachers understand the rules for manipulating logarithms. A master's student can go further and understand the mathematical theory behind them, including series expansions. And my professor knows all about their history.

But the pupils don't need all of that to use the graph successfully.

They can work with an advanced mathematical representation without knowing the algebraic rules and proofs behind it.

And that is exactly the point I want to make about the astrolabe.

Basic Start: the Star Trail



[Doğu Anadolu Gözlemevi
Eastern Anatolia Observatory]

Now let's return to the astrolabe.

The astrolabe has a star map with a dedicated scale. Here is a photograph of a starry night, taken with a very long exposure. The stars appear as trails.

It is difficult to measure the altitude of a star above the horizon, or its direction; north, east, south or west.

In my classroom, I like to ask three questions when I show such a photograph: What time is it? Where on Earth are we? And are the stars moving clockwise or anticlockwise?

The astrolabe gives us a way to answer these questions.

The rete carries the star pointers at their correct positions, according to their declination and right ascension. Underneath it is the plate, with the network of altitude and azimuth lines.

Now turn the rete clockwise. The stars rise on the left, that is east, and set on the right, that is west.

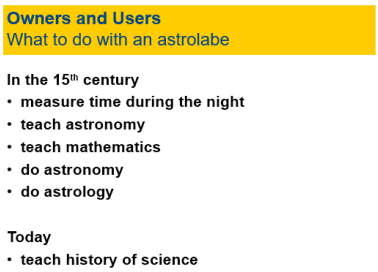
Put the rete in the correct position for the time, and you can read the positions of the stars.

Or work the other way around: match the rete to the observed stars, and you can determine the time.

So, suppose you have an astrolabe.

What would you like to do with it?

Owners and Users of Astrolabes



There were many reasons to own and use an astrolabe between the tenth and fifteenth centuries, and some of them still apply today.

You could use it to impress your neighbours: your astrolabe could be larger, richer or more delicate than theirs—just like your palace, your horses, or your wife's dresses.

But there were more serious reasons:

- to measure time during the night;
- to teach astronomy;
- to teach mathematics;
- to prepare horoscopes.

And what about today?

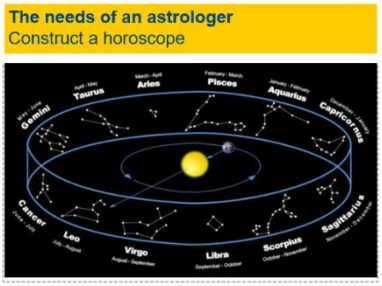
We can use an astrolabe to teach the history of science and to be proud of the scientific roots of our civilisation.

But I want to look at the astrolabe from a different point of view:

the point of view of the astrologer.

I believe this offers a refreshing way of looking at mathematics.

The needs of an astrologer



[zodiac signs in a wide band]

An astrologer uses the astrolabe to construct a horoscope. Knowing the date of birth is not enough for a precise horoscope. The astrologer also needs to know which zodiac sign was rising on the eastern horizon at the moment of birth.

The Sun and its zodiac sign may be somewhere in the sky, while another sign is rising in the east and another is setting in the west.

And the planets are usually close to the ecliptic, but not exactly on it. So the astrologer needs ways to project their positions onto the ecliptic and relate them to the astrological houses.

But here is the important point.

An astrologer does not want to construct an astrolabe.

He does not need to understand stereographic projection.

He does not need to know all the mathematical proofs.

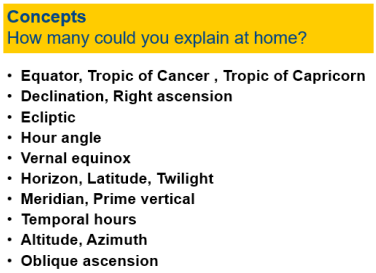
He wants to operate the astrolabe and construct a horoscope.

Ibn al-Samh understood this: he wrote a user manual.

Terminology

Astronomers, mathematicians and astrologers share much of the same terminology. Perhaps you recognize some of these words.

- Equator, Tropic of Cancer , Tropic of Capricorn
- Declination, Right ascension
- Ecliptic
- Hour angle
- Vernal equinox
- Horizon, Latitude, Twilight
- Meridian, Prime vertical
- Temporal hours
- Altitude, Azimuth
- Oblique ascension



That is quite a list.

Until the 1950s, cosmology was still taught as a subject in Dutch secondary schools. Today, much of this knowledge has disappeared from the school curriculum.

How many of these concepts could you explain at home?

So, do not underestimate the astrologer.

A competent astrologer knows all of these concepts.

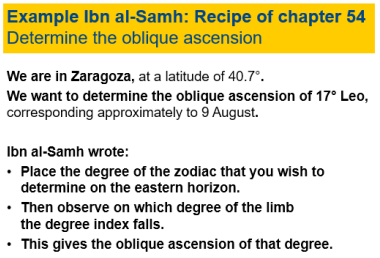
Example

[Recipe of chapter 54]

May I give you one of Ibn al-Samh's recipes? Would you like to do a mathematical exercise with this mathematical instrument: the astrolabe?

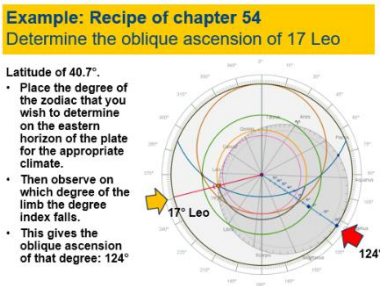


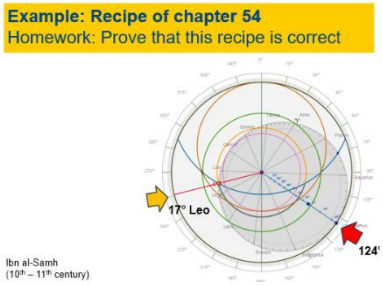
I will give you Ibn al-Samh's instruction, together with a practical example and its answer. Your task is to prove that the instruction is correct. Suppose we are in Zaragoza, at a latitude of 40.7°. We want to determine the oblique ascension of 17° Leo, corresponding approximately to 9 August.



Ibn al-Samh says: Place the degree of the zodiac that you wish to determine on the eastern horizon of the plate for the appropriate climate. Then observe on which degree of the limb the degree index falls. This gives the oblique ascension of that degree.

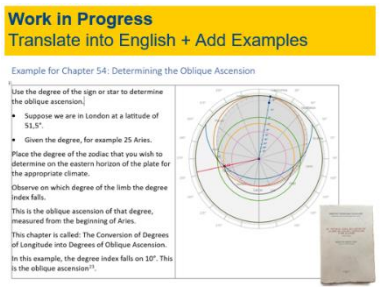
As you can see on the slide, in this example the degree index falls at 124°. So, thanks to Ibn al-Samh's instruction, the astrologer can use the astrolabe to obtain an oblique ascension of 124°, measured from the beginning of Aries.





Can you prove that this answer is correct?

Work in Progress



Mercè Viladrich wrote her thesis in 1986. She translated Ibn al-Samh's Arabic text into Catalan.

This year, we started a project to publish an English translation of her book, including the Arabic tekst.

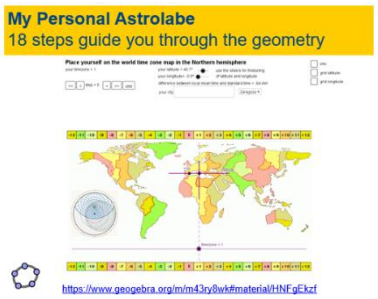
The result will be a unique book containing more than a hundred instructions for operating an astrolabe.

Alongside the translation, I am adding practical examples for every chapter, with illustrations from my digital astrolabe.

One day, you will be able to read Ibn al-Samh's user manual and try the exercises yourself, just as we did today.

My Personal Astrolabe

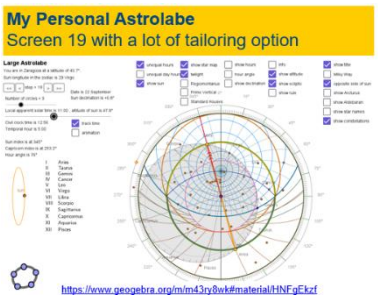
https://www.geogebra.org/m/m43ry8wk#material/HNFgEkzf



To understand the astrolabe better, I decided to build one myself. I did a digital astrolabe.

I coded an online astrolabe in GeoGebra, the well-known mathematical software environment that combines geometry and algebra.

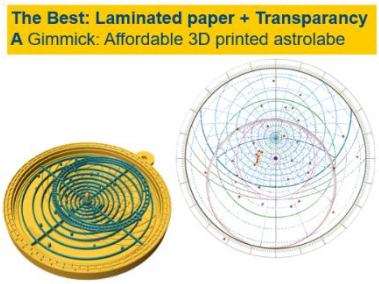
The project started in 2017, and I have continued to develop it ever since. Every year I try to add new features, including more of the functions needed by astrologers.



The app explains the geometrical construction of an astrolabe and allows you to operate it digitally.

For me, it is not just a digital copy of an old instrument. It is a way to understand how the astrolabe works.

[3D or laminated]



For my research, I love my digital astrolabe.
In workshops, I hand over a laminated paper model.

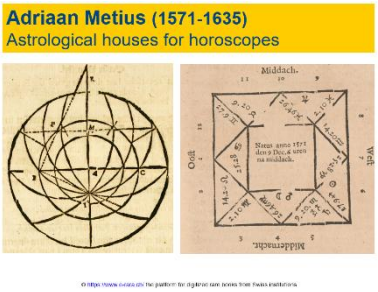
For fun, I printed a 3D model,
fancy but useless.

Adriaan Metius



We started our tour in Franeker, my hometown in Friesland, a province with a language of their own within the Netherlands.

Early 17th century, Adriaan Metius become professor in Franeker. He wrote mathematical treatises in Dutch and in Latin. He wrote a small book on how to construct an astrolabe and another book on how to use the astrolabe.



The construction book has six topics. It starts with the construction of the Tropics and the Zodiac and finishes with the astronomical houses, or, I would say, the astrological houses.

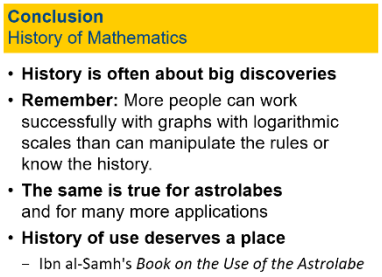
His user manual has six chapters:

1. The degree of the sun
2. Right ascension
3. Oblique Ascension
4. Twilight
5. Circumpolar stars
6. The rising and setting of the signs of the zodiac

The last page of the user manual deals with a horoscope.

This is quite amazing, because Metius was a Protestant professor working at a Protestant academy whose purpose was to educate Protestant ministers.

Conclusion



We often write the history of mathematics around discoveries: new theories, new proofs, new instruments and new mathematical ideas.

But mathematics also has a history of use.

It tells us not only what someone knew, but what someone had to learn in order to apply mathematics. And that is why practical mathematical handbooks deserve our attention.

Remember the graph with the double logarithmic scales. Far more people can work successfully with such a graph than can manipulate the rules of logarithms. And far more people can use logarithms than know the mathematical theory behind them or their history.

The same is true for astrolabes.

Ibn al-Samh's handbook gives us a glimpse of this history of use. He called it the *Book on the Use of the Astrolabe*.

One day, you may be able to operate an astrolabe yourself, following Ibn al-Samh's instructions, using my examples and my digital astrolabe.

Thank you.

