The front of the astrolabe of the astronomer al-Khujandī,
dated 984 and apparently made in Baghdad,
a scientific work of art.
The language of science at that time was Arabic.

The front of the astrolabe presented by the
German astronomer Regiomontanus to his patron the
Greek Cardinal Bessarion in Rome in 1462,
a scientific work of art.
The language of science at that time was Latin.

The Astrolabe:

What it is & what it is not

(A supplement to the standard literature)

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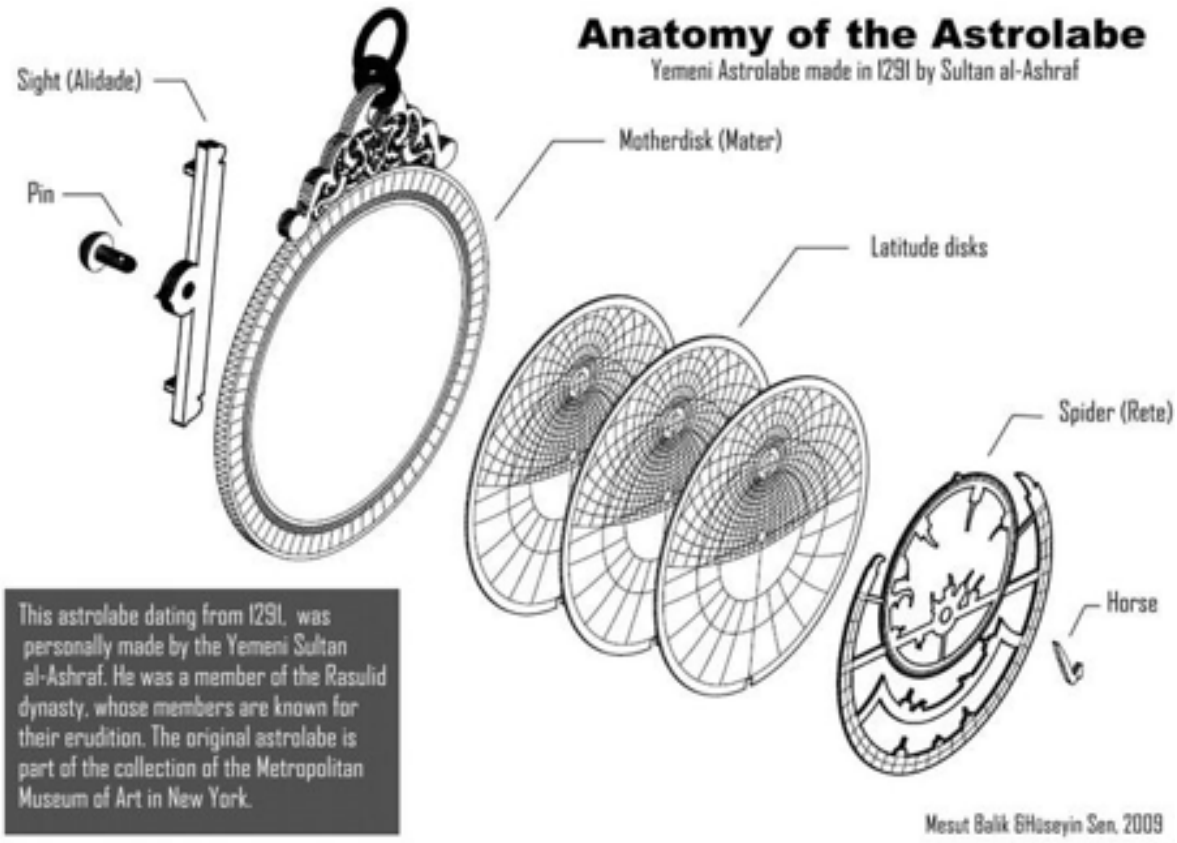
Academic note: When citing this paper, please make sure you are using the latest version. For Part I of this paper, more complete bibliographical references can be found in the similar text in the book *IN SYNCHRONY WITH THE HEAVENS* (available at www.davidaking.academia.edu).

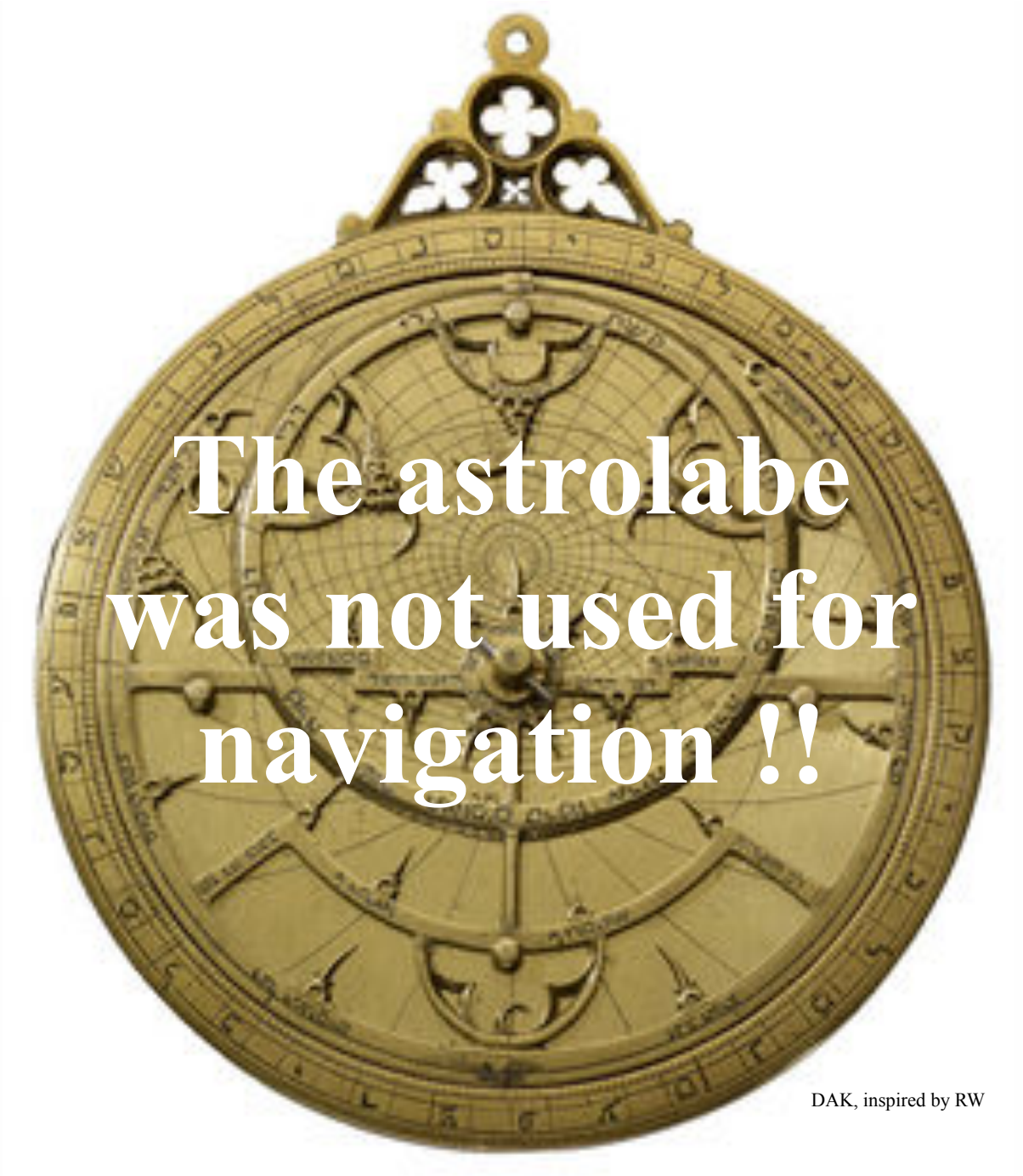
Technical note: Some of my readers have expressed their gratitude for my computer stories (read: nightmares) which I hope one day to publish separately. This document was prepared with PAGES software on a MacMini. There were many unwanted spaces between items in the bibliography which I was unable to remove. Also PAGES has the annoying habit of moving illustrations around in the text. It has no simple sorting facility and no means for working on two parts of a text at the same time. The entire text was converted to MS WORD, which necessitated reinserting by hand the footnotes one by one as well as the iluustrations. WORD had the annoying habit of freezing every time I inserted a new image until I realized that I could use the simple programme PREVIEW to somehow shield myself from the aggressive and greedy ADOBE. …

WARNING: In this version the page-numbers in the Table of Contents are not correct.



A breakdown of a typical astrolabe showing the basic components. This diagram was inspired by the astrolabe made in 1291 by the Yemeni Sultan al-Ashraf, who was a prolific astronomer and instrument-maker. Notice the plates look very different from European plates, because they serve the low latitudes of the Yemen or the Hejaz. A standard, very early, Greek, Islamic or European astrolabe might have seven sets of markings for the seven climates of Antiquity, six on three plates and one on the mater. [Reproduced with kind permission of Mesut Balik and Hüseyin Şen.]

A taste of things to come:



DAK, inspired by RW

Summary

The astrolabe is a symbol of astronomy in late Antiquity, the Islamic Middle Ages, the European Middle Ages, and the Renaissance. You can set it to show the instantaneous configuration of the heavens as they appear in your own sky. It is a veritable model of the universe that you can hold in your hand. The rete or star-map bears pointers for a selection of bright stars and a ring for the apparent path of the sun against the background of stars. This can rotate over the plates for different latitudes, showing the horizon and meridian and altitude circles up to the zenith of the observer. The astrolabe is primarily an instrument for reckoning time of day or night because one rotation of the celestial part over the terrestrial part corresponds to one rotation of the heavens about the observer, that is, 24 hours.

There is an imposing amount of excellent modern literature on the astrolabe and its history, as well as numerous reliable catalogues of the major and minor museum collections. Anyone can tap into this at any level in libraries or on the internet. Yet much of this modern literature is based only on medieval treatises on the astrolabe, without reference to surviving instruments, and these texts tell only part of the story. The instruments themselves can speak to us, if we understand their language, and they tell a very different, and far more interesting story than the texts.

All this not withstanding, over the past 20 years there has grown up on the internet a monumental pile of trash relating to the astrolabe. People who have no idea about history, about astronomy, about instruments, have set up dozens of sites misrepresenting the noble astrolabe, distorting its history, and potentially deceiving generations to come. These people are bloggers, faddists, teachers, museum folk, historians and astronomers, even university professors!

In the first part of the present study, we attempt to convey some of the power and the magic of the astrolabe and introduce the available literature on it, popular as well as academic. Some remarkable discoveries have been made in the past few decades by scholars who know the language of instruments and who afford them the same importance as textual sources, if not more, for many instruments tell us things that are not recorded in any texts. And there are still plenty of surviving astrolabes deserving of detailed study.

In the second part, we demolish some of the falsehoods that have been written on it by folk who are innocent of what the astrolabe is and/or what it can do. The astrolabe deserves better than that kind of rubbish.

Table of contents:

Do we need another work on the astrolabe?

Introduction

Imagine all you see of the heavens as being situated on a sphere of arbitrary radius. We call this imaginary sphere the celestial sphere. On it are the fixed stars and the ecliptic or apparent annual path of the sun against the background of the fixed stars between the limits of the circles of Cancer and Capricorn. (A celestial globe is an instrument displaying stars and these principal circles. An armillary sphere is an instrument featuring all of these circles, and more, as rings.) The celestial sphere appears to rotate about a celestial axis pointing toward a celestial pole, the motion being parallel to a celestial equator. The altitude of the celestial pole above the northern horizon is a measure of the latitude of the locality. The position of any celestial object relative to the horizon of the observer at the centre of the sphere can be defined by its altitude above or below the horizon and its direction or azimuth around the horizon. The moon and planets need not concern us here because they "wander" about the ecliptic and their motions are too unwieldy for our present purpose. So far, so good. Some people knew this 2,000 years ago. Kids should learn this at school, but they usually don't. I certainly didn't.

These spherical concepts and instruments can all be simplified and represented in a plane. This is achieved by means of a stereographic projection, the three-dimensional celestial sphere being reduced into the plane of the celestial equator, parallel to which all celestial motion appears to rotate. The projection has two very useful properties: circles on the sphere project into circles on the plane, and angles on the sphere project into equal angles on the plane. Brilliant!

The resulting astrolabe becomes a model of the universe that you can hold in your hands. It is a two-dimensional representation of the three-dimensional celestial sphere, with all of the principal stars and the most important celestial circles. The astrolabe can be set to represent the appearance of the heavens above and below the observer's horizon at any locality and at any time. The celestial part can rotate over the terrestrial part and simulate the apparent daily rotation of the heavens.

And that is why it's really brilliant and extremely useful.

The celestial part, called the rete, is a circular frame fitted with pointers for a selection of bright stars and an excentric ring for the ecliptic. The terrestrial part, called the plates, consists of a series of projections for different latitudes, and displays the meridian and the horizon and altitude circles from the horizon (0°) up to the zenith (90°). The rete lies on top of the plates which are fixed inside the mater, the front sometimes devoid of markings bounded by a raised 360°-scale. The back of the earliest astrolabes (Greek/Islamic/Latin) was devoid of markings beyond an altitude scale. The sighting device attached at the centre of the back is called the alidade and its movable extremity can move over the altitude scale to measure celestial altitudes. The ensemble is held together by a pin at the back fitted with a wedge at the front. Once the altitude of the sun or any star has been measured on the back of the instrument, this information is entered on the front of the instrument. One simply moves the appropriate position of the sun on the ecliptic ring or the appropriate star-pointer so that it lies on the appropriate altitude circle on the plate suitable for one's locality. Then indeed one has a model of the celestial configuration at that location at that time.

The astrolabe also displays the instantaneous configuration of the ecliptic relative to the horizon – the points of intersection are called the horoscopus or ascendant and the descendant – and to the meridian – the intersections are called upper and lower midheaven. The twelve astrological houses based on these major cusps and the presence of the sun, moon and planets in the individual houses and their imaginary influences on each other constitute the essentials of a horoscope or prediction. The astrolabe can at least show the configuration of the ecliptic. (A mechanical device for computing solar, lunar and planetary positions, called an equatorium, is vary rarely found on the backs of European astrolabes; otherwise these positions could be taken from an annual ephemeris, such as was available in Greek, Islamic and Latin astronomy.)

The astrolabe was invented in the Hellenistic world, perhaps by Theon of Alexandria in the 4th century CE, although the underlying theory was known already to Hipparchus of Rhodes in the 2nd century BCE. The theory of stereographic projection need not concern us here, being

so well documented in the modern astrolabe literature. Ptolemy's *Planisphaerium*, probably based on Hipparchus, is now available in an English version (translated from the medieval Arabic) and can serve as an introduction for the strong of heart to the mathematics of the projection underlying the astrolabe. Several Greek texts survive expounding the use of the instrument have survived, but only one astrolabe with Greek inscriptions survives, a Byzantine piece made in Constantinople in 1062. (Some confusion has arisen in the modern literature as a result of the fact that the great Ptolemy of Alexandria in the early 2nd century CE called his armillary sphere by the same term as the later instrument that concerns us here.)

Muslims encountered the astrolabe in the 8th century in Ḥarrān (now in Turkey), on the borders of the Byzantine Empire and the new Muslim domains. It became the favourite instrument of the Muslim astronomers of the Middle Ages, from Baghdad to Muslim Spain, to the Yemen, to Central Asia and India. Several hundred Islamic astrolabes survive in museums around the world, though most are from the last few centuries. It is the early ones that are usually more interesting from a historical and scientific point of view. And some astrolabes early and late are veritable scientific works of art. In addition to the numerous late examples, mainly from the Maghrib, Iran and India, we now have over a century's worth of fakes with inscriptions intended to deceive. (Astrolabes were not the only instruments inherited by the Muslims from their Greek predecessors: celestial globes, armillary spheres, fixed observational quadrants, and different varieties of sundials also became popular, although portable quadrants are mainly Muslim inventions.)

Christian Europeans, eager for the scientific knowledge of their Muslim neighbours, encountered the astrolabe in the Iberian Peninsula in the 10th century. Arabic texts were translated, Islamic instruments were copied, or so we used to think. The earliest astrolabe with Latin inscriptions dates from 10th-century Catalonia, and bears no resemblance to any known Western Islamic pieces or any later Spanish pieces; rather, it seems to be the sole surviving evidence of a Roman tradition. (We shall introduce what may be the second oldest European astrolabe below.) The other earliest medieval Spanish astrolabes also bear little resemblance to earlier Andalusī pieces.[1] Nevertheless they

represent the earliest one out of several medieval European regional schools, later ones being the English school, based in London and Oxford; the French school, based in Paris; the German school, based in Vienna; and the Italian school, as yet not properly researched.

In the Renaissance the astrolabe continued to be popular, and useful. Instruments were often large and richly decorated. Meanwhile in the Islamic world, at least in Morocco, Iran and India, as well as in Hindu India, astrolabe making continued into the 19th century, centuries after significant astronomical activity had ceased.

In each of the Byzantine, Islamic, Christian and Hindu cultural milieus the astrolabe became a symbol of astronomy. There are some beautiful inscriptions on certain astrolabes describing it as "an icon of the Universe" (Greek), "a mirror of the stars" and "a model of the Highest Sphere together with all that is within it" (Arabic). When one holds an astrolabe in one's hand, one has the whole world in one's hand.

In early modern times the astrolabe has been replaced by the planisphere, a star chart and analogue computing instrument in the form of two adjustable disks that rotate on a common pivot. This can be adjusted to display for a specific latitude the visible stars for any time and date, thus assisting the user to recognize stars and constellations. The mariner's astrolabe, a European device from the 15th century that serves only to measure celestial altitudes and which should never have been called an astrolabe, was the predecessor of the sextant.

In modern times the astrolabe continues to fascinate, and it is an extremely useful means of teaching astronomy in schools and colleges.

Are astrolabes important?

From the point of view of the history of astronomy in medieval times astrolabes are far less important than many people think. First, for representing the heavens globes and armillary spheres were available. For timekeeping there were other instruments available, notably the sundial and little hand-dials such as the nocturnal or the universal horary dial known as the *navicula*. For determining the positions of the sun, moon and five naked-eye planets one would need an equatorium, a far less common device. Second, for timekeeping by the sun and stars, at least in the Islamic world, there existed tables with thousands or tens of thousands or hundreds of thousands of entries for specific latitudes,

or universal tables for all latitudes. Likewise tables for computing solar, lunar and planetary positions would be available to every astronomer, and ephemerides displaying such positions for each day of a given year were compiled annually in various centres.

Portable instruments are, in fact, only one part of the history of astronomy, even though they are an important part. Books have been written about the history of astronomy in which the astrolabe is dismissed in a sentence or two, or not mentioned at all. It was only infrequently used in serious observations whose purpose was to improve astronomical parameters.

In life, especially in academic life, people are also divided into the numerate and the non-numerate, and in the same way, there are folk who can grasp what an astrolabe is, and others who cannot. Then there are museum curators and instrument fanatics who know nothing of the history of astronomy. There are specialists who cannot recognize a fake even when they catalogue one.

And as we shall see, both medieval Islamic and Latin astrolabes can confuse modern researchers who do not have the necessary experience to deal with them, or, to put it another way, do not understand the language of instruments. What I mean by that should become clearer below.

But there are other problems. For there are historians of astronomy who never mention instruments; there are some historians of astronomy who edit and translate medieval texts on the use of astrolabes without ever having seen an astrolabe; there are many people, scholars and others, who write about ‘the astrolabe’ or ‘the history of the astrolabe’ (that means ‘no pictures’) or ‘astrolabes’ (that means ‘some pictures’). And there have been some prominent historians of astronomy who simply do not like colleagues who work on instruments, especially those who work on astrolabes. This is symptomatic of the general disdain of those who work on written sources towards those who work on material sources.

Then there are those who are interested only in astrolabes, or only in sundials, or only in spheres, ... At least those who have looked at a medieval manuscript or handled a medieval astrolabe know the excitement that can accompany such a venture, and the humility one

can experience in face of the fact that there are thousands more of such manuscripts and hundreds more such instruments.

All history depends as much on the historian as on the subject of the history. We all have our special interests and prejudices and limitations. For myself, I very much prefer working on instruments, Islamic or European, that predate *ca*. 1500. Roughly speaking, before that time Muslim astronomers knew what they were doing, and after that time European astronomers knew what they were doing. Not least this saves me from getting too involved with the vast numbers of surviving Persian and Maghribī instruments that are available and which are not really part of any sophisticated astronomical tradition. And I shall mention sundials and quadrants and equatoria and horary dials only when they are associated with astrolabes, here our main concern. I shall not dwell on the principles of stereographic projection and the uses of the astrolabe, which are adequately handled in numerous other works.

On medieval instruments in general, including European ones, the reader may consult my paper "Astronomical instruments between East and West'' (Vienna, 1994), presented to a gathering of Byzantinists, Islamicists and Medievalists. The present article was written independently of, but contains the same materials as my study "The Neglected Astrolabe", dealing with both medieval Islamic and European astrolabes, which has full references and a detailed bibliography. It is published as Chapter XIIIa in my book *In Synchrony with the Universe* (2005). All my publications on instruments (and on the history of astronomy) are now on www.davidaking.academia.edu.

A personal note

We all come to astrolabes in different ways. My academic 'twin', George Saliba, and I were at the American University of Beirut during the academic year 1970-71, working with Prof. E. S. "Ted" Kennedy, the world's leading expert on the history of Islamic astronomy. We learned that in the Spring Semester a visiting astrophysicist and astronomy historian, Prof. Owen Gingerich, was going to offer a course on FORTRAN for recomputing medieval astronomical tables; both George and I signed up, and we were Owen's only students. Learning FORTRAN changed our lives, for we were both working on medieval astronomical tables, and, all of a sudden, we could recompute them.

But Owen also introduced us to astrolabes and had a pile of photos to show us. All three of us learned a lot, because George and I knew nothing about astrolabes but both of us were able to read the Arabic inscriptions on the astrolabes signed by ‘Abd al-A’imma that were Owen’s concern at the time, and confirm for him which pieces were genuine and which were fake. The triumvirate produced a paper together on these 18th-century Persian astrolabes.

That year in Beirut I had the pleasure of working with Frans Bruin, Professor of Physics at AUB and long-time director of the Observatory there. Frans was passionate about the early history of astronomy and ‘published’ the results of his researches in his privately-distributed *Biruni Newsletters* (1965-73). It so happened that in 1970 he completed a series on *The Planispheric Astrolabe, its History, Theory, and Use*. These are now very rare and should be scanned and made available. None of those who have written on the subject since has had any idea that Frans had already done this. The two of us spent many hours together during that year, and one day Frans produced two astrolabes which he had had made for him in Iran. He told me to measure the solar altitude with each astrolabe. To our joint surprise my results differed by some 10°.

Years later in New York George and I published Owen’s paper on zoomorphic star-pointers found on medieval Islamic and European astrolabes – the first study of a significant group of astrolabes with a common feature – for Ted Kennedy’s *Festschrift* (1986). George went on to catalogue the Islamic astrolabes at the National Museum of American History in Washington (1984) and I went on to catalogue quite a few astrolabes, Islamic and European, and to compose a lengthy essay “The neglected astrolabe” (2005) and then this wretched one, blighted by the inclusion of Part II. My goal is to help people understand what an astrolabe is and what it can do ... .

How sad the middle-aged man I saw one day in the 1990s looking at show-cases full of astrolabes in the Museum of the History of Science at Oxford, the largest collection in the world. He was there when I went in the morning to research astrolabes and he was still there when I went out for lunch. He came into the pub where I was having lunch and I motioned for him to join me. “How did you find the astrolabes?”, I asked. “Fascinating,” he replied, “but I didn’t understand a thing.” In

some museums in those days there were no visual aids, and in many there are still none. Happily nowadays the situation in certain museums housing astrolabes, particularly Oxford MHS, has improved dramatically, so that now that man would have said something like: “it blew my mind”, or “I feel enriched”.

Starting to understand the astrolabe

There are some good general introductions to the astrolabe and we should mention these here. Foremost is John North’s splendid and timeless 1974 article in *Scientific American*. His article contains all that the average reader might want to know about stereographic projection, what an astrolabe is, and how one can use the instrument. The astrolabe booklet published by the former National Maritime Museum at Greenwich available some 50 years ago was another splendid introduction to the instrument, including information on numerous Greenwich instruments. Already decades ago folk were heard to say it was “out-of-date”. Sadly, this is no longer available in the Observatory bookshop; it has been replaced by an excellent but much more expensive catalogue of the astrolabe collection.

An extensive and most valuable site www.astrolabes.org was prepared by the late Jim Morrison; it is rich with information but in 2018 was no longer accessible. Morrison’s book *The Astrolabe* is a splendid monument to the instrument and to its author, although Jim was less interested in its history and the numerous surviving examples than the underlying theory and the multiple uses. Other useful introductions by Harold N. Saunders serve the technical aspects and Darin Hayton the historical ones, respectively, with James Evans offering both. Most of the museum catalogues mentioned below have an introductory section describing the instrument in general terms. That of Anthony Turner for the now defunct Time Museum in Rockford IL is excellent. That one does not have to be a specialist to produce an excellent introduction to the astrolabe is shown by the book on perceptions of time in the Islamic world by the late Barbara Stowasser.

The first part of the present study is a shorter version of my 2005 essay entitled “The neglected astrolabe”, and dealing with astrolabes in both Islamic and Latin cultures. Dominique Brieux asked me which astrolabe had been neglected. The answer was: all of them.

Many astrolabes survive and can be seen in various museums or now on-line. Further, there is a vast amount of serious literature on the astrolabe available, which we will survey below (Part I). Perhaps one should take advantage of a current rebirth of interest in astrolabes, evident in England, with the 2014 conference in London, and Spain, with a new catalogue of all surviving astrolabes in al-Andalus and the Medieval Hispanic Christian Kingdoms. An effort has been made to at least mention most of the recent studies of the astrolabe. Notwithstanding these positive developments, there is still much scholarly literature circulating in which instruments are not given their just place or in which falsehoods about individual astrolabes are perpetuated. Worse than this is the fact that there is currently so much rubbish about the astrolabe circulating on the internet that perhaps it is worth documenting (Part II).

Educationalists have failed totally to create a new society in which people know what an astrolabe is, but I admit they have more pressing concerns. This is not completely a scholarly paper; I too have more pressing concerns. All of the references have been put into the bibliography. In Part I nothing much new is presented about the astrolabe. There is actually no need for another general article on the astrolabe. But with all the abundant reliable literature on the astrolabe that has been around for decades, it is very apparent that many people who dare to write on the astrolabe nowadays have never consulted any of it, or looked at a single astrolabe. I therefore feel compelled to gather some of the nonsense about the astrolabe which is now proliferating on the internet, not least because some of it is being generated by such dubious non-authorities as *Wikipedia*, but even by museum and university associates. It is seldom that an author tells potential readers not to waste their time reading what materials he has gathered. But perhaps the materials presented in Part II will serve as a warning about how much false and fake information is available on internet and in popular literature, not only about the astrolabe.

Finally, I make no claim that this is the ultimate work on the astrolabe and its history. That book has yet to be written. Rather this essay is intended only as a supplement to the standard literature on the subject, a rather whimsical overview that treats some aspects more fully than others. It includes a substantial bibliography as a guide to further study.

And at least, more than most other writings, it focusses on some of the surviving instruments. I try to set the scene for Raya Wolfsun (rayawolfsun.com/), who takes the study of astrolabes one step further:

> "As important as they are to historians of science, astrolabes also offer much to explore in their decoration and symbolism, their original social/ cultural/ political contexts, and the people who made them. I want to ask these historical questions, but also to probe further: Why do astrolabes captivate so many of us in the present? What can we learn about ourselves from our continued fascination with them?"

Part I: What an astrolabe is

"Ptolemy was riding on a donkey with an armillary sphere in his hand; it fell and the donkey trod on it and squashed it: the result was an astrolabe."
Legend recorded in a 13th-century Arabic text. [a]

"The astrolabe is an instrument with which one can achieve the solution of many astronomical problems, for practical and didactic purposes,
not including those relating to the (moon and) five planets, by the easiest procedures and simplest methods."
The Andalusī astronomer Abu 'l-Ṣalt, *ca*. 1000. [b]

"(The astrolabe) is not simply one object, it is many objects in one: an astronomical measuring device; a timepiece; an analogue computer; a two dimensional representation of the three dimensional celestial sphere; a work of art and a status symbol."
Thony Christie, "The astrolabe" (2016). [c]

a) See King, *In Synchrony with the Heavens*, XIIIe: 595.
b) In his treatise on the use of the astrolabe: see *Synchrony*, XIIIe: 603.
c) Thony Christie, "The astrolabe – an object of desire", at https://thonyc.wordpress.com/2016/04/28/the-astrolabe-an-object-of-desire/

"The astrolabe is a working model of the heavens, a kind of analog(ue) computer. *It enables the user to represent the heavens with respect to the sky of an observer.* In the astrolabe, the celestial sphere has been projected onto a plane surface*, actually the plane of the celestial equator*. Thus, the astrolabe can be considered a two-dimensional version of a celestial globe or armillary sphere. The basic principle of the astrolabe was a discovery of the ancient Greeks, but the oldest surviving astrolabes are medieval. Throughout the Middle Ages, first in Islam and later in Christian Europe, the astrolabe was the most common astronomical instrument. When precise results were called for, the astronomer had recourse to specialized instruments and to tedious trigonometric computation *or to extensive tables for timekeeping (Islam only)*. *Since the astrolabe is based on exact mathematical procedures, the accuracy of its various functions is limited mainly by the size of the instrument.* The beauty of the astrolabe was that approximate solutions (good to the nearest degree or so) to astronomical problems could be found by a mere glance at the instrument."
James Evans, 1998. [d]

d) James Evans' first paragraph on the astrolabe in his *The History and Practice of Ancient Astronomy*, p. 141 (with my additions in italics).

"What is an Astrolabe? The astrolabe is an astronomical computer for solving problems relating to time and the position of the Sun and stars in the sky. ... Astrolabes are used to show how the sky looks at a specific place at a given time. This is done by drawing the sky on the face of the astrolabe and marking it so positions in the sky are easy to find. To use an astrolabe, you adjust the moveable components to a specific date and time. Once set, the entire sky, both visible and invisible, is represented on the face of the instrument. This allows a great many astronomical problems to be solved in a very visual way. Typical uses of the astrolabe include finding the time during the day or night, finding the time of a celestial event such as sunrise or sunset and as a handy reference of celestial positions. Astrolabes were also one of the basic astronomy education tools in the late Middle Ages. Old instruments were also used for astrological purposes. The typical astrolabe was not a navigational instrument although an instrument called the mariner's astrolabe was widely used. The mariner's astrolabe is simply a ring marked in degrees for measuring celestial altitudes." Anonymous. [e]

e) Anonymous, "Astrolabe", at http://scienceislam.com/islam_astrolabe.php (accessed 2018).

Introductory remarks

I may be repeating myself, but here goes again. The astrolabe is a versatile model of the universe, flat and usually small enough to put in one's (large) pocket. More specifically, the astrolabe is a two-dimensional representation of the three-dimensional celestial sphere, an imaginary sphere of arbitrary radius, on which it is convenient to imagine all of the celestial bodies. The 'celestial' part of the astrolabe, called the rete, shows positions for the stars and the apparent path of the sun against the background of the stars. The 'terrestrial' part, a set of plates for a series of latitudes, has markings for the horizon and meridian and altitudes up to the zenith. One rotation of the rete over the plate for a given latitude corresponds to one apparent daily rotation of the heavens, that is, 24 hours. The astrolabe can be made to represent the instantaneous configuration of the heavens at any time of the day or night above and below the local horizon. Its primary function is in time-keeping, since rotating the rete over any plate simulates the passage of time. Some Islamic astrolabes bear special markings on the plates for the times of Muslim prayer: sunset, nightfall, daybreak, midday and mid-afternoon. On the back of a standard astrolabe we find a device, called an alidade, for measuring the altitude of the sun or any star, as well as, mainly on Western Islamic instruments, calendrical scales for finding the solar longitude on the ecliptic from the date in a given solar calendar, and shadow scales for deriving shadow lengths from solar altitudes and *vice versa*.

The Greek name for the instrument means something like "taker of the stars", as far as that means anything. The name hardly conveys what the instrument can do. Taking (the altitude of) stars is but a small fraction of what it can do. Variations of the Greek ἀστρολάβος, *astrolābos* are found in Near Eastern and European languages. Fanciful derivations of Arabic and Persian اسطرلاب, *asṭurlāb* were in circulation in the Middle Ages, and various myths about its invention were conceived.[2] The best is an Arabic story about Ptolemy holding a celestial sphere while riding on a donkey; inevitably he dropped it, the beast trod on it, and the result was an astrolabe. Second best is the phrase مرأة النجوم, *mirā't al-nujūm*, meaning "mirror of the stars".

I shall not dwell here on the 'real' history of the astrolabe. Certainly one cannot write the history of the astrolabe from Greek, Arabic and Latin and vernacular treatises about the astrolabe, though some colleagues have tried this. Perhaps the best introduction which systematically takes into consideration actual instruments, rather than only medieval treatises on the construction and use of the instrument is Burkhard Stautz' introduction to his catalogue of the astrolabes preserved in the museums of Munich.

The briefest overview might look like this:

-150	Hipparchus of Rhodes knows about stereographic projection
+400	Theon of Alexandria probably develops the astrolabe
+750	Muslims encounter Byzantine astrolabes in N. Syria
8C-15C	Muslims are leading astronomers; numerous improvements to astrolabes, including astrolabic clocks; regional schools of instrument-making
+1000	First Europeans learn of the astrolabe from Muslim Spain
13C-16C	Astrolabes made in European regional schools; astronomical clocks developed; Europeans become leading astronomers in the 16C
17C-19C	Muslim craftsmen carry on making astrolabes despite scientific stagnation
17C	Europeans move on to telescope and beyond

Astrolabe retes from the utilitarian to scientific works of art

Retes are designed to include all of the sky that one can see anywhere in the northern hemisphere, and quite a bit more. The outer rim corresponds to the Circle of Capricorn, and the ecliptic is fixed between that and the Circle of Cancer, so that the entire ecliptic, the path of the sun against the background of the fixed stars, is represented. The ecliptic ring, which is not concentric with the outer ring, is graduated with the 30°-divisions of the zodiacal signs. To find the solar longitude, or where the sun is on the ecliptic, one can consult an ephemeris or read off the longitude for a given day on the solar/calendrical scales on the back of the instrument.

Already by the 10th century exquisite designs were introduced on retes, the quatrefoil decoration evolved, and zoomorphic star-pointers

appeared. The rather simple, staid design of Greek and Byzantine retes gave way to retes such as we find on the magnificent astrolabe of al-Khujandī, made in Baghdad in 984. Sometimes designs went just a bit too far, except for art historians: one 12th-century Syrian astrolabe bears circus figures representing constellations, so the star-pointers are difficult to recognise. Some of these inspired European astrolabe design, so that, for example, the extensive quatrefoil decoration on an early 14th-century English astrolabe was surely derived from the Islamic and early medieval Catalan astrolabe tradition. Even at a later stage we find the 'tulip' design on 16th-century Flemish astrolabe retes, which was inspired by the Arabic بسملة , *basmala*, that is, the formula بسم الله الرحمن الرحيم , *bi-smi 'llāhi 'l-raḥmāni 'l-raḥīm*, "In the Name of God, the Merciful and Compassionate", written in Arabic "mirror" script and used on retes from 15th-century Iran.

We need not dwell on the fact that Muslim astronomers devised over a dozen different arrangements of the symmetrical ecliptic on retes. Most of these, with fanciful names, had no future, except for the "myrtle" (آسي , *āsī*) ecliptic which was occasionally used on universal astrolabes. And only one example is known, from 10th-century Baghdad, of a "complete" (كامل , *kāmil*) astrolabe, serving regions of the sky beyond the Circle of Capricorn (this time to declination 36°S).

The mater

The mater includes a raised circular ring fitted with a 360°-scale. This ring is either one piece with the mater, or it can be riveted or brazed onto the mater. At the top it bears a throne with a suspensory ring. The name 'throne' corresponds to Greek *thronos* and Arabic كرسي , *kursī*, which suggest that the instrument should be supported on the throne, analogous to a mirror standing on a pedestal. The very earliest Greek, Islamic and European astrolabes served the seven climates – see below – so that three plates and the mater itself would offer seven surfaces. Later the mater was often left empty. Sometimes, however, it might be supplied with a set of astrolabic half horizons for each few degrees of latitude. This device, invented by the leading astronomer of 9th-century Baghdad, Ḥabash al-Ḥāsib, was extremely popular in Islamic instrumentation, but did not feature on medieval European astrolabes. Using the rete on this horizon plate could solve horizon-related

problems for any latitude. Sometimes the mater will be engraved with astrolabic markings for the latitude of the Equator or the Tropic of Cancer, both serving didactic purposes and the latter also useful for converting ecliptic and equatorial coordinates.

Making astrolabes work "for the whole world"

The plates were originally conceived to make the astrolabe universal, serving the whole world. The Greeks divided the habitable world into seven 'climates' or latitudinal strips whose limits were defined in terms of the lengths of longest daylight at that latitude. The middles of the climates correspond roughly to the following latitudes:

16° 24° 30° 36° 41° 45° 48°

For this reason Greek astrolabes had seven sets of markings, one for each of the seven climates κλιμα pl. κλιματα / اقليم ج. اقاليم , *iqlīm* pl. *aqālīm*, on each side of three plates and on the mater. So did the very earliest Islamic astrolabes, and so did some of the very earliest European astrolabes. In each tradition plates for the climates were replaced by plates for a series of latitudes or specific latitudes relating to a specific locality. The plates should be called 'plates', which they are, not 'climates', which they are not; the mis-nomen 'climates' is a modern invention.

The "geography of astrolabes" is a key to understanding their development. The plates bear the following markings:

- The meridian from north to south or from top to bottom, and the local horizon.
- Altitude circles for each few degrees above the horizon up to the zenith. Sometimes azimuth circles are included, these being perpendicular to the horizon and passing though the zenith.
- Below the horizon we find curves for the seasonal hours of daylight, one-twelfth divisions of the length of daylight, with which one can find the time of day from a measurement of the instantaneous solar altitude. The curves also serve the seasonal night-hours.

Markings relating to Muslim ritual (I)

Muslim ritual involves five prayers a day – sunset, nightfall, daybreak, midday or shortly thereafter, and mid-afternoon – to be performed in the sacred direction قبلة , *qibla* – toward the sacred كعبة , Kaaba in

Mecca. The astrolabe can be used to determine when these prayers should begin, but only if the appropriate markings are present:

- Frequently on Islamic astrolabes we find amidst the seasonal hour curves additional curves for times of the midday and mid-afternoon prayers.
- Frequently on Islamic astrolabes we also find curves for morning and evening twilight, whose primary purpose was for regulating the times of the two prayers at nightfall and daybreak. Such curves for twilight are found on European astrolabes very rarely.

The use of astrolabes for the purposes of Islamic ritual has been very much exaggerated in the modern literature – see Part II.

Markings relating to astrology

When the rete and plate are set to display the instantaneous configuration of the heavens above the observer, one can immediately see the configuration of the ecliptic with respect to the horizon and the meridian. The points of intersection define the ascendant, lower midheaven, the descendant, upper midheaven, thought by the credulous to be of some significance. Very rarely Islamic and late medieval European astrolabes (starting in 10th-century Baghdad, then in al-Andalus, later even as far away as England) have additional plates for determining the astrological houses and the projection of the rays, which form the basis for casting a horoscope. The rest of the operation cannot be performed with an astrolabe; one needs an ephemeris or almanac displaying solar, lunar and planetary positions for each day of a given year. It is worth an extra sentence to repeat that one cannot draw up a horoscope with an astrolabe alone.

Markings on the back

All of the features we find on the backs of some Islamic astrolabes were introduced by Muslim astronomers, mainly in the 9th and 10th centuries, and also found on European instruments. These are:

- A trigonometric quadrant with ordered sets of horizontal lines, or vertical lines, or both, or with markings resembling graph-paper, all for performing trigonometric calculations. For example, one can use a simple approximate procedure to calculate the qibla for any location for which one has the geographical coordinates. (For more

on the qibla, see below.)

- A universal horary quadrant for finding the time of day quickly but approximately, with circular markings indicating the altitude of the sun at each of the seasonal hours of daylight on any given day of the year. The result is based on a non-exact formula but is adequate in the latitudes where the device was conceived.
- An horary quadrant for a specific latitude, with graphs of the solar altitude at each year throughout the year. One measures the solar altitude and compares it with the altitudes at the hours on that day.
- The shadow square for converting shadow lengths and solar altitudes, usually to base 7 'feet' or 12 'digits'. This has multiple uses in surveying.
- Calendrical scales primarily for finding the solar longitude from the date in a solar calendar. The earliest example dates from *ca*. 900 on horary instruments made by Nasṭūlus in Baghdad. Others display leap-years and perpetual calendars, and more. These solar / calendrical scales are common on Western Islamic astrolabes, but not on Eastern ones. On medieval European astrolabes they have been used with limited success to date otherwise undated pieces. On English astrolabes we often find calendars of saint's days.
- The astrological information recorded on the backs of some astrolabes was mainly useful for filling space that have would otherwise been vacant. There may be, for example, the names of the 28 lunar mansions; the names of the 12 zodiacal signs; indications of the sun, moon and planets; lengths of the limits; the lords of the faces; divisions of the faces; the lords of the day and night and the companions for each sign. This information, available in any textbook, could be learned by heart by anyone sufficiently interested.

All of these features are found on surviving astrolabes from 9th- and 10th-century Baghdad. It was mainly the universal horary quadrant, the shadow-scales, and the calendrical scales that were included on medieval European ones. Europeans do not seem to have been bothered by the fact that the universal horary quadrant did not give reasonable results in European latitudes.

Markings relating to Muslim ritual (II)

Occasionally we find special markings relating to the qibla on selected groups of Islamic astrolabes:

- If one knows the coordinates of one's locality and Mecca, it is fairly straightforward to use an approximate geometrical construction to determine a rough value for the qibla. To calculate the qibla accurately for any locality from scratch using the trigonometric quadrant is a very cumbersome procedure that is almost as complicated as calculating it using the appropriate trigonometric formula.
- A very few Iranian astrolabes display qibla directions of one or more cities in Greater Iran, marked by *miḥrāb*s, in a quadrant on the back.
- Some late Persian ones from the 16th century have graphs which display the altitude of the sun throughout the year when it is in the qibla for different localities: these are not trivial.
- A solar scale, mainly on Iranian astrolabes from the 16th century onwards, showing graphically the solar meridian altitude for a series of latitudes and the solar altitude when the sun is in the azimuth of the qibla for a series of cities in Iran and for any solar longitude.
- Likewise, late Persian astrolabes have gazetteers listing longitudes, latitudes and qiblas, for dozens of cities. This information was more appropriately included in manuscripts.

The alidade and the paraphernalia

The alidade is an essential component of the astrolabe. It is a diametral rule fitted with two sights, and its pointed ends can move over the altitude scale(s). With this device one can measure the altitude of the sun (by letting the light though the hole on one sight fall on the other sight) or the altitude of any bright star featured on the rete. Equipped with this information the user can feed it into the front of the instrument. Either by finding the solar position on the ecliptic or the appropriate star-pointer and moving it so that it lies on the altitude circle corresponding to the altitude just measured. Then the astrolabe is set for the place and the moment.

The alidade is sometimes marked with a non-linear scale for the seasonal hours of daylight for finding the approximate hour of daylight quickly for any latitude. This baby sundial is of Greek inspiration and

such markings are found on early Eastern and Western Islamic astrolabes, if not medieval European ones.

Rarely a sighting tube is attached to the alidade. Such a device (called بوق , *būq*, trumpet) is mentioned by al-Bīrūnī (*ca*. 1025) in his treatise on astrolabe construction, and is found on the astrolabe of the Yemeni Sultan al-Ashraf (1295).

A pin holds the rotatable alidade in place and passes through the mater with its plates and the rete to emerge at the front. It has a slit through which is fitted a wedge, often in the form of the head of a horse, to hold the ensemble together.

Quadrants

We have already mentioned the universal horary quadrant for quick determination of the time of day in seasonal hours. This device, based on an approximate formula for timekeeping, was extremely popular on the backs of astrolabes in both the Islamic world and medieval Europe. It has been much misunderstood in the modern literature, where the underlying formula has been misinterpreted. It was invented in 9th-century Baghdad. A treatise from that milieu mentions six varieties of the instrument, with a movable cursor for setting the latitude and inserting the solar declination or a fixed cursor for a specific latitude. The most common variety on the backs of astrolabes was a family of arcs of circles representing the solar altitude at the seasonal hours, culminating with a semi-circle for the 6th hour at midday. Any cursor is superfluous. In medieval Europe the universal horary quadrant with movable cursor reappears and is called the *quadrans vetus*. The *quadrans novus* associated with Profatius (Montpellier, *ca*. 1275) is an unhappy instrument combining the approximate feature of the universal horary quadrant and the accurate feature of an astrolabic projection of the ecliptic and a set of horizons for a series of latitudes. It is unhappy only from a mathematical point of view. But I am not aware of any discussion in medieval Europe about the approximate formula underlying the universal horary markings. The formula has not had much luck in the modern literature on instrumentation where several scholars have tried to derive it from modern considerations rather than recognizing it as a medieval formula involving seasonal hours.

The horary quadrant for a specific latitude also dates from 9th-century Baghdad and is occasionally fond on the backs of Islamic astrolabes. It also appears as a separate instrument in both the Islamic world and medieval Europe.

The trigonometric quadrant consisting of a grid of horizontal or horizontal and vertical lines is another invention from 9th-century Baghdad. This is to be used with the alidade to solve trigonometric problems relating to spherical astronomy.

An astrolabic plate for the equator, latitude 0°, which can be made to function for any latitude. A combination of two such plates attached at their centres, the upper one cut out so as to show the other one beneath it, constitute a brilliant means of solving any problem in spherical astronomy. The universal quadrant is known only from a text by the 14th-century Syrian astronomer Jamāl al-Dīn al-Māridīnī and a 16th-century Spanish instrument.

The astrolabic quadrant consists of half a set of astrolabic markings for a specific latitude, taking advantage of the symmetry of the markings on a standard astrolabe plate about the meridian. The instrument is much easier and cheaper to make than an astrolabe, but serves only a single latitude. The first known treatise on the instrument is from Cairo and is datable to the 12th century; however, the author makes no claim to have invented it. A few examples in brass survive from 14th- and 15th-century Egypt, Syria, Hejaz, and Tunis, and most later quadrants from Ottoman Turkey are in wood with the markings on paper, then lacquered. (Such very useful quadrants do not appear to ever have been used in Europe, and in the modern literature they are sometimes confused with the Profatius quadrant, which is a different instrument altogether.)

Surveying

Now with the graduated scales on the back, together with the alidade, the astrolabe could be held vertically or laid horizontally in order to solve problems of surveying, within the limits of its size. Finding the height of tall buildings, the depth of wells, or simple triangulation, all these can be theoretically achieved with the astrolabe, even though they are somewhat beneath the dignity of this noble instrument and the average astrolabe is rather too small to expect spectacular results.

Universal astrolabes

Astrolabic markings for latitude 0° are, in a sense, latitude independent. With the appropriate rule or alidade such markings become universal, that is, they can be used for any latitude. These were first developed in al-Andalus, and later a universal plate, either of the types of Ibn al-Zarqālluh (Toledo then Córdoba, d. 1100) or Ibn Bāṣo (Granada, *ca*. 1300), was included among the plates of a standard astrolabe. The late-11th-century Andalusī scholar ʻAlī ibn Khalaf devised a universal astrolabe. No examples are known from the Western Islamic world, but the *maestro* Ibn al-Sarrāj of Aleppo in 1328/29 constructed a spectacular astrolabe that was universal in five different ways, a monument to human ingenuity but not something one needs every day. He was not obviously influenced by the Andalusī tradition and he far surpassed it in ingenuity. The connection between these instruments and the "Mathematical Jewel" of John Blagrave of Reading, 1584, is much clearer now that a 15th-century universal plate for latitude 52° has surfaced, auctioned at Bonhams of London in 2017.

It is a mistake to think of the universal plate or universal astrolabe as the ultimate invention in medieval or Renaissance instrumentation; they are simply alternatives to the standard astrolabe. And we should distinguish between three different instruments:

a) The single plate with universal astronomical markings (called شكازية , *shakkāziyya*) and an alidade with a graduated scale. With this, some operations, such as determining time from celestial altitudes, could be performed only approximately.

b) The single plate with two sets of universal markings inclined at about 23.5° to each other (called صفيحة زرقالية , *ṣafīha zarqālliyya*) and an alidade with a movable arm attached. This served only to convert ecliptic coordinates (celestial longitude and latitude) and equatorial coordinates (ascension and declination) and *vice versa*.

c) The universal astrolabe, with one half of the rete bearing a grid of universal markings, and a plate underneath bearing the same markings. Rotating the markings on the rete over the other set underneath could serve to solve any of the problems of spherical astronomy for any latitude, which are all problems of coordinate conversion.

The most useful of these three devices was the one least frequently

constructed. The clearest account of its use is in the treatise of Jamāl al-Dīn al-Māridīnī mentioned above, which deals with all of the operations that can be performed with a double *shakkāziyya* quadrant.

Spherical astrolabes

The spherical astrolabe consists of a globe with altitude and azimuth circles on the upper half and (optional) horary markings for a specific latitude on the lower half. Around this is fitted a spherical cut-out rete fitted with an ecliptic as base circumference and star-pointers. It could be made universal, that is, for all latitudes, with a latitude scale, in which case the seasonal hour markings could only be used when the scale is set to the latitude underlying those markings. It could be northern or southern, depending on whether the stars on the rete were north or south of the ecliptic. The instrument first appears in a treatise devoted to it by the 9th-century Baghdad astronomer Ḥabash al-Ḥāsib, the most innovative of the astronomers in the new capital. Several other early treatises survive, including one in the *Libros del saber de astrología*. Only two Islamic examples are known to survive, each with its own problems, and these have recently been investigated anew. One is unsigned from Tunis, probably 14th or 15th century, but unfortunately it lacks the rete. It comes from a milieu where there was an active tradition of mathematical astronomy. The other one, signed simply "Mūsà", is dated 1480/81 and has horary markings for latitude 41°. It comes from Istanbul, just at the time Sultan Bāyazīt II with his passionate interest in astronomy came to power. It has some problems of design – only one out of 19 stars represented is a bright star – and accuracy – even that star is misplaced by 30° along the ecliptic, but is a fine piece of craftsmanship. The maker of this remarkable instrument is the prolific, multilingual Jewish astronomer-medic Mūsà Jālīnūs or Moshe Galeano, an enigmatic figure whose historical importance has only recently been realized. (Other surviving astronomical instruments by Jewish makers, all astrolabes, are all unsigned.)

Linear astrolabes

The Persian astronomer Sharaf al-Dīn al-Ṭūsī *ca*. 1200 invented a highly ingenious and completely functional linear astrolabe for a specific latitude, with strings attached along a *baguette*. Some improvements were made by Kamāl al-Dīn al-Fārisī in the 13th

century. The instrument was also known to the Andalusī astronomer Ibn Arqam al-Numayrī (d. 1259). No examples survive. The historian Ibn Khallikān mentions the linear model, pointing out that neither Ptolemy not any earlier Muslim astronomers before al-Ṭūsī had realized that a sphere could be represented on a line. He concludes his discussion by mentioning the futility of trying to represent the sphere on a point. No original examples of the linear astrolabe survive. Every few years someone comes up out of the blue with their own description of the instrument and its *modus operandi*. The publications of Sajjad Nikfahm-Khubravan on the available texts are awaited with anticipation.

The boat astrolabe

Various exotic non-standard astrolabes, with ecliptics composed of partly northern and partly southern markings, were described by al-Sijzī (*ca*. 1000) and again by al-Bīrūnī (*ca*. 1025) and again by al-Marrākushī (*ca*. 1280), with new variations in Najm al-Dīn al-Miṣrī (*ca*. 1325). The relevant text of al-Marrākushī was translated in the 1840s by L.-A. Sédillot, which enabled the illustrations to appear in several 20th-century writings on the astrolabe without any explanation of what they represented. The 1922 German translation of the relevant part of al-Bīrūnī's treatise by Joseph Frank did not help. In the 1980s the astrolabe types unique Istanbul manuscript of al-Sijzī's treatise were surveyed by Richard Lorch, again in German. Najm al-Dīn's treatment was translated and commented upon by François Charette. One result of this difficult situation is that even historians of Islamic science have referred to these astrolabes as "degenerate" when they are merely exotic and rather impractical. One particular astrolabe variety has suffered more than any other, namely, the زورقي, *zawraqī* or "boat" astrolabe. It has even been confused with the 14th-century English instruments called the *navicula*, with which it has nothing in common aside from the name.

The rotatable horizon is fixed on the rete of the *zawraqī* astrolabe, indeed it is part of it. Its two halves can serve different latitudes. A mast rises from the middle of the bottom of the boat-shaped horizon and includes a ring to be attached at the centre. The ensemble rotates over a stereographical projection of the stars and the ecliptic. The motion is

precisely equivalent to the stars and ecliptic on a regular rete moving over a plate of astrolabic markings. Two sights can be fitted on the horizon so that it can function as an alidade. Obviously only horizon-related problems could be solved with this instrument. However, in several late Indo-Persian an adaptation of this is found. The relatively small horizon is fixed on the rete near the central ring. There is a small circle at the centre of the plate bearing a stereographic projection of the stars and the ecliptic, within the regular astrolabic markings for a specific latitude. In this case the horizon is too small to be fitted with sights. The correct interpretation of the *zawraqī* markings is to be found in S. R. Sarma's new catalogue of Indian instruments.

How to make an astrolabe

The astronomical markings on an astrolabe be constructed with a straight-edge and compass, with the components – mater, back and plates – laid out successively on a board. The individual circles can be constructed one after the other using a geometrical procedure. However, this was not the only way: they also used tables.

A very useful auxiliary trigonometric function was tabulated by al-Khwārizmī in early-9th century Baghdad. But it was his contemporary al-Farghānī who, using such a function, compiled tables of coordinates for constructing the circles on astrolabes and their plates: these showed the centre distance and radius of the altitude and azimuth circles, both for each degree of altitude and azimuth, and for each degree of latitude, a total of some 13,000 entries. (Muslim astronomers also constructed tables of radial coordinates to facilitate the construction of hyperbolae on sundials. Neither kind of astrolabe nor sundial tables are known from medieval Europe.)

How to use an astrolabe

This not the place to go into any detail on such a topic, not least since there are plenty of works where the reader can find this information. If one has used the alidade and altitude scale on the back to measure the altitude of the sun or a given star, it suffices to put the solar marker or the star-pointer on the rete on top of the appropriate altitude circle on the appropriate plate: the astrolabe then displays the instantaneous configuration of sky above the observer. Do this twice and the amount by which the rete has been rotated will be a measure of the time elapsed

between the two observations. The potential of this device should be obvious. Around the year 1000 the Shiraz astronomer ʿAbd al-Raḥmān al-Ṣūfī, more famous for his work on constellations and star-positions, wrote two major treatises of 250-odd and 300-odd folios containing, respectively, 402 and 1760 chapters on the use of the astrolabe.

Were astrolabes actually used?

Already Derek Price in the 1970s suggested that astrolabes might have been used far less than one might expect. Having inspected several hundred I can attest that very, very few show signs of extensive use. This means that they were the thing to have, the thing to present, the thing to know how to use, the thing to use occasionally. They surely served a significant role in teaching the basics of astronomy. However, I very much doubt that medieval Islamic or European astrolabes with markings for prayer-times on the plates or simply the 3rd, 6th and 9th hours of daylight, were used to regulate the prayer-times on a regular basis. I am not aware of any Latin text describing how to regulate the prayers of medieval monasticism.

Astrolabes were surely not often used to actually determine the qibla for any locality, but sometimes to indicate the qibla for a number of specified localities. Some rare ones have a *miḥrāb* or prayer-niche on the back indicating the qibla for a specific locality. Safavid ones often have graphs displaying the solar altitude in the qibla at various localities throughout the year.

And who needed to constantly know the time of day? It is the sundial that will serve that purpose, as well as showing the times of the daylight prayers. And for greater accuracy, at least in certain major centres, and if only in the Muslim world, extensive tables were available showing, for the local latitude, the time of day for any solar altitude at any time of the year. To use these tables, of course one needed something like an astrolabe to measure the solar altitude. And of course a clock would obviate the need for any and all of these tools.

The geography of astrolabe-making and the leading astrolabists

The leading places of astrolabe production, marked * if they are hypothetical, and printed bold if there was also serious activity in astronomy, are as follows:

C4-C6	Alexandria*	
C6–C11	Constantinople*	
C7–C8	Harran	
C8–C13	**Baghdad**, then also **Isfahan**	
C11	**Córdoba, Toledo**	Catalonia
C13	**Granada, Seville, Marrakesh**	
C14	**Granada, Aleppo, Damascus**	**London & Oxford**
C15		**Paris**, then **Vienna**
C16-C17	Isfahan	Madrid, Flanders
C17	Lahore	
C19	Jaipur	

This list is based on subjective judgement, is questionable and very debatable, and will surely be subject to revision.

The following list may be of interest, not least since many of the names may be unfamiliar to Europeans and certainly to Muslim readers. The list of Muslim astrolabists from the 8th, 9th, and early 10th centuries is well known, although only the one woman in the list is ever cited in the modern literature. These are the leading makers of astrolabes and related instruments over the centuries, whereby we should keep in mind that most medieval European astrolabes are undated. All dates are approximate.

850	**Baghdad**	Ḥabash al-Ḥāsib (only treatises survive)
900	**Baghdad**	Nasṭūlus
950	**Baghdad**	Ḥāmid al-Wāsitī
1000	**Isfahan**	Aḥmad & Muḥammad sons of Ibrāhīm
1100	**Baghdad**	Hibat Allāh al-Baghdādī
1200	**Seville**	al-Khamā'irī
1200	**Marrakesh**	Abū Bakr ibn Yūsuf
1225	Isfahan	Muḥammad ibn Abī Bakr al-Fārisī
1225	**Damascus**	ʿAbd al-Karīm al-Miṣrī / al-Baʿlabakkī
1325	**Aleppo**	Ibn al-Sarrāj
1300	**Granada**	Ibn Bāṣo

1325			**London**	"Sloane A"
1350	**Damascus**	Ibn al-Shāṭir		
1400			**Paris**	Jean Fusoris
1425	**Samarqand**	Jalāl al-Kirmānī		
1450			**Vienna**	Regiomontanus
				Hans Dorn
C16/17	Isfahan	M. ibn Muqīm Yazdī *et al*.		
C17	Lahore	Allāh-dād and descendants		

The most significant early treatises on the construction and/or use of the astrolabe are:

C6-13	Constantinople	Various texts in Greek (Anne Tihon & others)
825	**Baghdad**	al-Khwārizmī (François Charette & Petra Schmidl)
850	**Baghdad**	al-Farghānī (publ. w/ English transl. by Richard Lorch)
1000	**Shiraz**	al-Ṣūfī (no translation published)
1000	Madrid ?	al-Majrītī / Pseudo-Māshā'allāh (no transl. published)
1025	**Ghazna**	al-Bīrūnī (no translation published)
1280	**Cairo**	al-Marrākushī (partial French translation J. Sédillot)
1325	**Cairo**	Najm al-Dīn al-Miṣrī (translated, François Charette)
1360	Paris	Pèlerin de Prusse (Robert Fisher & Edgar Laird)
1390	**England**	Geoffrey Chaucer (various edns./transls. in mod. Engl.)
1400	**Paris**	Jean Fusoris (Emmanuel Poulle)
1530	Nuremberg	Georg Hartmann (John Lamprey)

Reception and transmission

There are so many studies of the reception of the astrolabe in this culture or that, and so many on the transmission of the astrolabe from one culture to another, too many, one might argue. Virtually all of them are based on Greek or Arabic or Latin texts on the construction or use of the astrolabe, and virtually none of them are based on actual astrolabes or groups thereof. Thus, for example, people have written on the astrolabe in Byzantium, ignoring the only surviving Byzantine astrolabe because they wrongly think it is not Byzantine. People write about the Muslim reception of the astrolabe without looking at any of

the many surviving early Islamic astrolabes. People write about the European reception of the astrolabe without looking at any numerous Andalusī astrolabes or early European instruments. Only texts are sacred, some would claim. And Latin texts are so sacred that nobody who edits a medieval Latin text on the astrolabe feels the need to translate them into a modern language. And astrolabes and astrolabe texts are not so closely related as some people think, so in order to understand the reception or transmission of the astrolabe one does actually look at a few astrolabes as well as a few texts:

- The stars we find on medieval European retes as often as not do not correspond to the stars listed in Latin star-tables taken from Arabic sources.
- We question certain medieval latitudes without realizing that they are nothing other than *calculated* latitudes of the climates (for various values of the obliquity of the ecliptic).
- Many researchers do not recognize the climates and their latitudes if these are disguised, without the word 'climates'.
- Folk find a table in an instrument treatise and have no inkling that such tables have a history of half a millennium.
- Nobody asks the questions like why do the earliest Spanish astrolabes bear so little resemblance to Andalusī astrolabes?
- What did French astrolabes look like before Fusoris?
- Are there any early Italian astrolabes?
- Where did the magnificent Sloane astrolabe come from, being far more technically and artistically advanced than later medieval English astrolabes?
- Is there anything original on any medieval European astrolabe (to *ca*. 1500) that is not attested on an early Islamic piece, except, of course, some decorative items and Easter scales and saint's days (only English)?

For all these reasons I shall not dwell on reception and transmission. Taro Mimura has recently published a paper entitled "Too many Arabic treatises on ... the astrolabe ... ". It is satisfying that now at last we have an overview of the instruments in the 13th-century *Libros del saber de astrología*. Meanwhile, during 2017-18 I gave lectures in Granada,

London and Frankfurt on Renaissance instruments with Islamic precedents which nobody knows about,[3] so I do not think the topic is without interest, and it is certainly not closed.

Research on medieval "Islamic" and "Christian" astrolabes

Already in the 19th century various orientalists prepared detailed and accurate descriptions of some particularly important Islamic astrolabes. These included the Frenchman Frédéric Sarrus, two Germans Bernhard Dorn and Franz Woepcke, one Spaniard Eduardo Saavedra, and the Englishman William Morley.[4] Morley published in 1856 the magnificent Sloane Persian astrolabe in the British Museum. Very few medieval European astrolabes were published, mainly by antiquarians, for example, C. H. Read, Secretary of the Society of Antiquaries, London. In 1893 he published a fine description of a medieval "Spanish" (actually Catalan) astrolabe that had shortly before been presented to the Society.

A major boost to the subject of Islamic instrumentation was achieved by the Sédillots, father-and-son, in Paris in the early 19th century. They had access to the splendid manuscripts of an enormous compendium on instrumentation compiled in Cairo *ca*. 1280 by the Maghribī astronomer Abū ʿAlī al-Marrākushī. The father Jean-Jacques translated most of the treatise dealing with spherical astronomy and sundials, and the son Louis-Amélie summarized the remainder of the text dealing with astrolabes, quadrants and other instruments. Nothing like this was published thereafter until François Charette in 2003 published, with an English translation and well-informed commentary, the 14th-century instrument compendium of the Cairene astronomer Najm al-Dīn al-Miṣrī, describing and illustrating over 100 different types of instruments.

During the period 1923-45 Robert Gunther published his monumental 14-volume work *Early Science at Oxford*, of which one volume contains masterly accounts of the medieval instruments preserved in Oxford. In 1932 Gunther published his monumental overview of some 300 astrolabes, Islamic and European, mainly from the Oxford collection, but drawing on information from other collections, not only the British Museum. Alas his knowledge of Arabic was not up to the task to deal adequately with the Islamic pieces, and he was not well

served by the Oxford Arabists from whom he sought help. As a preface he wisely included a facsimile of Morley's account of the Sloane Persian astrolabe. If his descriptions of Islamic instruments were sometimes problematic, it was not least because, in the spirit of the time (which lasted till the demise of the Shah and still continues), he put "Persian, Indian, Hindu" astrolabes before "Arab" instruments, thereby distorting completely the development of the astrolabe in the Islamic (and Indian) worlds. But his treatment of European astrolabes was also sometimes fraught with deficiencies. His section on medieval "Spanish astrolabes" consisted of the London SA piece and an Oxford piece, which was clearly Northern French. His section on English astrolabes was inevitably better than the others, and his description of the magnificent English Sloane astrolabe shows him at his best. For decades the field has relied on Gunther and auction catalogues and exhibition catalogues. Gunther has been indispensable over the decades because he actually completed the task in hand.

A monumental survey of the history of astronomy and instrumentation in the German-speaking world was published by Ernst Zinner in 1967. Elsewhere, histories of astronomical instrumentation have tended to focus on principal figures: Chaucer of 14th-century England (John North and numerous others), Jean Fusoris of late-14th-century Paris (Emmanuel Poulle, but no-one since), Regiomontanus of 15th-century Vienna and elsewhere (again Ernst Zinner), and inevitably Copernicus, who surely had an astrolabe but it is not one of those now preserved in Cracow. The 1947 article by Baxter D. Wilson on the astrolabe and English life in the Middle Ages is still worth reading, not least because it contains no hype.

Catalogues of major collections

A handlist of all astrolabes was prepared by Derek de Solla Price in 1972 but published only privately. In the following survey of catalogues of astrolabe collections, authors dealing with Islamic and Latin objects are separated thus //. Reliable catalogues are now available for the collections in the following locations:

Washington NMAH (George Saliba // Sharon Gibbs), Rockford, Ill. TM (Anthony Turner), Greenwich NMM (François Charette // Koenraad van Cleempoel), Madrid MAN and other Spanish collections

(Salvador García Franco, and now Azucena Hernández – see below), Nuremberg GNM (King), London NG (Francis Maddison), Munich DM (Burkhard Stautz), Paris IMA (Jeanne Mouliérac), and Chicago AP (David Pingree // Roderick & Madge Websters), as well as for very small collections in Bernkastel-Cues (J. Hartmann), Frankfurt (Silke Ackermann & Petra Schmidl // Reinhard Glasemann), Kassel (Petra Schmidl), Leiden (Robert van Gent), Utrecht (van Cittert), Naples MC (Ornella Marra), Strasbourg OBS (Francis Debeauvais & Paul-André Befort).

Astrolabes in Oxford MHS and Florence MG are inventoried online.

Each of these catalogues represents a mammoth achievement on the part of the authors and a substantial contribution to our knowledge.

Selected studies

In the course of the past few decades the following topics have been addressed:

- the star-names of astrolabe-stars and related star-tables in medieval Arabic and Latin manuscripts (Paul Kunitzsch), sometimes tested on actual instruments (Elly Dekker, King, Burkhard Stautz);
- star-position on retes (Dekker, Stautz);
- the design of retes, quatrefoil decoration (King, taken up again by John Davis), zoomorphic star-pointers (Owen Gingerich, Sreeramula Sarma);
- the tables of coordinates used by Muslim astronomers for marking circles on astrolabe plates (King);
- the latitudes of the climates and the latitudes of localities used on plates (King);
- tables of longitudes, latitudes and qibla-directions on Persian (King) and Indian (Sarma) astrolabes;
- the universal horary quadrant and underlying formula for timekeeping (King), and latitude-specific horary quadrants (Mercè Viladrich);
- universal astrolabes and universal plates (*ṣafā'iḥ*) in the Andalusī tradition of Ibn al-Zarqālluh (Roser Puig) and Ibn Bāṣo (Emilia Calvo);
- astrological tables (Willy Hartner, Silke Ackermann);

- calendrical tables (Ackermann);
- problematic inscriptions (Rachel Ward, Mohammed Abu Zayed & King & Petra Schmidl)
- metallurgical investigations of individual instruments (Robert Gordon, Brian Newbury, Gerard Turner, John Davis);
- textual transmission from Byzantium to Islamic world (Paul Kunitzsch, Anne Tihon);
- instrumental transmission from Byzantium to Islamic world (Burkhard Stautz)
- the precarious attempts at dating astrolabes by means of the First Point of Aries on calendrical scales (Henri Michel, Emmanuel Poulle, Gerard Turner, Giorgio Strano)
- textual transmission from al-Andalus to Europe (Kunitzsch, Julio Samsó & colleagues, Emmanuel Poulle, Guy Beaujouan, & many others)
- instrumental transmission from al-Andalus to Christian Spain (Azucena Hernández)
- instrumental transmission from al-Andalus to the Islamic East (François Charette)

Bio-bibliographical studies of astrolabe-makers and their works

Most Islamic astrolabes are signed and many are also dated. A monumental contribution to the study of Islamic astrolabes, at least to *ca*. 1500, was made by the prolific Israeli orientalist Leo Aryeh Mayer in his *Islamic astrolabists and their works*, published in 1956. For each maker, Mayer listed all of the known instruments made by him with a full bibliography. His work is a model publication, but it inevitably became more out-of-date with each the appearance of each new catalogue. A revision of this valuable research tool, also arranged alphabetically by maker, was made in the 1980s by the Paris antiquarian Alain Brieux together with Francis Maddison, then curator of the Museum for History of Science at Oxford. There is apparently some hope that their long-anticipated *Répertoire des astrolabistes et leurs oeuvres* will appear in print in 2018. This should be well illustrated and is certain to arouse some interest in Islamic astrolabes. A similar undertaking for medieval European astrolabes would have

been inconceivable since most are neither signed nor dated.

The Frankfurt medieval astronomical instrument project

A project in Frankfurt organised by the present author during the 1990s made considerable progress in the documentation of medieval Islamic and European astrolabes, quadrants and sundials to *ca*. 1500. (Late Islamic, Indian, and Renaissance European instruments were deliberately omitted.) The project was generously funded during 1992-96 and 1998-2001 by the German Research Foundation (Deutsche Forschungsgemeinschaft). Hundreds of astrolabes were catalogued and their descriptions inserted into a master-text. The text of the catalogue in its entirety has now been put on put online in two parts (for the present it is available at davidaking.academia.edu.), even though many parts were unfinished. Much of the text is still raw, having been prepared in the 90s with software for diagrams and graphics and diacriticals that is now longer compatible with anything. Numerous descriptions await proper photos. The project ceased to function when funding ran out, the participants – Silke Ackermann, Kurt Maier, Burkhard Stautz, François Charette, and Koenraad van Cleempoel – being scattered, and our institute was eventually closed. The two parts of the table of contents of the catalogue have long been available separately; they were inevitably easier to generate than the catalogue itself. Also several sections of the catalogue have been published elsewhere, notably those dealing with the Byzantine astrolabe of 1062, all Eastern Islamic astrolabes before 1100, instruments from medieval Syria and Yemen, astrolabes from medieval Catalonia, and astrolabes of the Regiomontanus-type.

The major collections investigated – **only for medieval instruments, including astrolabes and quadrants, Islamic and European** – were New Delhi, Cairo, Kuwait, Istanbul, Rome, Florence, Milan, Paris, Strasbourg, Madrid, Barcelona, Brussels, Nuremberg, Frankfurt, Munich, Berlin, Cracow, London, Oxford, Cambridge, New York, Washington, Rockford IL and Boston, as well as particularly important minor collections such as Athens, Brescia, Genoa, Turin, Pavia, Venice, Toulouse, Copenhagen, Cologne, Schweinfurt, Edinburgh, Dublin, Innsbruck, Salzburg, Vienna, Graz, Prague, Leiden, Cambridge MA, Damascus, Aleppo, and also Hyderabad, as well as the

major private collections, those being in Belgium, Italy and the US. Not visited personally were Tehran, Baghdad, Rabat, Fez, Stockholm, Kassel, Salem MA.

Major problems, often insurmountable, were obtaining decent photos and then storing them efficiently. Museum hours were generally constricting and often there were just too many astrolabes and too little time.[5]

In the course of the Frankfurt project, apart from the budding catalogue, certain astrolabes of singular importance, now known as "the landmark astrolabes", various collections of astrolabes, and groups of related astrolabes, as well as quadrants and sundials, were studied in detail. What has been published besides the catalogue are the following:

- a new description the sole surviving Byzantine astrolabe from 1062, with new insights into its arrival in Italy and its relationship to the 1462 astrolabe of Regiomontanus;
- all Eastern Islamic astrolabes up to *ca*. 1100;
- the descriptions of all Western Islamic astrolabes up to *ca*. 1200 have been superseded by the new descriptions of Azucena Hernández – see below;
- many important later Islamic astrolabes, including those of the Yemeni ruler al-Ashraf, the Nuremberg circus-figures astrolabe, various pieces made for Ayyubid and Ottoman sultans, and another for the Sultan Ulugh Beg;
- a group of spectacular astrolabes, quadrants and sundials from medieval Syria (prepared for the 1993 Paris IMA exhibition on Syria);
- the earliest European astrolabe, from 10th-century Catalonia, and all later medieval astrolabes from Catalonia;
- the sole surviving astrolabe with inscriptions in Judaeo-Arabic, that is, Arabic in Hebrew script, related to an earlier Catalan astrolabe with inscriptions in Latin with Catalan influences;
- many individual astrolabes from Spain, Italy, France, England;
- survey of all astrolabe retes, Islamic and European, with quatrefoil decoration;
- the 14th-century Toledo astrolabe, with inscriptions in Hebrew, Latin

and Arabic;

- the earliest known German astrolabe, from Einbeck and datable *ca*. 1330;
- all of the earliest Vienna astrolabes, focusing on the 1462 Regiomontanus piece (with Gerard Turner).

In addition the retes of dozens of astrolabes, Islamic and European, were analyzed using computer graphics and the results compared with available star-lists (Stautz).

Some particularly spectacular instruments have still not been researched adequately, or their descriptions are not yet publishable. For example:

- the astrolabe with astronomical tables on the plates (زيج الصفائح , *zīj al-ṣafā'iḥ*) and moving parts for an equatorium, invented by Abū Ja'far al-Khāzin, this example made in 1120 by the renowned Hibat Allāh al-Asṭurlābī, lost after World War II, first studied in the 1970s from incomplete photos (King), resurfaced in Berlin MIK, together with the unique copy of the associated text, preserved in Srinagar, and recently investigated anew (Emilia Calvo);
- the quintuply-universal astrolabe of Ibn al-Sarrāj of Aleppo, dated 1328/29, by far the most sophisticated astrolabe ever made, preserved in Athens BM, together with the available texts on its inevitably very complicated use, book-length publication in preparation since 1975 (François Charette & King);
- the 14th-century N. French astrolabe with solar-lunar gear mechanism which came to light since 2000 and which is far more sophisticated than the one in London SM known already to Gunther (Koenraad van Cleempoel);
- the albion associated with Regiomontanus, datable Vienna 1450-60, preserved in Rome AA, briefly studied (Emmanuel Poulle) and now enjoying detailed investigation at the hands of Giancarlo Truffa; and
- the 15th-century N. European universal plate auctioned at Bonhams of London in 2014.

Catalogue of Indian instruments

More recently, all Indian and Indo-Persian astronomical instruments have been catalogued on-line, a monumental feat still in progress, by

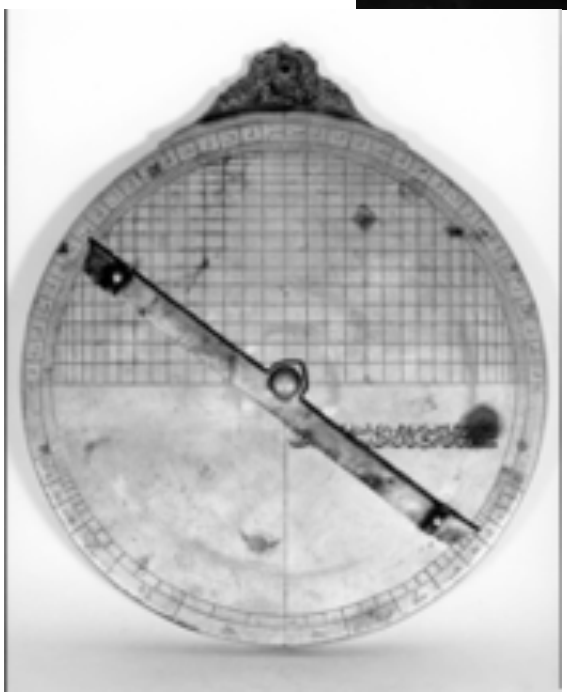
Sreeramula R. Sarma. This is a model production, complete with a historical introduction and overview and close to 4,000 pages of text. Some 300 astrolabes are included, all described in detail. Prof. Sarma achieved this single-handed, with his son Ananda organizing the website, and he writes in his introduction, "had I known the enormity of the project, I would probably not have ventured in the first place". Fortunately he achieved this very valuable contribution whilst continuing to produce his other publications on instruments. In addition he has included in his catalogue large extracts with translation from Mahendra Sūri's *Yantrarāja* of 1370*,* which is the first Sanskrit manual on the astrolabes.

How to illustrate an astrolabe

In the old days, all but a few museums would photograph astrolabes as pieces of metal-work so as to convey the overall impression of the instrument. Inscriptions and components were of no consequence so it did not matter that they could not be seen. And the alidade invariably had to be attached on the front of the astrolabe lest it be overlooked. To give credit, even then Oxford and Florence could make decent photos of any object.

Nowadays things should be different. The full front and back should be shown, with the astrolabe at the side of the back. Ideally the empty mater and each side of each plate should be photographed. Also the main inscription on the back if there is one. Again images should be detailed enough so that all star-names on the rete and all inscriptions on the plates can be clearly seen. Images of a single plate are better than no images of plates. Such images can serve to identify schools or individual makers and/or locations, where these are in doubt. The alidade and rule should be removed from the astrolabe and placed by the side of it. Not least this prevents either from obscuring important inscriptions.

These three images of 13th- and 14th century astrolabes show what one should not do to such important historical objects. Put the rete on the back! Put the alidade on the front! Obscure an important inscription with an alidade! Oy weh!



These brilliant photos show: a monumental 13th-century Syrian astrolabe preserved in the Maritime Museum in Istanbul with the rete on the back; an astrolabe made by a late-13th-century Yemeni Sultan that is preserved in the Metropolitan Museum of Art in New York with the alidade on the front; and an astrolabe preserved in the Observatoire de Paris made by the leading astronomer of 14th-century Damascus, then the most significant astronomical centre in the world, with part of his name covered by the alidade.

The major medieval treatises on instruments

The importance of various treatises dealing with different kinds of instruments cannot be overestimated. They bear repetition here for they tell us far more than the average treatise on the astrolabe. We begin nevertheless with the splendid treatise on the astrolabe, not yet available in any Western language, by the greatest scientist of medieval Islam, al-Bīrūnī (Ghazna, *ca*. 1025). The sections on different kinds of astrolabe retes, mainly modifications of the standard rete exploiting the symmetry of the ecliptic ring, are well documented in German and French.

Then there is the *summa* of the Maghribī astronomer Abū ʿAlī al-Marrākushī, compiled in Cairo *ca*. 1280. Half of this was translated into French by J.-J. Sédillot in 1834-35, the other half was summarized by his son L.-A. Sédillot in 1844. A remarkable treatise by the rather enigmatic Najm al-Dīn al-Miṣrī, compiled in Cairo *ca*. 1325, describes and illustrates over 100 instrument types either known to him or devised by him. This has been published in a model fashion – text edition, translation and commentary – by François Charette in 2003.

The *Libros del saber de astrología*, compiled in Toledo for King Alfonso el sabio, "the Wise" during 1276-1279, contains detailed discussions with illustrations of various instruments, including the sphere, the spherical astrolabe, the plane astrolabe, the universal astrolabe, the universal plate, the armillary sphere, the quadrant, and mechanical clocks. The Castilian text has yet to find an editor, let alone a translator.

The substantial book containing numerous illustrations of European astronomical instruments by Georg Hartmann of Nuremberg is not yet published, as far as I am aware, but the similar treatise of Nicolas Bion of Lyon published in 1712 is available in a new facsimile edition (2018).

Astrolabes with more than one layer of inscriptions

It has long been apparent that instruments with more than a single set of inscriptions have the potential to be more historically significant than those that have never been reworked. Take the Destombes astrolabe with one set of Latin inscriptions from the 10th century and a second set from the 14th (?) displaying Catalan influence. Take the

‘Berselius astrolabe’ with an original set of markings from 14th-century monastic Picardy and an additional set from 16th-century Humanist Liège and Louvain. Take the monumental astrolabe from the mid 17th-century for the Moghul Emperor Shāh Jahān with additional Sanskrit markings.

Consider the following additional example that has been published by Kurt Maier, Arabist and Romanist: A remarkable Islamic astrolabe in the Jagiellonian University Museum in Cracow is dated Córdoba, 1054/55. Unlike most Andalusī astrolabes, it is unsigned. On the five plates and mater there are 11 sets of astrolabic markings for latitudes between Hadramawt (beginning of the 1st climate) and Saragossa. Additional markings in Latin with Catalan variants render the Arabic star-names and the names on signs and months, and three plates have inscriptions CARDEYA, TORTOSA and PPYA, for Cartagena, Tortosa and Perpinyà / Perpignan. The Latin forms of signs, such as ARIAS and ACARI show Catalan influence and are attested in the astronomical treatise of the Majorcan Ramon Llull of 1297. However, the additional markings, which have a very medieval look bout them, are punched, and there is even a single punch for the ligature AL, which is used to render some of the Arabic star-names. Maier thought perhaps 15th century? But there is more. How did this Arabic-Catalan astrolabe come to Cracow? There is, in fact, a historical connection between Catalonia and Cracow, but alas I’ve forgotten what it was.

Astrolabes with replacement parts

An Ottoman astrolabe from *ca*. 1700 now in the Museum of Islamic Art in Doha looks like an Ottoman astrolabe. But when one takes it apart, one finds all of the plates are much earlier, about 600 years earlier, from an 11th-century Andalusī astrolabe. The plates serve range of latitudes from 23° (Mecca) to 45° (Constantinople), with altitude circles for each 9°. An additional set of astrological markings serves latitude 35°, and the corresponding regular plate for that latitude is marked Ceuta, Tangiers, Sicily, Mosul, Manbij and Qum. Under the Ḥammūdids in the first part of thee 11th century Ceuta and Tangiers were united with Algeciras and Málaga in a single principality, which may point to the place of manufacture. However, the biggest surprise of all was an astrolabic plate for latitude 16°30’ south, corresponding

to Anti-Meroë, corresponding to the middle of the first climate in the southern hemisphere and the lowest limit of the inhabited world in the three cartographic grids associated with Ptolemy of Alexandria. The existence of one replacement Ottoman plate indicates that one Andalusī plate has been replaced: perhaps this had markings for 0°/90° and 66°/72°, which would have made this a truly universal set of plates, unparalleled amongst known astrolabes.

Already Gunther noted an unusual rete on an early European astrolabe in Oxford (#191), and to his credit he wrote that it was "an interesting instrument on account of the alterations or additions to the original design". His predecessor Lewis Evans, who purchased the piece in Paris, had already recognized an Islamic connection. (Many investigators have spurned such instruments, as have private collectors.) The rete has an Islamic look about it, not least because there are two *miḥrāb*s in the lower half. The plates are a mess, with some bearing altitude circles for each 5°, others for each 9°, and others for each 12°. Recently Petra Schmidl turned her attention to this piece not least because a few years before she had catalogued an astrolabe by a highly competent astrolabist Ibrāhīm al-Sahlī of Valencia in 1086, now preserved in Kassel, which has an identical rete to that of the Oxford piece. (The truth is that cataloguing instruments brings rewards; Derek Price started his passion for instruments by cataloguing the important collection in the British Museum, and his passion increased when somebody else published his catalogue.) The Oxford rete has been reworked with Latin inscriptions and fitted in a French (?) mater. One of the plates is labelled for Saragossa, two others for Paris. Schmidl diligently traces an itinerary Valencia — Saragossa — Paris — Oxford for this remarkable astrolabe, and her article is appropriately entitled "Knowledge in motion".

Regional studies

The expression "material culture" covers things like pottery, glassware and metalwork, but inspires little confidence. In German there is the word "Realienkunde" which means the same thing but sounds much more convincing. In Krems on the Danube there is an Institute for Realienkunde of the Middle Ages and Early Modern Period. In 1993 they organized a conference attended by Byzantinists, Islamicists and

Medievalists. Following a lecture of mine on medieval instruments from Byzantium, the Islamic world and medieval Europe, a saucy young colleague commented "Sehr schön, und ... ?", meaning "Very nice, but so what?". Most people don't know that Vienna was the most active centre of astronomy in the world in the 15th century; I didn't think I needed to stress that in Austria. I had been to Austria on several research trips, so, in the conference proceedings published by the Austrian Academy of Sciences, I appended to my paper two critical lists which I thought might answer my colleague's question: the first a list of all medieval instruments in or stolen from Austrian collections, and the second of all instruments from 15th-century Vienna in museums around the world. After the lists had been in available for some 25 years, John Davis was the first person to use them and to find to his surprise a 14th-century English astrolabe preserved in Innsbruck. No such lists exist for any other country in Europe.

A major contribution to the field is the brilliant and extremely useful 2017 Madrid doctoral dissertation including a detailed catalogue of all Islamic and Christian astrolabes from al-Andalus/Spain to *ca*. 1500, including close to 50 pieces (Azucena Hernández Pérez). This deals with artistic aspects of the instruments as well as the technical aspects and raises all manner of questions for future research. Q1: why does the earliest Latin astrolabe, from 10th-Catalonia, bear no resemblance to any early or later Islamic pieces? Q2: why do none of the other medieval Spanish astrolabes bear much resemblance to earlier Andalusī astrolabes? This splendid work was published in Madrid in 2018.

Some other recent contributions

Very few astrolabes bear signs of extensive use, many bear no signs of use whatsoever. So they often served as gifts and collectors' items. François Charette has considered the main locales where Islamic instruments were ordered, made, sold, used, explained, modified, rejected, or admired, in an attempt to provide a sense of the manifold dimensions of the material culture of science in Islamic societies. His contribution focuses on 9th- and 10th-century Baghdad and beyond (Iraq and Iran) and 14th- and 15th-century Cairo and Damascus.

In recent years, for the first time since Gunther, serious attention has

been paid to various early English astrolabes, not only to technical details but also to artistic considerations and cultural context (John Davis). In particular, new studies have been published of:

- the monumental Sloane astrolabe in London BM, made in London ca. 1325, with extensive quatrefoil decoration;
- various medieval English astrolabes with Y-shaped or quatrefoil retes.

An important doctoral dissertation completed in 2016 (by Seb Falk) discussed aspects of a sub-group of medieval English astrolabes, some 10 in number, which I had previously treated together, separating them from others with quatrefoil decoration. These have now been considered in light of the Chaucer manuscript tradition. Some of them, with the traditional Y-shaped frame on the rete can be related to an earlier Catalonian tradition of rete design – how this came about it not yet clear.

A catalogue of the few (10?) surviving astrolabes with Hebrew inscriptions has been promised for several years by Josefina Rodríguez Arribas, and numerous useful contributions are found in a volume of proceedings of a 2014 London conference, "Astrolabes in medieval cultures".

Catalogues or surveys of medieval French, English, Italian and German astrolabes have yet to be prepared. The first two groups are clearly defined and each survey would be a substantial project. Medieval Italian astrolabes are not clearly defined and a fewer in number. Surviving medieval German astrolabes (before the Vienna school of the mid 15th century) can be counted on one hand.

Again, astrolabes were not the only instruments in medieval times. Catalogues and surveys and numerous studies are available of medieval celestial globes, Islamic (Emilie Savage-Smith) and European (Elly Dekker). Numerous individual medieval Islamic sundials have been published (Louis Janin, King), and very few non-trivial medieval European sundials are known to have survived.

From geared astrolabes to astronomical clocks

A unique example of an astrolabe fitted with a geared mechanism for reproducing the relative motions of the sun and moon survives from

13th-century Isfahan, made by the highly-competent and innovative Muḥammad ibn Abī Bakr al-Rashīdī al-Ibrī. We also possess an account of a similar mechanism by the early-11th-century scholar al-Bīrūnī, and various earlier treatises survive but have not been studied yet. The precise relationship of this kind of mechanism to earlier Greek and Byzantine devices, as well as to later European ones remains to be established. Some Italian texts of the early 14th century, if not earlier, provide evidence of the design of astronomical clocks of a highly complex variety with extensive gear mechanisms to reproduce solar, lunar and planetary motions. They seem to represent an Islamic tradition for which we have no evidence from the Islamic world itself. It is known, however, that in 1232 ambassadors of the Ayyubid Sultan al-Ashraf presented to the Emperor Frederick II, whilst in Southern Italy, a kind of planetarium which had "within itself the course of the planets". A large device for timekeeping resembling an astrolabe was seen by a 14th-century historian in the home of the contemporary Damascene astronomer Ibn al-Shāṭir, and the face of a water-driven astrolabic clock originally made in Fez in the late 13th century survives (in a later replacement) to this day. These two instruments and a text in the *Libros del saber* are testimonials to an Islamic tradition on which we have virtually no other information. An inscription preserved in Palermo mentions a مجانة مع اسطرلابه , *majāna ma'a asṭurlābih*, "a waterclock with its astrolabe", apparently made for a Merinid Sultan in 1363. [This paragraph taken from *In Synchrony with the Heavens*, II, pp. 66-68.]

On the history of the astronomical clock in Europe there is abundant literature.

Associating astrolabes with their original provenance

Recently, various studies have appeared attributing individual astrolabes to patrons or owners. For example, there is a splendid 15th-century astrolabe preserved in Copenhagen, on which the name on the dedication to a prince has been deliberately effaced. There are silver-inlaid azimuth curves for the *qibla*s of Samarqand and Herat marked on two plates. I have argued that this piece was dedicated to the later Sultan Ulugh Beg, who as a prince oscillated between those two cities. His astrolabe was made by a well-known Iranian astrolabist who, it

turns out, was later the instrument-maker at the Observatory in Samarqand.

In the past few years there has been a welcome revival of interest in English astrolabes. John Davis has painstakingly investigated various medieval English astrolabes seeking clues to their origins not only from such unmistakable features as latitudes and localities on the plates from such cryptic features as the saint's names on the calendrical scales, which indeed turn out to have regional flavours. In particular, he has uncovered some of the background of the magnificent Sloane astrolabe from the British Museum, more sophisticated than any of the Chaucer instruments, concluding that it was associated with King Edward III *ca*. 1326. His investigation still does not explain how the most sophisticated medieval English astrolabe could have preceded other more mundane pieces from the same milieu.

Relating specific instruments to the associated manuscript tradition presents challenges of its own, not least since most medieval European astrolabes are unsigned (and undated). Catherine Eagleton has considered some of the available astrolabes in English collections which are in the "Chaucer" tradition, comparing details on them with the illustrated manuscripts in the Chaucer tradition. "Chaucer's own astrolabe" is somewhat exaggerated for her title, and already in the 'abstract' it becomes" not so much 'Chaucer's own astrolabe' as 'an astrolabe just like the one belonging to Geoffrey Chaucer'".

Some astrolabes declared fake that are not fake

An astrolabe in the Metropolitan Museum of Art in New York purports to be signed by the Yemeni Sultan al-Ashraf in 1295. In the 1950s it was declared a fake by a leading historian of science in the US who said "there was no astronomy in the Yemen". In fact there was, and the present author's first book was entitled *Mathematical Astronomy in the Yemen* (1983) and was based on some one hundred Yemeni astronomical manuscripts. Appended to a substantial treatise on the construction of astrolabes, extant in Cairo, there is a statement by two of his teachers affirming the excellence of six astrolabes that he made. One of these is clearly the MMA piece. I published the astrolabe in 1985 together with the relevant textual materials, and of course sent a copy to the MMA. At least they removed the question mark from their

statement of provenance: “Yemen (?)”. The Museum itself still does not have an appropriate webpage for this jewel and does not mention that it has been published down to the last detail. However, a well-informed description with substantial bibliography has been prepared by Diana Rosenthal Roberson for ‘timeinart’ and this can be accessed by Google if not from the Met site.[6]

The French naval officer Marcel Destombes had a passion for historical instruments and a real ‘feel’ for them, acquired by actually inspecting the instruments themselves and studying writings about them. In the early 1950s near the Spanish border he purchased a medieval astrolabe which immediately sparked his interest. He thought it was the earliest surviving astrolabe with Latin inscriptions, and he published it in 1962 as such, claiming it came from 10th-century Catalonia. His article raised a furore amongst certain academicians and medievalists in Paris with no experience with actual instruments and quite innocent of their ‘language’, who set out to demolish both him and his astrolabe. Destombes died in 1983, bequeathing all of his instruments to the Institut du Monde Arabe in Paris rather than any French museum. In 1993 a special session of the International Congress on the History of Science met in Saragossa, and various scholars were able to pronounce on it: one had found the original inscriptions were of a genre found only in 10th-century Catalonia (Ascari Mundò); another found that the secondary inscriptions from the 14th century involved Catalan influence on the Latin (Maier); another showed that FRANCIA, the name found on one of the plates for latitude 41°30′, corresponded to the Arabic بلاد الافرنج , *bilād al-Ifranj*, meaning “Land of the Franks”, that part of the peninsular not under Muslim rule at the time (Julio Samsó), and another showed that the piece bore no resemblance to any early Eastern or Western Islamic astrolabes or to any early European piece (King). In brief, Destombes was right.

Another very old European astrolabe in the Nikolaus Kusanus-Stift at Bernkastel-Kues on the Moselle could be from the 11th or, at the latest, the 12th century. It is very basic and has, unfortunately, no rete. Appropriately, it has plates for each of the seven climates. I see no way to localize its provenance, but it makes me think of the well-known, very charming story about Radolf, a monk from Liège, and Ragimbold, a monk from Cologne. Both of these men had studied with Fulbert of

Chartres (*ca*. 960-1028), student of the celebrated Gerbert d'Aurillac (*ca*. 946-1003), later Pope Sylvester II, who earlier had come into contact with Muslim scholarship in monasteries of Catalonia. Around the year 1025 Radolf in Liège invited Ragimbold from Cologne to come and examine an astrolabe he had acquired. Ragimbold replies that he cannot come to Liège but could they please send the astrolabe to Cologne so that he can inspect it. The Liège monk replies that they cannot part with their astrolabe, not only because it is their model for making other astrolabes, but further they will not send it to Cologne because there is nobody there who could understand it.

In 1959 the British historian of science and expert on historical instruments Derek de Solla Price published a description of an astrolabe on loan to the National Maritime Museum in Greenwich as "the first scientific instrument of the Renaissance". According to a Latin inscription this beautiful little instrument with an angel on the back was presented by "Ioannes" to the Greek Cardinal Bessarion in Rome in 1462. Now the Ioannes could only have been Ioannes de Monte Regio, known as Regiomontanus, the foremost astronomer in Europe, who accompanied the Cardinal from Vienna to Rome about that time. In 1989 the owner offered it to Christie's for auction, and an accurate, detailed description was prepared by Gerard L'E.Turner. The piece sold for close to £250,000. But then doubts were raised by the press and would-be experts about its authenticity, what with the "absurd" angel and the "*latin de cuisine*" of the dedication, and the purchaser returned it to Christie's. All doubts were allayed when it was realised that the piece was one of a dozen astrolabes made in the Vienna workshop and the whole lot were published by Turner and the present author in 1994.

Years were to pass before it was realised that the dedication was an acrostic, with hidden meanings that would be of interest to donor and the recipient, some referring to the 1062 Byzantine astrolabe which Bessarion seems to have brought with him from Constantinople. I doubt that there is a more brilliant Latin inscription from the Renaissance. And it was finally realised that the angel engraved on the back of the astrolabe represented the 5th-century St. Bessarion, from whom the Cardinal had taken his name when he became a monk, since the saint was venerated as an angel in the Byzantine liturgy. And there

is much, much more, too much, indeed, for art historians, too much for science historians or Renaissance scholars, and certainly for Dan Brown, for here we have the key to the most enigmatic painting of the Quattrocento: a Latin acrostic coupled with an angel.

In the meantime even specialists on the history of astronomy are repeating the erroneous assertion of scholars over 50 years ago concerning the 1062 Byzantine astrolabe. These had never seen an astrolabe but when they saw a bird on illustrations of the Byzantine astrolabe, they claimed that it "apparently reveal(s) Oriental influence". In fact, it reveals many things, but no "Oriental influence".

Other astrolabes deemed important because they have been misinterpreted

Other instruments have basked in the limelight for decades without meriting it. In the Museo Galileo in Florence there is preserved an Islamic astrolabe with some extraneous undatable European markings on the back (an electrotype exists in the Museo Naval de Madrid, which has caused much of the confusion). In the late 19th century the Spanish scholar Eduardo Saavedra unfortunately associated it with Pope Sylvester II, the Frenchman Gerbert d'Aurillac who studied in Córdoba in the 10th century. Gunther was rightly suspicious of this pedigree. Much rubbish has been written about this piece in the past century, mainly in exhibition catalogues. In fact, we can safely associate it with 10th-century Baghdad, but for some reason the back was never finished there. It was messed up by a European sometime between the 14th century (if the additions are genuine) and the 19th century (if the additions are fake) and provided with a case with a dubious Latin inscription purporting to relate to the 13th century. I tend toward an early date because of a fraction that occurs on a calendrical scale, which makes me think of the Toledo astrolabe, the earliest known occurrence. This piece is the most commonly and persistently exploited astrolabe as a symbol of the glory of Arabic science in al-Andalus, when in fact it comes from Baghdad, probably has nothing to do with al-Andalus, and even less with a French pope. It seems that this astrolabe is no longer being associated with Gerbert in the scholarly literature. However, it keeps cropping up all over the place, as *the* astrolabe representing the transmission of Islamic astronomy to Europe.

No descriptions of this instrument – except that in my own catalogue of all Eastern Islamic astrolabes before *ca*. 1100 – mention that this astrolabe is from 10th-century Baghdad. Myths of an Andalusī provenance, and an association with Pope Sylvester II, will surely continue to flourish. And this unsigned, undated, incomplete astrolabe with spurious markings on the entire back, will continue to feature in every presentation or video on the astrolabe from Italy (it is still housed in Florence) and from Spain (because of the electrotype in Madrid).

Other astrolabes deemed less important than they actually are because they have been misinterpreted

The Byzantine astrolabe dated 1062 which is preserved in the Santa Giulia Museo della Città in Brescia is one of the landmark astrolabes: it is the only surviving medieval astrolabe with inscriptions in Greek. The instrument was described in 1926 by the British classicist Ormonde Maddock Dalton in an outstanding article that did great credit to it. One of the things Dalton said about the Byzantine astrolabe was, believe it or not, that it was a Byzantine astrolabe.

The Brescia astrolabe is one of several of the most historically important astrolabes surviving from the Byzantine and Islamic and European Middle Ages that have been treated inappropriately by modern scholars who know very little about astrolabes. These are often scholars who study treatises on the astrolabe – be it in Greek, Arabic, or Latin – but who have never properly studied an actual instrument. Nor have those who have written on the Byzantine astrolabe read Dalton's article properly. Nor have they looked at any of the early Islamic astrolabes inspired by Byzantine astrolabes.

The Byzantine astrolabe bears the name of a high-ranking Byzantine official named Sergios, who was of Persian extraction. Therefore, say some, the astrolabe is not Byzantine. In fact, it <u>is</u> Byzantine. One of the star-pointers is decorated with a bird, such as we also find on some of the earliest Islamic astrolabes. Therefore, say others, it shows Islamic influence and is therefore (!) not Byzantine. In fact, the earliest Islamic astrolabes are now all published, and the very earliest were inspired by Byzantine astrolabes. Burkhard Stautz has compared the rete of the Brescia instrument with that of the earliest-known Islamic astrolabe, datable to the 8th century and apparently stolen from the

Archaeological Museum in Baghdad a dozen years ago. The star-positions on the Byzantine astrolabe are reasonably accurate and not in the Greek tradition (Ptolemy's value of precession was inaccurate), so maybe there is indeed some Islamic influence there, and the star-positions on the Baghdad astrolabe are for the 5th century, not the 8th, because they are based on Ptolemy's star-positions and his inaccurate value of precession! By the 9th century Muslim astronomers and instrument-makers had outstripped their Byzantine contemporaries, a situation that was never reversed.

Making instruments count – a personal account

Making instruments count was the title of a *Festschrift* for Gerard L'E. Turner published in 1993. Gerard came to instruments in Oxford and became the expert on microscopes. He later moved to Elizabethan instruments. It was during the course of the fiasco surrounding the "unique" Regiomontanus astrolabe in the mid 1980s that he taught me many things about European instruments (and I taught him where to find ten more from the same Vienna workshop). My contribution to Gerard's *Festschrift* was a paper entitled "Rewriting history through instruments: The secrets of a medieval astrolabe from Picardy". This astrolabe had been known to Gunther *ca*. 1930 (#202), when it was in a private collection in England, and he remarked on the curious numerical notation that was used on it. The astrolabe could have been acquired by Oxford in the 1950s when it first came up for auction at Sotheby's, but after several attempts it did not sell and was sold privately to a French collector, who then kept it for decades without letting anyone publish it. When I first saw this astrolabe in the 1990s I was fascinated by the ingenious number-notation in which each numeral from 1 to 9999 is represented by a unique cipher. A number-notation which virtually nobody knew about?? There were a couple of articles on it by colleagues who had found the notation used or recorded here and there in medieval Latin manuscripts, but that was a closed door for me, or so I thought until I realized that these manuscripts, and others, were mainly of Cistercian provenance. I also thought there was a problem with the medieval French month-names, but my colleague Kurt Maier took great pleasure in informing me they were in medieval Picard. The instrument is clearly 14th century French, or rather, Picard, but it bears a later inscription indicating that it was given by one

Berselius to one Amerotius in 1522, and of course I had no idea who these two individuals were. Things changed when I found both of them in the index of a book on Erasmus one day whilst browsing in Blackwell's in Oxford. Paschasius Berselius was a Benedictine monk from Liège and Hadrianus Amerotius was his teacher of Greek at the *Collegium Trilingue* in Louvain, and the latter had published a small book on number-notations. The first fruits of these endeavours were presented to Gerard, who had taught me how to look at European instruments. But there are many more instruments that are full of surprises: in 1995 I gave a lecture to the Scientific Instrument Society in London entitled "Making instruments talk – Some medieval astronomical instruments and their secrets". I still maintain that this is an exciting field in which to work.

The mariner's astrolabe, unrelated to the 'real' astrolabe

When is an astrolabe not an astrolabe? When it is a mariner's astrolabe. The navigational instrument known as the mariner's astrolabe is not an astrolabe.

The mariner's astrolabe is to a 'real' astrolabe as a DONUT is to a MULTI-LAYERED WEDDING CAKE.

The former should never have been called an astrolabe – its name is well explained by a favourite Spanish expression of mine, "obstinación historiografica",[7] meaning something like "a misnomen which stuck for centuries and still won't go away". It would not be worth a dissertation to establish who introduced this unhappy nomenclature.

The mariner's 'astrolabe' serves only to measure solar or, with any luck, stellar altitudes. It is far more useful if one has on board an astronomical table displaying the altitude of the sun at each (seasonal) hour of daylight. One can then measure the solar altitude, even at sea, and find the time of day. One does not need a table for different latitudes because the most serviceable tables were based on an approximate formula that worked reasonably well for all latitudes (at least in the Near East, where it was conceived, if not in Europe, where it was used with abandon for centuries even though it didn't work properly at higher latitudes).[8]

All known examples of the so-called "mariner's astrolabe''– at that time, some 68 pieces – were documented by Alan Stimson in 1988. A new project has been launched to document the entire corpus (Castro *et al*.). Confusion between the mariner's astrolabe and the planispheric astrolabe is on the rise as the press greets the booty of each newly-discovered shipwreck from the 16th, 17th or 18th century as an astrolabe, and some people who write on the mariner's astrolabe have no idea what a 'real' astrolabe is – see Part II. The mariner's astrolabe was indeed eventually replaced by the sextant.

Modern astrolabe copies

The best copies available these days, in fact, since 1975, are those made by Martin Brunold in Abtwil near St. Gallen, Switzerland (www.astrolabe.ch). These are based on actual historical instruments, usually those with special historical importance, and of course are signed and dated by Brunold, who has done great service to the astrolabe. Health considerations forced him to cease making instruments in 2015, and his tradition is being continued by Torsten Hiller of Brandenburg (www.chronos-manufaktur.de).

Copies of astrolabes are also available from Brigitte Alix in Montigny le bretonneux, 25 km SW of Paris (www.astrolabes.fr/index.html) – see further below.

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My former colleague, the late Prof. Fuat Sezgin of Frankfurt, has had dozens of copies made of Islamic and European astrolabes and related instruments for his 'museum' of the history of Arabic-Islamic science. Several of these were made by Martin Brunold. Similar 'museums' have been opened in Istanbul, Riyadh and Abu Dhabi. The general impression made by these copies on somebody who has seen real astrolabes will vary between wonder and horror. The copies are often

stripped of plates and superfluous features. The text of the accompanying catalogue – in German, French, English or Arabic – is informative and contains illustrations and descriptions of the instruments:

www.ibttm.org/ENG/museum/collection/2-3.pdf.

The descriptions are as faithful to the partial copies as they can be but the bibliographical notes are inadequate. The spectrum of astrolabes featured is, on the other hand, impressive indeed.

Nir Shafir in a highly significant article entitled "Forging Islamic science" published in 2018 points to the way in which such copies of medieval Islamic instruments in 'museums' of this kind take attention away from the real instruments preserved in real museums.[9] He also shows how fake miniatures of Muslim scientists at work with instruments of one kind or another have proliferated in tourist markets and have even ended up in major European collections.

Is it really so difficult to understand what an astrolabe is?

No, because one can understand it from several points of view. One does not need to be a rocket scientist.

Brigitte Alix has a very pleasing website on astrolabes (www.astrolabes.fr/index.html.), and on the astrolabes she constructs for others. This includes a brief and factually correct history of the instrument such as we rarely find on the internet.[10] The introduction reads:

> "Qu'est ce qu'un astrolabe ? – 2000 ans d'Histoire et d'aventures ... . – De tout temps l'Homme fut un grand voyageur. Aussi dut-il se donner les moyens de répondre aux questions : "Où suis-je ? Où vais-je ?" [DAK ajoute: Quelle heure est-il ?]. La nécessité de pouvoir se repérer dans l'espace et dans le temps lui a fait mettre en oeuvre toute son ingéniosité pour concevoir un instrument lui permettant d'apporter des réponses à ces questions fondamentales. Tout commence avec Hipparque, ..." // "What is an astrolabe? – 2000 years of history and adventures – Man has always been a great traveller. So he had to acquire the means to find out the answers to the questions: "Where am I?", "Where am I going", [DAK adds: "What time is it?"]. The need to be able to find his bearings in space and time made him exercise all of his ingenuity

> to conceive an instrument that would allow him to find the answers to these fundamental questions. It all begins with Hipparchus ... .”

And so it does, and, as Alix points out, it continues almost to the present day in Morocco.

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Yes is the answer to the above question, because there really are a lot of things going on with the astrolabe. The British historian of science Thony Christie, writing in a well-informed blog about Renaissance astrolabes,[11] wants his readers to know that:

> “To begin with it is not simply one object, it is many objects in one: an astronomical measuring device; a timepiece; an analogue computer; a two dimensional representation of the three dimensional celestial sphere; a work of art and a status symbol.”

A wee bit of history will be useful. High-school mathematics is certainly a help but not a necessity. More important is a basic knowledge of the way in which the Heavens appear to rotate about a celestial axis and about the way in which the sun unseen moves against the background of fixed stars. Alas, this cannot be taken for granted.[12]

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Fortunate readers may be able to benefit from an astrolabe workshop conducted by an expert such as Dr. Hüseyin Sen (listed in uu.academia.edu/HuseyinSen). Otherwise, various websites offer introductions to the astrolabe and its use. The most useful and most complete is the website www.astrolabes.org of the late Jim Morrison. It deals with both the construction and use of the instrument, and it respects both historical texts on the instrument and the surviving astrolabes themselves. It is also one of the few that contains any reference to the vast bibliography on the subject. I single out five others that can be recommended, one by Emily Winterburn for MuslimHeritage.org, another with Tom Wujec giving a reasonably-well informed TED talk on how to use a Chaucer-type astrolabe, and another with music instead of commentary from the Institut du Monde Arabe in Paris. There is a French site compiled by people who know what an astrolabe is and how it works, namely, that of the association called Méridienne at Nantes. A German Muslim site about Islam has a page on the nature and use of the astrolabe in which virtually every

single statement, be it historical or scientific, is correct. Quite a few more will be mentioned in Part II, but most of them are of little historical or scientific value.

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In concluding this brief overview of good news about astrolabes, we should remind the reader that both in the Muslim world and in Christian Europe, other instruments were used besides astrolabes, namely, globes and armillary spheres, quadrants, sundials, and other instruments harder to classify. And then there are large-scale observational instruments, the purpose of which was to assist in improving astronomical parameters and tables, the latter being the main tool of astronomers from Antiquity through to the Renaissance and beyond. Serious timekeeping, at least in the major Muslim cities, involved the use of extensive tables computed for specific latitudes; to use some of them one needed to know the solar altitude and the solar longitude. Presumably an astrolabe would serve to determine the former, and the latter would be best found in an ephemeris for the year in question. Very few such tables are known from medieval Europe, but they become more widespread in Renaissance times. And nowadays, although many people might claim to 'like' astrolabes, very few people like tables.[13]

Fig. 1: The front of the magnificent astrolabe of the astronomer Ḥāmid ibn al-Khiḍr al-Khujandī, dated 374 Hijra, that is, 984/85. The simple design of the earliest Islamic astrolabes, adopted from Byzantine astrolabes, has here been developed into a scientific work of art. The throne shows two splendid lions (inspired by those at Persepolis?). There are 33 stars on the rete, all standard astrolabe stars, several with zoomorphic pointers. A charming quatrefoil betrays Byzantine influence and remained a feature of astrolabe retes until the Renaissance. The plates serve latitudes 21° (for Mecca) then each 3° from 27° to 42°. The back, which, more than most astrolabes, shows signs of use. In the upper left there is a trigonometric quadrant with horizontal parallels for each 1°. In the upper right there is an horary quadrant for latitude 33°, which is one of the latitudes used for Baghdad since the time of al-Khwārizmī. Now al-Khujandī is usually associated with al-Rayy (outside modern Tehran), but this feature of his astrolabe proves that he spent time in Baghdad. Below the horizontal diameter is a series of astrological tables displaying: the names of the 28 lunar mansions; the names of the 12 zodiacal signs; indications of the sun, moon and planets; lengths of the limits; the lords of the faces; divisions of the faces; the lords of the day and night and the companions for each sign. This astrolabe was published by the author in detail in Kuwait in 1995 and again, together with all other surviving Eastern Islamic astrolabes till *ca*. 1100, in 2004 (*In Synchrony with the Heavens*, XIIIb: 503-517). The piece is now in the Museum of Islamic Art, Doha, Qatar. [Photo courtesy of a previous owner.]

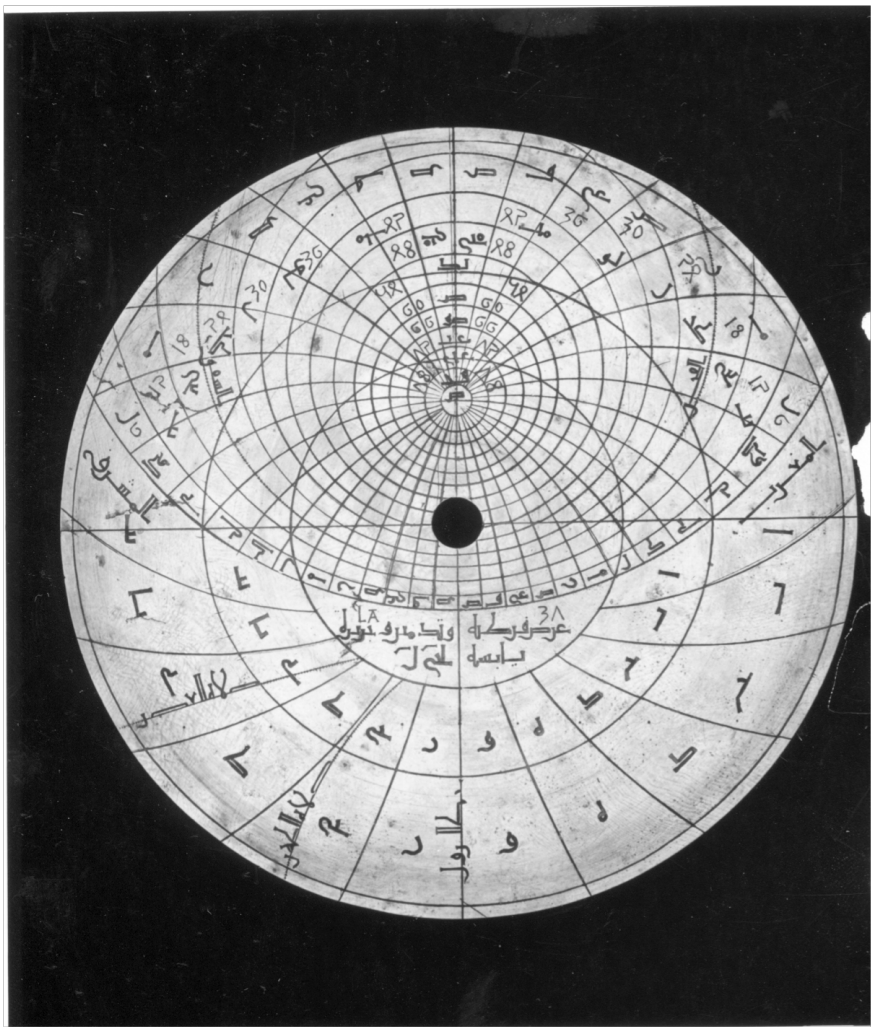


Plate 2a: One of the plates on what is perhaps the oldest surviving Andalusī astrolabe, that is, from the 10th century. This piece is preserved in the British Museum, but has yet to be acknowledged for what it is, probably because is unsigned and undated. The rete has the appearance of an Eastern Islamic astrolabe rete, which is precisely what one would expect. It is this plate that concerns us here. It bears altitude circles for each 6° and azimuth circles for each 10°. The underlying latitude is 38°30’ and is here associated with Córdova, Tudmir (Murcia) and Ibiza. The western horizon is marked *al-maghrib*, the eastern one *al-mashriq*, the meridian as *al-zawāl*. Amidst the curves for the seasonal hours below the horizon we find curves for the *ẓuhr* prayer and the *‘aṣr* prayer. The circle for altitude 18° above the horizon is marked *al-fajr* (daybreak) on the left and *al-mughīb* (nightfall) on the right. These markings suffice to determine the times of all five of the daily prayers. There are additional markings by a European all over this piece. He has messed up the rete and not completed his attempt to remove the Arabic inscriptions. On this plate he has engraved in “Western” numerals the altitude arguments and has misinterpreted the latitude as 37° (“LA 37”). [Image courtesy of the British Museum.]

Fig. 2b: Some of the instruments made by Muslim astronomers have defied interpretation in modern times. With markings such as these on an unsigned 14th-century Syrian astrolabic plate, surely conceived and constructed by one of the leading astronomers in that milieu, we have come a long way from the standard astrolabe. Practical and easy to use is this astrolabic plate for multiple latitudes not. [Photo courtesy of the Deutsche Staatsbibliothek, Berlin. See *In Synchrony with the Heavens*, XIVb: 709-712.]

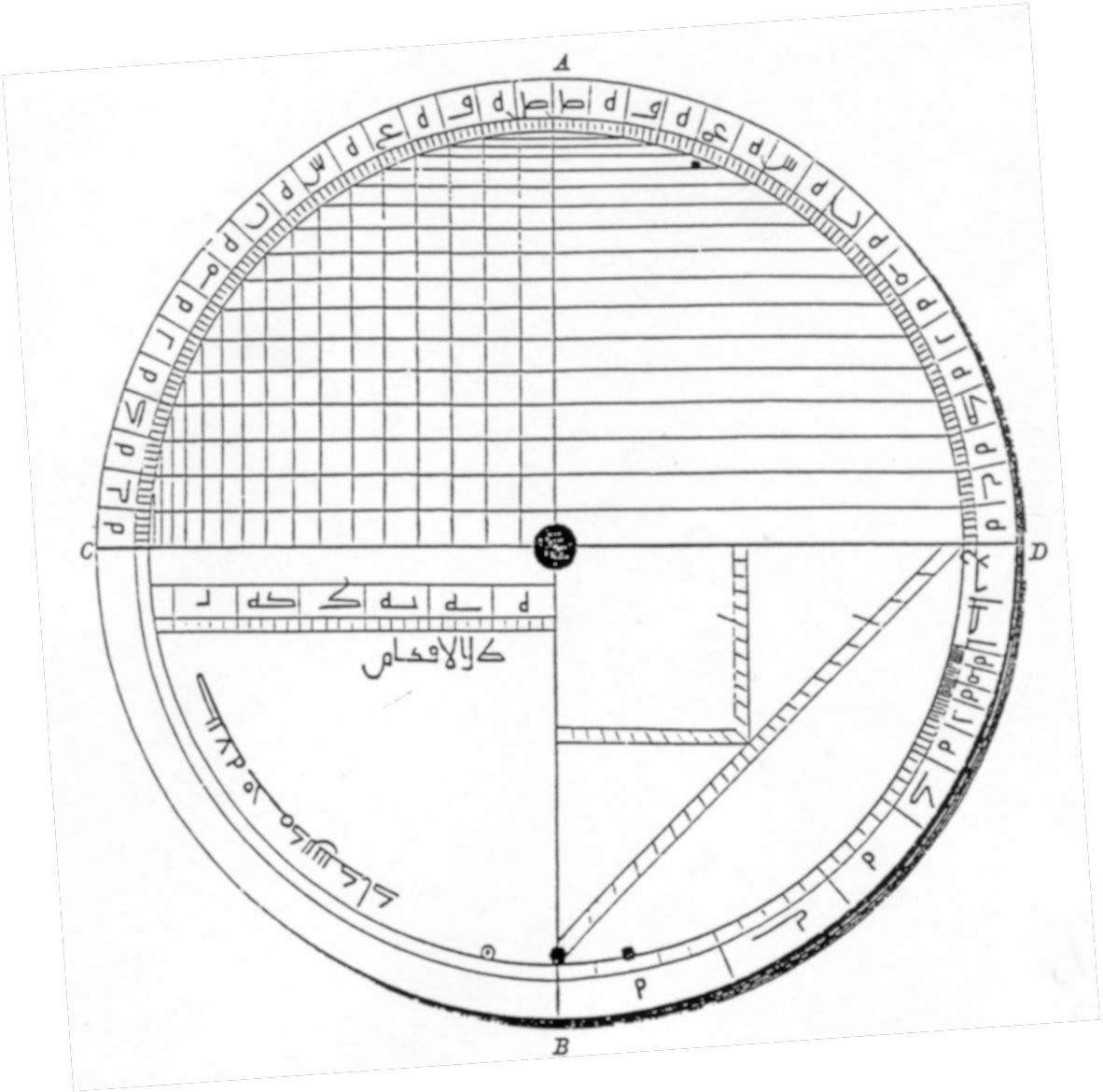


Fig. 3a: The back of an astrolabe made in Baghdad in the early 10th century by Muḥammad ibn Shaddād al-Baladī. In the mid-19th century the piece was in Berlin, belonging to Dr. J. G. Wetzstein, at one time Consul in Damascus, but it is now missing. Fortunately, it was published by the orientalist B. Dorn, "Drei arabische Instrumente" (1865), pp. 115-118. There are two trigonometric quadrants above the horizontal diameter. In the lower left there is a scale for horizontal shadows to base 7 situated at 7 out of 60 units below the horizontal diameter (such a scale was introduced by al-Khwārizmī). In the lower right there are three shadow scales for the reader to interpret. Only one plate was available: it bears markings for latitude 11° (Aden) and 21°(Mecca). The original rete was missing. See now *In Synchrony with the Heavens*, XIIIe: 484-487. Notice that 19th-century lithographs of astrolabes are often more useful than 20th-century photos and even 21st-century digital images.

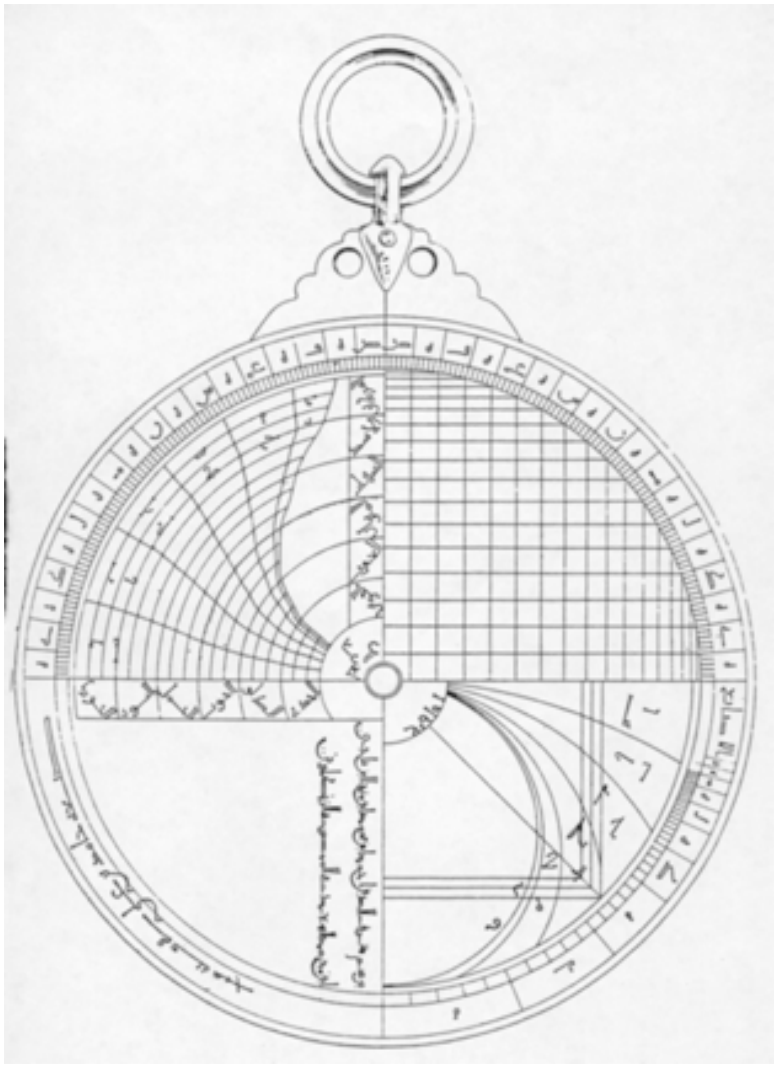
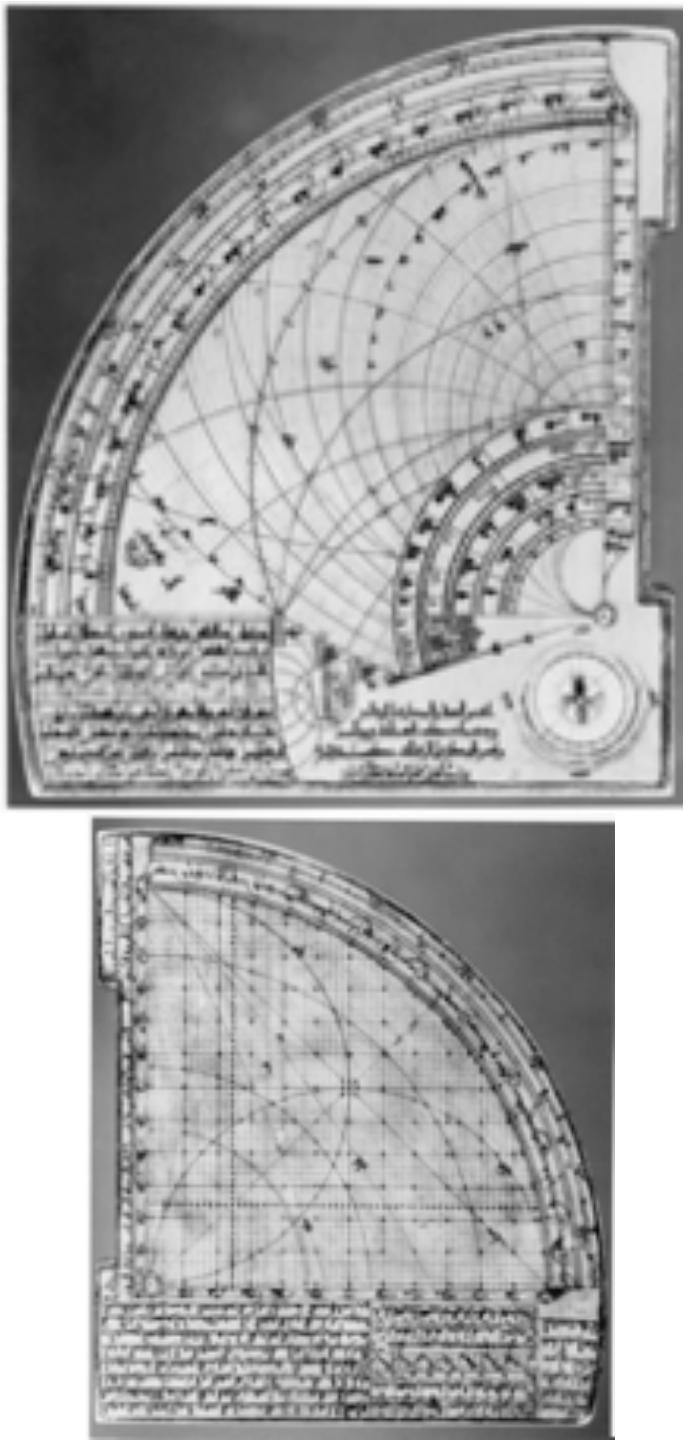


Fig. 3b: The back of an astrolabe made by the renowned instrument-maker Hāmid ibn ʻAlī al-Wāsitī in Baghdad in the year 343 Hijra, that is, 954/55. Here we see a spectrum of newly-introduced features designed by Muslim astronomers in the 9th and early 10th centuries to fill the void on the back of Byzantine astrolabes. First in the upper left we find an horary quadrant for latitude 33°, serving Baghdad. In the upper right we find a trigonometric quadrant. In the lower right we find two sets of markings which journeyed together from 9th-century Baghdad to medieval and Renaissance Europe. These are the universal horary quadrant, for finding the time of day quickly by means of an approximate formula that works quite well in the latitude where it was derived (but not in Europe), and the single shadow square, with divisions on the perimeter. This happy couple of features reappears, for example, on the universal horary dial, for example, on the 14th-century English *navicula*. Only the mater of this astrolabe is known to have survived into the 19th century. Inside the mater there are astrolabic markings for a series of horizons which constitute evidence that the there missing rete was of the *kāmil*, "complete" variety, including stars outside the Circle of Capricorn and with declination down to 36°S. Lithographs of both sides of the mater – of better quality than most photographs of instruments produced by museums in the 20th century – were published by the Sicilian orientalist Vicenzo Mortillaro in 1848. It was stolen from the Museo Nazionale in Palermo in the mid 20th century. For a detailed description see *In Synchrony with the Heavens*, XIIIe: 496-503.

Fig. 4: The rete on this English astrolabe from *ca*. 1300 is a monumental scientific work of art. This, the oldest known English astrolabe, was at one time in the possession of Sir Hans Sloane and in 1753 was acquired by the British Museum, where it was put in a cellar for over a century. We can trace the quatrefoil decoration and bird images for star pointers back to the archetype of the astrolabe of al-Khujandī, which was probably originally inspired by Byzantine instruments. However, the question that arises with the Sloane astrolabe is: how is it that this astrolabe is more sophisticated, technologically as well as aesthetically, than any later English astrolabes before the Renaissance? And how is it that this English astrolabe is more developed artistically than any astrolabes from al-Andalus, or medieval Christian Spain and France, where quatrefoil astrolabes developed over the centuries. See further King, *In Synchrony with the Heavens*, XVII: 963-992 "The quatrefoil as decoration on astrolabe retes", and Davis, "Decoding the Great Sloane Astrolabe". [Image from Google Art & Culture.]



Figs. 5a: A 19th-century astrolabic *cum* trigonometric quadrant typical of the instruments made in past centuries in Egypt, Syria, the Maghrib and Turkey. The astrolabic quadrant, here for the latitude of Damascus, was apparently invented in Cairo in the 12th century; it consists essentially of half of a set of astrolabic markings for a specific latitude with a thread and movable bead attached at the centre. The kind of markings on the back appear in simpler form in 9th-century Baghdad, and these markings, resembling graph paper, are first attested in 10th-century Baghdad. This combination of markings is not known in medieval or Renaissance Europe. The quadrant is now in the British Museum. [Images courtesy of a previous owner.]

Fig. 5b: A 14th-century English quadrant with markings for a single shadow scale and universal horary quadrant adapted to latitude 52°, namely, London. The outer scales are superfluous. On the back is a simple calendrical scale. This instrument came to light in 2008 and is now in the British Museum. [Images courtesy of *The Telegraph*.]

Fig. 6: This spherical astrolabe signed simply ‘Mūsā’ and dated 885 Hijra (1480/81) has been in the Museum of the History of Science at Oxford since 1962. The identity and milieu of its maker of this (at the time) unique piece remained a total mystery until recently, when another example surfaced in a private collection, obviously made by the same person but now signed with an epithet. However, the horary markings on the Oxford sphere are for ~41°, which brings us to the parallel of Istanbul. Both instruments can be safely attributed to the mysterious, prolific and multi-lingual Jewish astronomer Mūsā Jālīnūs ben Yehūda, active in the proximity of the Ottoman Sultan Bāyazīt II, who was passionately interested in astronomy. These two instruments can now be added to his *oeuvre*, which includes writings on astronomy (Arabic), medicine (Turkish) and scientific miscellanea (Hebrew), all of which have been published only in the past 10 years. On the other hand, the existence of his minor writings on instruments, all translations from Arabic into Hebrew, has been known for over a century. Close inspection of the names on the star-pointers and their positions has revealed that those on the ‘new’ instrument are very confused, mainly incorrect; the Oxford piece is much better but still features some of the mistakes that are on the earlier piece. The only bright star featured on the two retes is in error by 30°. In other words, neither instrument is functional. Yet these are unquestionably genuine instruments and so the mystery surrounding them is not yet fully solved. In 1976 another spherical astrolabe, sadly lacking its rete, surfaced in another private collection: it is unsigned but was made in Tunis in the 15th, if not 14th century. The spherical astrolabe was invented in 9th-century Baghdad by the leading astronomer there, Ḥabash al-Ḥāsib. His treatise on the instrument, as well as several treatises by prominent Muslim astronomers, awaits study. See further Maddison, “15th-century spherical astrolabe” (1962); Canobbio, “An important fragment of a West Islamic spherical astrolabe” (1976); and King, “Three spherical astrolabes from Tunis and Istanbul” (2018). [Image courtesy of the Museum of the History of Science, Oxford.]

Fig. 7: A Renaissance Italian astrolabe datable to *ca*. 1600. Various features of the rete and throne reflect aspects of al-Khujandī's astrolabe. The flame-shaped star pointers betray French influence, since these are a feature of the astrolabes of Jean Fusoris (Paris *ca*. 1400) and a broad spectrum of later instruments based on these. The present location of this piece is unknown; the image is taken from de Vries, "Some notes for the use of an astrolabe". The astrolabe in Italy is one of the least documented chapters in the history of the instrument. Several medieval Italian astrolabes in Milan collections were catalogued by Tullio Tomba, but there are more to be studied. In 2018 a late medieval Italian astrolabe was auctioned in London as "Spanish or French". The most spectacularly beautiful Renaissance Italian astrolabe, preserved in Hamburg, has been labelled a fake, which, inevitably, it is not.

Part II: What an astrolabe is not

"Perception is more important than reality. If someone perceives something to be true, it is more important than if it is in fact true. This doesn't mean you should be duplicitous or deceitful, but don't go out of your way to correct a false assumption if it plays to your advantage." Ivanka Trump. [a]

"There is a dimension beyond that known to man, between the summit of nonsense and the pit of implausibility ... ." Maureen Dowd (2018).

"The astrolabe was first invented in North Africa and it quickly spread throughout the Middle East." [b]

"Astrolabes are inclinometers that were used for navigation and locating astronomical objects from ancient times to the Renaissance.'' [c]

"It is not known when (the astrolabe) was invented but it widely used in the 6th and 7th century by Arab pilots at sea and also used by European navigators." [d]

"Developed in the Middle East to help traders chart their course through the desert, the (mariner's) astrolabe was the most popular western navigational instrument for centuries." [e]

"In the same way that the Internet has brought the world even closer together, the astrolabe pushed boundaries and horizons, making the entire globe navigable." [f]

a) *The Trump Card* (2009), cited at http://www.amreading.com/2017/04/25/the-7-most-singularly-terrifying-quotes-from-ivanka-trumps-trump-card-book/
b) https://study.com/academy/lesson/arabic-astrolabe-definition-navigation-history.html
c) Anonymous, article "Inclinometer" in *Wikipedia*
d) http://www.southernfriedscience.com/try-your-hand-at-celestial-navigation-with-an-open-source-glowforge-ready-astrolabe/
e) https://www.hunker.com/13411071/the-impact-of-the-astrolabe
f) https://www.interestingfacts.org.uk/what-is-an-astrolabe/

Just a reminder:

Introductory remarks

Readers genuinely interested in astrolabes should not read this section of my paper. It will make them weep. It is of no scientific interest. But it relates a story in keeping with our times: those who create fake news do so because they cannot face or handle the truth. The citations from the tertiary literature on the astrolabe that I shall present below show how far some moderns can stray from the truth when writing about things they know nothing about or spend no time trying to find out about. Behind all of the quotes is, on the one hand, an arrogance in thinking that on historical objects one can write 'any old rubbish' / *n'importe quoi* / *lauter Blödsinn* / *sciocchezza* / أي كلام , *ayyi kalām* and get away with it, and, on the other, an ineptitude to access the most accessible of the many internet sites dealing with the instrument properly. If one simply googles the word 'ASTROLABE' one comes straightaway to the pathetic *Wikipedia* page, on which see below, but then to the late Jim Morrison's reliable and highly recommended site offering all that most people would want to know. In Part I we have mentioned numerous reliable websites and detailed catalogues of astrolabe collections and several thousand pages of scholarly articles on medieval astronomical instruments. All of this has not hindered the proliferation of much nonsense about astrolabes on the internet.

I write not to play the arrogant academic showing how popular culture has got it all wrong, but out of genuine concern that first, people should know that an enormous amount of work has been done on the astrolabe and its history, and that second, it would not be a bad thing if more people realized what an astrolabe actually is. The late Stephen Hawking said:

> "Remember to look up at the stars and not down at your feet,"

but I think he would have approved of looking down at an astrolabe.

Furthermore, I have as much respect for numerous amateurs as I do for various academics, if not more. I have not consulted the vast literature on the history of astronomy to see whether the authors 'got it right' concerning the astrolabe. At least most of those authors would have had a vague or reasonable idea of what the astrolabe is and what one can do with it.

So the concerned reader might ask why did I waste my time with all this nonsense from the internet. In fact, it did not take long to collect the following quotes, and anybody could dig out even more such useless material. I have seen maybe two-thirds of all the stuff that is available, which is more than enough for my purpose. Most of the quotes are in English, which reflects the nature of the Web: there are, for example, as many *Wikipedia* pages in English as there are in French, German, Spanish and Italian put together. I will spare the reader extracts from the Arabic web, which are depressing indeed when one thinks that the language of serious science from the 8th century to the 15th was Arabic. I shall also make no attempt to unravel the various cases where wording and phrasing of false information are identical, meaning that people are just copying from somebody else without consulting any informed or academic literature.

A frightening thought is that a similar undertaking could be conducted for so many other subjects. And the first subject that comes to my mind and which is most poorly represented on the internet is the history of Islamic science, not written by "malevolent orientalists", but by well-meaning but hapless Muslim university students who have no conception of the vast literature on the subject and no idea about the most accessible websites already in existence. Some colleagues have told me that one should not criticize anybody in print; here I promise only to criticize the many people who have written *n'importe quoi* on the astrolabe. And I don't doubt I shall be criticized for even that. But many are not identified in the text, simply quoted *verbatim*.

The confusion about the astrolabe begins with the fact that the word "astrolabe / *astrolabio* / *Astrolabium*" is derived from the Greek, meaning something like "taker of the stars", as far as that means anything in translation. It is not fully clear in Greek either, but it seems that it means something like "measurer of (the altitudes of) the celestial bodies, namely, the sun and stars (with the alidade)", with the purpose of "correctly placing their representations on the rete with respect to the horizon and meridian on top of the appropriate plate". In any case, that is what an astrolabe does. Ptolemy called the armillary sphere an astrolabe, so perhaps he thought of the name as a generic word for a series of instruments that combined observation with representation of the instantaneous configuration of the heavens. A serious modern

Greek site on the substantial scientific and technological achievements of the Ancient Greeks refers in a moment of weakness to the armillary sphere as "The astrolabe of Ptolemy (the G.P.S. of the ancient Greeks)".[14]

The Muslims used the name اسطرلاب , *asṭurlāb*, and my 1981 paper on the origin of the astrolabe according to the medieval Arabic sources[15] is probably the most-cited paper I ever wrote, possibly because it is the least significant, for a lot of what the medieval Arabs and Persians wrote about the word itself was fantasy. The same holds for much of what we find in the non-specialised literature and the internet today. I particularly like the pronunciation "astrolobe", which I often hear.[16] At a cocktail party in Frankfurt in the 1990s a lady asked me how my work on 'Skylab' was progressing.

The biggest problem we now confront is that there are two completely different instruments with the name "astrolabe". As we shall see, these are often either confused one with the other, or amalgamated into a single instrument. The person who first applied the word "astrolabe" to that trivial European device which we now call "mariner's astrolabe" should perhaps have been made to walk the plank.

Some of the blame for astrolabic misinformation lies with the museums themselves. The largest collection of Islamic (and European) astrolabes, namely, Oxford (MHS), does have a website featuring individual instruments. However, the next largest collections, Washington DC (NMAH) and Greenwich (NMM), and now Doha (MIA), do not even have on their websites a clear (or correct) statement of what an astrolabe is or what one can do with it.

The National Museum of American History has an excellent catalogue

of their important collection but allows incompetents to publish on astrolabes in the *Smithsonian Magazine* without mentioning either the Smithsonian astrolabes or the NMAH catalogue.

Greenwich used to have a splendid booklet offering all one really needs to know about the astrolabe and giving a list of their own astrolabes; this is apparently no longer available at the Observatory bookstore. The lavish scholarly catalogue of their astrolabes is an expensive alternative. It is available for between $100 and $300 on the internet.

The best the Islamic Art Museum in Doha can do, after having spent a king's ransom to purchase several dozen medieval Islamic astrolabes, is to teach students about the astrolabe:[17]

> "Students will learn about the structure and function of each part of the astrolabe; as well as the astrolabes many uses and role in society and navigation."

Actually students should learn that **the astrolabe was not used for navigation**.

This kind of sloppiness facilitates the circulation of such more detailed misinformation as we find in a recent London auction catalogue offering an 17th- or 18th-century Maghribī astrolabe:[18]

> "Astrolabes were widely used in the Islamic world both for navigation and for finding the qibla, or direction of Mecca. They were used to find the time of sunrise in order to help schedule morning prayers. … ''

This text has been circulating for decades, and it is time to put an end to the false notions that it contains.

- In fact, **astrolabes were not used at all in navigation in the Islamic world**.
- Most Islamic astrolabes have no means whatsoever for determining, in the sense of calculating the qibla. If one knows what the qibla direction is, then one can find out the qibla on any horizontal scale laid out in the cardinal directions. A very few astrolabes have special markings for finding the qibla – see Part I and also below.
- The claim about sunrise and the morning prayer (at daybreak) is naïve, for if you determine the time of sunrise, the time for the morning prayer, at daybreak, is passed. On many Islamic astrolabes

there are indeed special markings on the plates for each of the five times of prayer: sunset, nightfall, daybreak, midday, mid-afternoon – see below.

A researcher has recently written on the astrolabe:[19]

> "... the astrolabe is an ancient astronomical instrument used for observing planetary movements. Astrolabes are amongst the most sophisticated scientific instruments ever made."

"Planetary movements"? How can you measure the movements of the planets with such a device? But the sophistication of the astrolabe is not in doubt.

Myths about Islamic astrolabes

In the introduction to a catalogue of an important collection[20] we read that the astrolabe

> "solved problems related to the three main concerns of Islamic astronomy: 1. astrology; 2. finding the azimuth of the qiblah, that is the direction of Mecca; (and) 3. the determination of the astronomically-defined times of Muslim prayer."

As should be obvious from Part I of this study, none of this is correct.

With an astrolabe one can determine immediately the four 'cardinal' points of the ecliptic at its intersections with the horizon and meridian – the ascendant (sometimes called the *horoscopus*), lower midheaven, the descendant and upper midheaven – and then, with some effort, the longitudes of the other eight houses. Maybe the instrument has a solar scale to find the solar longitude from the date. But that's about it. Otherwise the longitudes of the sun, moon and five naked-eye planets must be calculated or taken from an ephemeris, giving such positions for a specific year. Then one can begin to develop a horoscope, determining which celestial bodies find themselves in each house, but not with the astrolabe.

To calculate the *qibla* for a given locality from scratch with an astrolabe is a complicated process. One needs to know the geographical coordinates of one's locality and of Mecca and make a trivial geometrical approximation or get involved in a complicated process using a trigonometric grid to solve the accurate formula. Some medieval authors suggest one should find the azimuth of the zenith of

Mecca so that the *qibla* problem is transferred to the celestial sphere; to do this one needs to know the solar longitudes when the sun is directly overhead in Mecca, which will be given in the text. If the *qibla* is marked on the back of the astrolabe, one has simply to hold the instrument horizontally and aligned with the cardinal directions and *voilà*. If the astrolabe has a gazetteer with the *qibla*s of dozens of localities marked on it (usually Persian and Indian astrolabes after *ca*. 1600), one is in luck. In general, however, the astrolabe is not an instrument for finding the *qibla*.

***

Obviously the astrolabe can be used for finding the times of sunset, midday and sunrise. The first prayer, the مغرب , *maghrib*, begins at sunset. The second prayer, the عشاء , *'ishā'*, begins at nightfall and the third, the فجر , *fajr*, at daybreak; only if curves for nightfall and daybreak are marked on the astrolabe plate can the times of these two prayers be determined using an astrolabe. The daybreak prayer must be completed by sunrise. In the Islamic East the ظهر , *ẓuhr* prayer began at midday and in the Islamic West it began at a specific time determined by shadow-lengths; in the latter case, only if a curve for the *ẓuhr* is marked on the plate can the astrolabe be used to determine its time. The same holds for the beginning and end of the عصر , *'aṣr* or afternoon prayer, whose times are also determined by shadow-lengths. Most Eastern astrolabes do not have markings for the prayers; most Andalusī and Maghribī instruments do. A generalization about the use of the astrolabes for finding the times of prayer is incorrect.

However, it is true that the earliest Islamic astrolabes have markings neither for astrology nor for the *qibla* nor for the times of prayer. This is also true for most later ones.

The inclinometers of *Wikipedia*

Claims like these, and others yet more far-fetched, such as the use of the standard astrolabe for planets and eclipses[21] and casting horoscopes or even for time-keeping by the moon,[22] have been circulating in the popular literature since the 1950s and are now common on the web. Thus, for example, the English *Wikipedia* article on the astrolabe is pathetic. The French, Italian, Spanish and Dutch versions are not much better, whereas the German version is excellent. The wretched English

version begins:

> "an elaborate inclinometer, historically used by astronomers and navigators, to measure the inclined position in the sky of a celestial body, day or night. It can thus be used to identify [!] stars or planets [!], to determine local latitude given local time [!] and vice versa, to survey, or to triangulate.''

The same author seems to have also written the article "Inclinometer'' for *Wikipedia*, for there we read:

> "Astrolabes are inclinometers that were used for navigation [!] and locating astronomical objects [!] from ancient times to the Renaissance.''

The astrolabe is not an inclinometer, what a ridiculous word! The astrolabe can, however, be called an inclinometer if one has no idea what it can be used for, as in this case. In addition, we note:

- Medieval users of astrolabes had no need to "identify stars'' or to "locate astronomical objects''. They might measure the altitude of a particular star and then place the marker for that star on the rete on top of the appropriate altitude curve on the plate beneath. They would then have an image of the instantaneous configuration of the heavens above their horizon, which is very good for a start.
- The principal use of the astrolabe is not "to determine local latitude given local time''. How many times does one need to determine one's own latitude? even on a journey? The astrolabe serves to determine the time of day or night, for any of the latitudes served by the plates, through determination of the altitude of the sun or a particular star. The passage of time after or before any 'base' time, be it sunrise or sunset, midday or midnight, can be found by rotating the rete forwards or backwards to the 'base' position.
- I have been claiming for almost half a century that **standard astrolabes were not used for navigation**. I am perhaps wasting my time.
- The use of the astrolabe for surveying and, if you must, triangulation, involves fairly trivial applications of the alidade together with the altitude scale and the shadow scales on the back of the instrument. This all works better in theory than in practice since astrolabes are usually too small for such operations.

Astrolabes used for astrology

Astrology is mentioned again as the main function of the instrument in a museum site:[23]

> "There were two main types: the mariner's astrolabe used for navigation – to determine the altitudes of the sun and stars; the planispheric astrolabe, the most common instrument, was used for astrological purposes. ... ..."

I repeat, the astrolabe was not (only) used for astrological purposes. The most one can do with it is to position the sun and to determine the astrological houses. For the rest one needs an ephemeris or almanac to find the positions of the moon and five naked-eye planets. Or one needs special plates.

The great advantage of astrology is that at any stage of casting a horoscope a mistake will not influence the chance of the outcome being accurate. A series of videos showing the use of astrolabes in astrological calculations have been prepared by Dr. J. Lee Lehmann. I have seen one purporting to "calculating house cusps",[24] which left me quite confused.

Emily Winterburn's otherwise reasonable treatment of the astrolabe, mentioned in Part I, suggests that:

> "to cast a horoscope, it is necessary to know the position of the stars visible in the sky at the time of birth."

But it is the sun, moon and five naked-eye planets which supposedly influence affairs on earth, and if one has an astrolabe one can do no more than determine the twelve houses, starting with all-important ascendant (the point of the ecliptic instantaneously rising over the horizon). From then on, one needs an ephemeris – a set of tables showing for each day of the year the ecliptic positions of the sun, moon and five naked-eye planets – to see which houses the seven bodies are in and then to establish their interactions and their influences.

One series of videos in French on astrology deals with "The astrolabe, symbol of the astrologer".[25] I have not investigated these beyond noting the succinct and correct introduction to the astrolabe:

> "L'astrolabe est le cousin de la sphère armillaire. C'est la version portative. L'astrolabe est un outil conçu par les grecs. C'est one projection de la sphère armillaire dans un plan. L'astrolabe était

> indispensable à l'astrologue car il permettait de lire l'heure de jour comme de nuit. C'est grâce à lui que l'astrologue pouvait "faire l'horoscope", étymologiquement "examiner l'heure". ... ." // "The astrolabe is the cousin of the armillary sphere. It is the portable version. The astrolabe is a tool conceived by the Greeks. It is a projection of the armillary sphere in a plane. The astrolabe was indispensable to the astrologer because it enabled (him) to read off the time of day or the time of night. It is thanks to the astrolabe that the astrologer could 'cast a horoscope', the word meaning 'examine the hour'. ... ."

***

The author of *The Astrology Book – An Encyclopaedia of Heavenly Influences*, published in 2003, has the following to say on the astrolabe:[26]

> "An astrolabe is a mechanical device that, prior to the development of the sextant, was widely used by mariners. Said to have been developed by Hipparchus, greatest of the ancient Greek astronomers (although some scholars give Ptolemy the honor), the astrolabe was used by astrologers when they erected horoscopes to determine the positions of the planets. ... ... Originally Greek, this instrument was lost to western Europe until its reintroduction by Arabic sources."

There is almost too much nonsense in this account for me to know where to begin, but I feel obliged to say a few words. The astrolabe was developed neither by Hipparchus nor by Ptolemy. The mechanical device called an astrolabe was not used by mariners. The astrolabe was not used by astrologers to "erect horoscopes", whatever that is supposed to mean. If one did "erect" a horoscope, it would not be to determine the positions of the (sun, moon and five naked-eye) planets. You need the seven positions to set up the horoscope.

I love the phrase "lost to western Europe," for when the Europeans did encounter the astrolabe they did not have the astronomical knowledge to fully appreciate it. The astrolabe was not reintroduced anywhere in Europe. (Classical Greece can hardly be put on the same continent as Dark Age Europe.) And it was not reintroduced by Arabic sources. It came to the attention of a few enlightened Europeans in Northern Spain

who were captivated by its – for them – originality. A reliable history of astrology cannot be written by believers, a situation not restricted to astrology.

What's in a name?

The noble name 'Astrolabe' has recently been hijacked by a group of American astrologers,[27] who fortunately refer visitors to their site to the webpage of Jim Morrison for information on the instrument. It has also been used for ships, ice-breakers, reefs, lagoons, hotels, restaurants, wines, apps, and more. A tech startup company called 'AstroLabs Dubai' recently came into being, apparently without anybody there knowing what an real astrolabe was – see below.[28]

The tradition apparently started in the 12th century with the French scholar Pierre Abélard and his lady Héloise, who named their son 'Astralabe'.[29]

Astrologers discover the astrolabe

The astrologer *cum* magician Jarkmand de Vries is rightly much taken with astrolabes:[30]

> "My fascination with astrolabes began a while ago, but I think it stems mainly from my fascination with clockwork and mechanical devices in general (I'm a bit of a steampunk tragic, but it's tough to translate this into Ars Magica as it stands although perhaps exciting as a variant setting). The image to the right is one of the most interesting I've found, a spherical astrolabe that would be almost impossible to craft with thirteenth [read: fifteenth] century technology, but potentially simple with Hermetic craft magic. I think a spherical astrolabe would make a great talisman concept for an astrological magus and is distinct enough from an armillary sphere to play a potential role in ArM5 (Ars Magica Fifth Edition) Sagas."

This requires no commentary, and it is the late-15th-century Oxford spherical astrolabe to which the author refers, and which he presents an illustration. The same author continues on another undated page on the same site:[31]

> "Although only recently introduced into Western Europe in the 11th century via Iberia, the planispheric astrolabe (*Greek:* "star

> taker") has a long history of use in Andalusia and the Levant, having been built by the Persian mathematician al-Fazari, although probably from ancient Greek descriptions. As an analog calculator comprised of a flattened planisphere and an *alidade* (sighting ruler), it allows the calculation of a multitude of spherical astronomy problems, assists navigation, helps determine the timing of morning prayers and aids in finding the *qibla*, the correct direction of Mecca."

The accompanying illustration promises an English astrolabe but delivers one made in Morocco *ca*. 1200. al-Fazārī was not a Persian. The rest of the text discusses the manufacture of astrolabes without magic but soon loses control.

***

On that same website for astrologers from 2010 we find an article promisingly entitled "The wonder and beauty of the astrolabe".[32] A beautiful detail of a Fusoris astrolabe (from the Greenwich collection) invites our attention: "If you look closely, you can see astrological signs inscribed on this astrolabe's face". There are, however, no astrological signs, simply the names of the zodiacal signs around the ecliptic. The author begins:

> "In fact, it was with the astrolabe that my interest in astrology began. My fascination with them stems from the elegance of converting a map of the heavens into what is essentially a clockwork mechanism, so that the astronomer/astrologer could observe the movement of the spheres simply by adjusting components, observing the location of both visible and occluded planets. Once those components were adjusted, no matter whether it was day or night, the user could determine his location based on the position of the stars and planets. This was an incredible technological advance, and not an insignificant one for those who existed for millennia without electrical light or the wristwatch.
>
> "The reason we are on astrolabes at this point is very simple: it is probable, although not certain, that the Persians created the earliest fully functional astrolabes. Ibrāhīm al-Fazārī (either Persian or Arabian, historians are not sure), is said to have been the inventor of the first true astrolabe (although its history goes back to the

> Greeks, as I shall discuss below). The oldest known astrolabe still in existence was made by a man named either Nasṭūlus or Basṭūlus, depending on who is doing the interpreting in which language, Persian or Greek."

In fact, the name Nasṭūlus is (medieval) Arabic, and the man concerned with a Muslim Arab in Baghdad *ca*. 900. It is time for us to move on.

Uninformed academics on the astrolabe

The spectacular exhibition "*Circa* 1492" at the National Gallery of Art in Washington in 1992 included the magnificent British Museum astrolabe by ʻAbd al-Karīm al-Miṣrī, made in Damascus (?) or Mayyafariqin (?) in 1235/36. A renowned historian of Islamic art wrote the description in the catalogue. Although he could handle the decoration and the inscriptions, he was unable to present a viable account of what an astrolabe actually is:[33]

> "The astrolabe, the most important astronomical instrument of the Middle Ages, was designed to measure the altitude of the stars, moon [!] or sun without any mathematical calculation [!]. It was used in much the same way as the astronomical quadrant [!] or sextant [!], but in addition it bore various diagrams [?] or scales [?] which made it possible to determine immediately the positions of the sun, moon and planets [!] – most significant, the earth [!] – in relation to the fixed stars [!]."

Where the author got the clever idea that with an astrolabe one could determine the position of the Earth I do not know. In his detailed account of the rete and back he completely ignored the plates, which hold the key to the enigmatic geographic provenance of the piece.

***

A medievalist website, which one would expect to be halfway serious, has recently discovered that the astrolabe is a "medieval multi-tool of navigation'', the "Swiss Army knife of medieval travellers''.[34]

***

Some students at the University of Oklahoma, using the *Wikipedia* article but hopefully without the help of their professor, have this year (2017) posted the following uses of astrolabe:[35]

- to identify stars [how can you identify a star in the sky by looking

at a rete?] or planets [!];

- to calculate the position of celestial objects [?];
- to determine local latitude [!] given the local time [!] and vice versa [it is the vice versa which is the most important use of the instrument];
- to measure the time of the year [really?];
- to compute what part of the sky is visible [how can you compute that? certainly an astrolabe reveals it at a glance];
- to predict celestial events such as eclipses [that would be really clever since the moon is not featured on the astrolabe];
- to triangulate current location [no, one can determine the position of a distant location by measuring its direction from two different locations relative to the line between them];
- and it can be used at night or day [*contra* several sites which maintain the astrolabe can only be used at night [!]].

***

The National Museum of American History, home to the largest astrolabe collection outside Europe, has a description of their 1537 astrolabe by Georg Hartmann[36] of Nuremberg which begins: "

> "The astrolabe is an astronomical calculating device used from ancient times into the eighteenth century. Measuring the height of a star using the back of the instrument, and knowing the latitude, one could find the time of night and the position of other stars. ... ."

The implication is that the astrolabe can only be used for timekeeping at night.

The answer to the question "What is an astrolabe?" provided by study.com[37] is:

> "The astrolabe was a two-dimensional, movable disc with a sighting arm used to line up celestial bodies above the horizon to determine their altitude. Knowing the altitude made it possible to predict the locations of the sun, moon, stars, and planets. ... ."

So be it.

A Turkish researcher in geography, Yasemin Nemlioğlu Koca, has

recently published an article in Turkish about the astrolabe in general and some astrolabes in Istanbul collections in particular.[38] Alas this study was not controlled by a historian of astronomy. The abstract reads as follows, unaltered but for explanatory information in square brackets:

> "Astrolabe which was a device used on navigation by navigators until the 18th century, was used in areas such as representing of the various graphical problems, measuring of the altitude angels of the stars, determining of the latitudes, measuring of the time, obtaining information about the zodiac and etc. in astronomy. Astrolabe which was a portable device like a quadrant and used upright on observation, the altitude and positions of the stars and the sun were measured and located by an astrolabe on the horizon. Astrolabe was the most common and best-known device in astronomy and known by the Greeks in the 2nd-4th centuries BC. It can be known that, however it was developed in ancient times, its variations and usage was increased in the Arab-Islamic culture in the 8th-9th centuries. Astrolabe which was learned by Muslims during the period of the Crusades and the Andalusia, was used on the open sea navigation especially by the Spanish and Portuguese navigators thanks to its practical usage about measuring of the latitudes according to the polar altitude. Towards the end of the 15th century, astronomy studies which were developed as a continuation of the Islamic culture in Ottoman were institutionalized and continued in "Müneccimbaşılık" [the office of chief astronomer]. The using and producing of astrolabes were continued until the 18th century in muvakkithanes [buildings attached to major mosques for the use of astronomers] and observatories under this institution. There are protected and extant examples of astrolabes in the various museums in İstanbul. The article aims to study, the principles, usage and extant examples of astrolabe on the İstanbul Topkapı Palace Museum, İstanbul Kandilli Observatory and İstanbul Maritime Museum."

The article confirms what is in the summary. The instruments from the Istanbul museums have already been catalogued elsewhere. The instruments made in Istanbul but preserved in museums elsewhere are not mentioned.

Astrolabes and pirates

Rob Ossian's "Pirate Cove" site has an entry on the astrolabe, with a mention of how to use one:[39]

> "Astrolabes are used to show how the sky looks at a specific place at a given time. This is done by drawing the sky on the face of the astrolabe and marking it so positions in the sky are easy to find. To use an astrolabe, you adjust the moveable components to a specific date and time. Once set, the entire sky, both visible and invisible, is represented on the face of the instrument. This allows a great many astronomical problems to be solved in a very visual way."

Now there is much to be said for this account for at least it is original and honest and it is correct. Unfortunately, it is followed by some misinformation from the *Wikipedia* "Astrolabe" article, and a quick but reasonable overview of astrolabe history, considerably more than most pirates would venture.

***

So what is an astrolabe? Readers still curious can go to worldhistory.biz and find all they need to know in a few hundred words.[40] The only thing wrong with the text there is that it has obviously been scanned from another. Thus page-breaks in the original have become new paragraphs and 'ū' has become 'ii' or 'ti'. No source is mentioned for the original text but at least the jokers at worldhistory.biz didn't suppress the name of the author of the original text they had pirated to produce this 'page'. Thanks at least for that.

The pirates at worldhistory.biz did include a wretched image of a very important astrolabe in Cracow on which one cannot read any of the engraving. I checked my original publication and to my surprise found the same image there too: it had been inserted by the publisher or the editor without my knowledge. Of course I have a set of excellent photos that were used by my colleague in Frankfurt, Kurt Maier, when he published this precious instrument (see Part I). So least in Maier's publication one can see the original Arabic and later Catalan additions. The photo credit on the worldhistory.biz site from a New York agency states that the additional markings were put on the instrument in Italy.

How not to use an astrolabe

Brother William (Sean Connery) held up an astrolabe toward the moon in "The Name of the Rose". This was not a good idea. Looking at planets is also not calculated to achieve much because if you measure the altitude of a planet there is not much you can do with that information. Neither the moon nor the planets are marked on the rete, for reasons that would take too long to explain. That's the way it is.

***

In an article published in an English newspaper in Turkey in 2016,[41] we read:

> " ... . The astrolabe has many uses, including allowing people to identify and/or predict the position of the sun, the moon, the planets and stars. It is possible to use the astrolabe to determine the time or the time in another latitude (or if you know the time, but do not know in which latitude you happen to be [!], you can find this out using an astrolabe). ... ."

These remarks show a basic misunderstanding of the way in which time was reckoned in medieval days, as well as of the way in which people wasted their time between different latitudes. Why would a hapless medieval want to know the time in other latitude? He might want to know it in a different locality, but that is another matter.

***

William Harris has contributed information on the subject "How Astrolabes Work" to a site howstuffworks.com.[42] His distinction between two types is cute, his descriptions absurd:

> "Planispheric or Maritime, Madam? Zip back to the ancient world and you'd encounter two basic types of astrolabes. The first type, known as a planispheric astrolabe, helped astronomers calculate the positions of celestial objects [!]. All early astrolabes were of the planispheric sort until seafaring folks saw how useful the instruments could be [?].
>
> By about the 15th century, maritime astrolabes began appearing. They were like hacked versions [!] of their planispheric cousins [!], used primarily to determine the altitude of the sun or a star, which could then be used to determine latitude. They came with two basic parts – a graduated circle and an alidade, a sighting device or pointer used to measure angles. Planispheric astrolabes

> were a bit [!] more complicated. They were also more idiosyncratic [!] because their operation depended on the user's latitude."

I just love the last two sentences.

***

In a webpage on Islamic astronomy on the site "Explorable – Think outside the box" we read:[43]

> "The astrolabe, used for measuring latitude, was invented by the Greeks, but the Islamic astronomers refined the equipment, improving the accuracy and building beautiful, elegant instruments. Unlike the Greek predecessors, Islamic astrolabes were independent of latitude and incorporated complex gearing mechanisms to track celestial bodies."

Sometimes it is better to stay in a box. Astrolabes used for measuring latitude? Astrolabes independent of latitude? Astrolabes incorporating complex gearing mechanisms? Just one early Islamic astrolabe and two medieval French ones with a luni-solar gear mechanism have survived. The same author continues:[44]

> "Although there is a lot of debate about who built the first astrolabe, the consensus is that Hipparchus has that honor, using it as a much more accurate way of measuring latitude than a gnomon. The astrolabe is an instrument that allows observers to measure the position of celestial bodies relative to the horizon, which allows accurate star mapping. The utility of the instrument does not end there, because it can be used to measure latitude, give the local time and estimate the height of objects; astrolabes were used by surveyors for measuring distance through triangulation. The standard astrolabe consists of a disc with a rotating arm complete with sights, but quadrants, sextants and inclinometers all use the same principle."

Hipparchus preferred to use an astrolabe over a gnomon to measure his latitude? An astrolabe allows accurate star mapping? It's time to move on.

***

Not even professors master the use of the astrolabe. Richard Covington interviewed one for *Aramco World* in 2007:[45]

> ""See that light?" the professor asks, pointing to a ceiling fixture. "Hold the astrolabe up to the light, look along the pivoting ruler on the back and line it up with the light, which is your star," he explains. "Where the ruler crosses a scale that circles the back rim of the instrument, the number shows the altitude, in degrees, of that star above the horizon. You take that measurement and the sun's celestial longitude, using the separate calendar scale on the back, match them up with the star's altitude and the sun's coordinates on the front of the astrolabe, and you can determine the name of the star and its location.""

Again the mind boggles.

Videos on the use of the astrolabe

The blurb on TED.com to introduce Tom Wujec's fine presentation of the use of an astrolabe,[46] mentioned in Part I, reads:

> "With thousands of uses, from telling time to mapping the night sky, this old tech reminds us that the ancient can be as brilliant as the brand-new."

"Mapping the night sky"? This has already been done for you: the rete is a map of the night sky. Nobody ever mapped the night sky with an astrolabe. It is not recommended.

***

A video recorded for a Malaysian TV station features a serious historian of astronomy and specialist on the astrolabe and confirms that an informed scholar can hardly share his knowledge whilst being bombarded with uninformed questions.[47] This is especially the case when the interviewer has no idea what an astrolabe is; she gets the discussion off to a bad start by reading aloud the first paragraph of the *Wikipedia* "Astrolabe" article.

***

Then there is the problem of serious museums with important collections of historically-important instruments that pander to the public with materials, written or visual, that are an insult both to the instruments and to the public. One such museum is the Germanisches Nationalmuseum in Nuremberg, which possesses the richest collection of medieval and Renaissance astrolabes in Germany, has allowed the

diffusion of a video of some seven minutes' duration attempting to feature the importance of the collection and displaying bits and pieces of one astrolabe "in focus". We should not blame the Museum: the fault lies more with a program at the University of Erlangen which produced this pathetic video. No astrolabe should be viewed "in focus" just suspended in space without taking it apart or trying to use it.[48]

The discussion of the astrolabe on Muslim.Heritage by Emily Winterburn, mentioned in Part I, is well thought out and mainly adequate. However, the many illustrations need better captions and the section on horoscopes is misleading (because one can not draw up a horoscope with nothing but an astrolabe). Also for a website of this kind the opportunity to explain the way in which some Islamic astrolabes can be used to find the times of all five daily prayers was lost.

A video of myself talking about the astrolabe was made by Muslim Heritage at The University of Sharjah in the Emirates some 10 years ago but the video was also lost.

Illustrations and videos featuring individual astrolabes

Darin Hayton illustrates his *Introduction to the astrolabe* (2012) with bits and pieces of a pretty astrolabe that is a recent replica by Martin Brunold. Why not mention that the original is a Catalan astrolabe from *ca*. 1300? Why not state that the instrument is one of the few medieval European astrolabes to have been published in great detail? And why use a replica anyway, when there are hundreds of real medieval European astrolabes available?

***

A visitor to the Pergamon Museum in Berlin noticed an astrolabe in a case and put an image of the front of the instrument on the website *The Mathematical Tourist*. The briefest information is given about this piece, with a statement that it is "unique!".[49] It is indeed unique, and it is a pity that the instrument is just hanging in a case and is not displayed properly, with all of its parts showing. The piece is indeed an astrolabe, with a plate for the latitude of Baghdad, but it also houses the sole surviving Islamic equatorium, a brilliant device for calculating solar, lunar and planetary positions, with the mean motions of the seven bodies displayed in tabular form on some of the plates. The device was

invented by the astronomer-mathematician Abū Jaʿfar al-Khāzin of mid-10th-century Khurasan, and this sole surviving example was made by the renowned Baghdad instrument-maker Hibat Allāh al-Baghdādī in 1120. This piece was thought to have disappeared during air-raids on Munich in World War II. But some photos surfaced in Paris in the 1970s and I published them in 1980, and then the complete instrument was rediscovered in a cellar of a Berlin museum. And by then a treatise by al-Khāzin on the use of his instrument (and much more) had been rediscovered on Srinagar. Thanks to the informed tourist who realized the importance of this piece!

In a charming display of incompetence gettyimages.de offers an image of what is arguably the most historically important astrolabe preserved in any German collection – this 12th-century astrolabe *cum* equatorium of Hibat Allāh al-Baghdādī – as a "universal astrolabe", which it is not, made by "Allah al-Baghdadi", which was most certainly not the maker's name.[50]

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An astrolabe by Aḥmad ibn ʿAlī al-Sharafī of Alcalà (east of Madrid) dated 729 Hijra (= 1328/29) and preserved in the National Maritime Museum in Stockholm is insulted on the discoverislamicart.org site (taken from *Museum without Frontiers*?) to the extent that the accompanying image is of a modern fake astrolabe.[51] Even the maker's name is misspelled.

***

The website discoverislamicart.com defines the astrolabe as "a medieval scientific instrument used for astronomical calculations and navigation", and is doing further damage to our field by producing inadequate images and sloppy descriptions of various historically important astrolabes. Consider what they have wrought with the 11th-century astrolabe of Ibn al-Ṣaffār of Córdoba preserved in Edinburgh. There are images of the front and back, but no plates (why not show the plate for Córdoba?), and in a whole page of text there is one rather important sentence that states that the rete is a considerably later Persian replacement. The astrolabe itself is referred to as "European-made", by which is surely meant "made in Europe (by a Muslim) craftsman)". Inevitably, it is also stated that the astrolabe was used for

navigation, and maybe indeed somebody once took it on the River Guadalquivir. In the site of the so-called "Museo Imaginado de Córdoba" we find the same information repeated, but the fact that the rete is a later replacement is now omitted.[52] Perhaps that piece of information would be inappropriate for "the oldest (known astrolabe) manufactured and dated in Europe".

***

A video produced by the Museum of Islamic Art in Doha of an important astrolabe by the astronomer Ibn Bāṣo of Granada, dated 1309/10, shows snippets of the front and back with the alidade carefully covering part of the maker's signature. The video can serve no useful educational purpose.[53]

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On the web-page of 'Islamic Studies Online' there is a section on "Islam and Science" with such a strong philosophical bent that it says nothing of consequence about Islam or Science or Islamic Science.[54] The text begins:

> "The debate over Islam and science covers a wide range of issues and extends from political leaders and experts to the public at large. Revealing the ever-present tensions between theory and practice, this debate takes place at two levels: practical and intellectual."

This at least explains why there is a problem. Appropriately the text is illustrated with the image of an unidentified astrolabe, actually one by Jean Fusoris of Paris, *ca*. 1400.

The web-page of the Sharjah International Foundation for History of Arab and Muslim Sciences[55] features a modern copy of the backside of a German astrolabe dated 1509. This appeared out of the blue after I, as a member of the Board of Trustees, suggested they find a new logo. However, the old logo has been maintained: it is the rete of a Fusoris astrolabe (Paris, *ca*. 1400). Alas I was not asked to provide an image of any of the hundreds of available Islamic astrolabes.

An outfit named *Hemisferium* produces models of historical instruments in various sizes.[56] The packaging for its miniature astrolabes bears the blurb:

> "From the Greek 'star searcher' this instrument was introduced in

> Europe by the Arabs [DAK: no, it was not; it was introduced by Europeans smart enough to have learned from the Muslims]. It became [?] a vital tool for astronomers, astrologers and surveyors. Among other calculations one can establish the height of the sun, the planets [?] and the stars, determine time and latitude, measure heights, calculate distances and astrological implications."

At least the navigators have gone, not least because models of the mariner's astrolabe are also available. The planets are still there. The astrolabe was not introduced in Europe by the Arabs; it was introduced by eager Europeans who went to Córdoba to learn from Muslim savants, or who learned their limited skills by way of Jewish translators ... . But it always has to be about 'us'. One cannot determine time with an astrolabe before one knows one's latitude. The mini-astrolabe has the alidade on the front, which takes us back to the mid 20th century when alidades were often wrongly placed on the fronts of astrolabes on display or before the camera. The website betrays a Spanish source for *Hemisferium* and the above text is less accurate than the Spanish original.

Modern astronomers have a look at the astrolabe

A website featuring images of the astrolabe prepared by the Planetarium in Montgomery College in Maryland starts out reasonably but then shows a fake rete, confuses azimuths with almucantars (altitude circles), as well as seasonal-hour curves with hour-angles, ... , and has a general tendency to lose the plot.[57]

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A description of the astrolabe published by an astronomer at the Institute for Astronomy at the University of Hawaii in 2003[58] informs us:

> "An astrolabe is a two-dimensional model of the celestial sphere. ... (It) is an instrument that once was the most used, multipurpose astronomical instrument. Historically, astrolabes were elaborately inscribed brass discs [!]. The portability and usefulness of an astrolabe made it something like the multipurpose "lap-top computer" of our predecessors. With an astrolabe, an astronomer could make quite accurate measurements of the following things:
>
> position of celestial objects;

- measure the time of the night (or of the day, using it as a mobile sundial [!] or, more accurately by measuring the altitude of the sun);

measure the time of the year [!];

- compute [!] what part of the sky is visible at any time;
- determine the altitude of any object over the horizon;
- determine the current latitude, and
- determine (very accurately) the NPS orientation."

- Now most of the uses of the astrolabe listed here are not completely unreasonable. But one does not "measure" the position of celestial objects; and normally one has a fair idea of the time of the year. A user would only need to measure his/her own latitude once (most folk would be happy to use a plate with their own locality marked on it). Further, we are witness here to the way the ridiculous idea of **the astrolabe only being usable at night** comes from. Using the astrolabe as "a mobile sundial" sounds crazy but, as mentioned in Part I such a sundial device was conceived by the Greeks and survives on some early Islamic astrolabes. This information is irrelevant here.

I do not understand how one can "determine (very accurately) the NPS orientation", because I do not know what NPS stands for. If it stands for "North Pole Star" then we have a problem because this NPS is not actually situated at the celestial pole (this was known, for example, to medieval Arab navigators), and the pointer for the NPS on an astrolabe rete is the most sensitive pointer (or marker on the central ring), and the one most prone to error. Also Honolulu has a latitude similar to that of Mecca, so the NPS is fairly low on the horizon. On the other hand, NPS may stand for "National Park Service". And Hawaii is full of national parks that maybe an astrolabe would be useful to find one's way to, around, and out of any of these. And this NPS does offer Astronomy programmes.

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In *Cosmos – Study Astronomy Online Encyclopedia of Astronomy*, put out by Swinburne University of Technology in Australia, we read in

the entry "Astrolabe" stuff that could hardly have been first penned by an astronomer:[59]

> "Astrolabes could only show one hemisphere of the night sky [rubbish!], with the north celestial pole corresponding to the centre of the mater. The night sky (i.e. circles of altitude) [?] were then projected onto the disk [?], with the outer edge of the mater corresponding to the limiting declination of the device. The rete was used to locate [?] the ecliptic – the path of the Sun through the sky, and the location of several prominent stars. Once the altitude of a star was determined (using the alidade), the rete was rotated until the star was aligned with the correct 'circle' of altitude. The centre of the rete was off-axis, to allow for the different stars that appeared throughout the year. As an observer moved to different latitudes, the actual spherical projection required to map the night sky to a flat disk changed [?]. Rather than limiting an astrolabe to a single observing location, interchangeable disks were manufactured: called climates [nuts!]. The observer would choose the climate suitable for their latitude, and the measured altitudes of stars would be consistent with the coordinate lines engraved on the astrolabe [?]."

The mind boggles. But astrolabes have never been made down under. The night sky is also the day sky. Several websites state that an astrolabe can only be used by day, I guess because the sun does not seem to appear on the rete and folk don't know about the ecliptic.

***

Even the website of the august Smithsonian Institution has recently published a ridiculous article on the astrolabe in which the splendid astrolabe collection of the Smithsonian's National Museum of American History is not even mentioned.[60] The author cunningly confuses the astrolabe with the mariner's astrolabe, so that it can be used at sea. "Astrolabes had blended uses, from scientific to what we would today consider spiritual'', referring to the Muslim requirements of five daily prayers towards Mecca, and Christian European decisions from "when to go to battle to how to go about bank dealings''. The author had no idea what an astrolabe is, or what it does, but she was happy to suggest to innocent readers that it was a precursor of the Smartphone. Alas, she cannot claim that her article serves the

Smithsonian Institution's noble mission to serve "the increase and diffusion of knowledge''.[61]

Writing about Benjamin Franklin in the early 18th century colonial America, another author in the Smithsonian magazine wrote in 2017:[62]

> "Accurate instruments, such as the astrolabe, allowed people to measure the motion of the planets and thus predict movements in the heavens, particularly phenomena like solar and lunar eclipses and the motions of planets like Venus."

This curious nonsense was certainly not taken from the Smithsonian's astrolabe catalogue.

Just as pathetic are two pages on the site of the Smithsonian's Air and Space Museum dealing with the astrolabe, which is illustrated with four instruments from the NMAH.[63] We read:

> "The Astrolabe. Islamic Astrolabe (illustrated). Astrolabes served as mechanical [?] maps of the Universe [?]. Sophisticated, hand-held instruments, they were used for centuries to teach people about the sky [really?]. The back side had a moveable sighting arm and a scale of degrees for measuring altitude. The front side was engraved with a flattened map of the heavens [!], which was used with other moveable parts to solve practical astronomical problems. This astrolabe has several interchangeable plates, each engraved with the celestial coordinates [?] for a different latitude. The pointers on the top plate [!] indicate the positions of 22 bright stars. The top plate can rotate to show where those stars will appear at different times or dates, much like a modern paper or plastic star finder. The instrument could also be used to predict [?] when the Sun or certain bright stars would rise or set on any date."

The astrolabe displayed is a poor quality Indo-Persian one from *ca*. 1800. Although it bears a very dubious 'signature' of the celebrated mid-17th-century astrolabist Muḥammad Mahdī of Isfahan, it bears but faint resemblance to his excellent work, a fact noted in the 1984 NMAH astrolabe catalogue. Maybe the Museum wanted to honour the donor (I.B.M.) more than the astrolabe; that would explain why it seems to be the only astrolabe out of some 40 pieces that features in multiple superb images on the Smithsonian's own site.[64] All of the astrolabes illustrated on that site are marked "Currently not on display". Missing from the

archive are the few astrolabes that are of extraordinary historical importance. In any case, as far as Islamic pieces are concerned, the NMAH has a real treasure of an instrument by Ibn Bāṣo of Granada dated 1304 that could be used on future occasions. Or the very fine astrolabe made by Hāmid ibn Maḥmūd al-Iṣfahānī in Isfahan in 1152. Anything is better than the late Indo-Persian junk that features on the website. Our text continues:

> "French Astrolabe (illustrated). When this astrolabe was suspended from the ring at the top, the sighting arm and scale of degrees on the back could be used to measure the height of the Sun or a star above the horizon. Such measurements could be used to determine latitude [silly!] or the time of day or night [yes!]. **This astrolabe was made about six centuries after the Islamic astrolabe**."

The astrolabe illustrated is signed by I. Galois and dated 1548. The (single?) plate serves latitude 48°, a value often used for Paris. A far more important European astrolabe from the NMAH, and far more photogenic, would have been the charming zoomorphic astrolabe from 14th-century England. The last sentence in our text (my emphasis), if taken at face value, would mean that the French astrolabe was actually datable to the year 2400 C.E.

Equally worthless is the information provided on the quadrant:[65]

> "Quadrant. Quadrant astrolabe (illustrated). Quadrants were used to measure altitudes of celestial objects and were especially useful for mapping the sky [? DAK: the sky is already mapped!]. They consisted of a sighting device mounted on a quarter circle, or quadrant, which was engraved with degree markings. Quadrants ranged in size from small hand-held or table-mounted versions to large mural quadrants mounted on walls. [DAK: These instruments are less related than the author imagines.] This rare instrument – only seven dating from medieval times are known to exist – combines the features of a quadrant and an astrolabe [nuts!]. Essentially, the circular face of an astrolabe has been "folded over" twice to create a quarter-circle [DAK: This is a very clumsy description, which also makes little sense.]. This instrument could serve as a measuring tool and perform many of an astrolabe's calculation functions as well [DAK: Not so. The so-called

> Profatius quadrant can perform only a selection of functions because it bears no altitude circles. The astrolabic horizons are useful only for calculations relating to horizon phenomena. The universal horary markings serve only approximately for finding time from solar latitude.]."

Here the instrument illustrated is a superb medieval English quadrant, one of two in the NMAH collection, the other being engraved on the back of the zoomorphic astrolabe mentioned above. Both await serious study.

The astrolabe at the hands of scientist and medievalist dilettantes

Kristine Larsen is an astronomer who is Professor of Physics and Astronomy at the Central Connecticut State University. In addition to many publications on popular astronomy, she regularly writes about the astronomy and cosmology of J. R. R. Tolkien's Middle-Earth.[66]

Larsen has presented workshops on how to use an astrolabe in Paris and Kalamazoo. In 2015 at the International Congress on Medieval Studies at Leeds, Larsen gave yet another workshop on how to use an astrolabe, basing her exposition on Chaucer's *Treatise on the astrolabe*.[67]

One of the participants in that workshop was Danièle Cybulskie, author of a book(let) entitled *The Five-Minute Medievalist* and one of the editors of medievalists.net.[68] Cybulskie published her report on medievalists.com[69] with the following title, already pregnant with possibilities for absurdities:

"The Astrolabe: Medieval Multi-Tool of Navigation".

The text begins:

> "Of all the many sessions I've attended at the International Congress on Medieval Studies, one of the most enlightening was a workshop by Dr. Kristine Larsen of Central Connecticut State University that taught us how to use a medieval astrolabe. I will admit to only having a vague notion that astrolabes used stars for navigation (?), but I learned they have many essential uses such as telling time, predicting where the sun and stars will be at any time on any given day, and figuring out your location [!]. They were the Swiss Army knife of medieval travellers.

> "A helpful medieval instruction manual for learning how to use an astrolabe, and the focus of Larsen's workshop, is Chaucer's *A Treatise on the Astrolabe*, which he wrote for his son "Lytel Lowys" circa 1391 CE. ... ... Like so many educational manuals that have come to us from the Middle Ages, *A Treatise on the Astrolabe* is as useful for teaching a room full of medievalists as it was for its intended audience.
>
> "The back of the astrolabe, we learned, is designed to help determine the position of the stars [!] on a certain date [!], using months, days, and zodiac signs as indicators [!. Turning the dial [?] on the back to March 12 (the date Chaucer uses in one of his examples [DAK: I wonder why.]) indicates that the sky above is at the beginning of Aries. Once the position of the zodiac is determined, the astrolabe can be flipped over [?] and its plate turned to find out the more practical details, such as when the sun will rise and set; what position the sun will be in at a certain time of day; how high the sun will be from the horizon; and how long the day or night will be. This is all determined from geometry: the time of the sunrise on March 12, for example, is when the line [?] on the plate [?] indicating the beginning of Aries [?] intersects the horizon line on the surface [?] of the astrolabe (in the section indicated as the eastern sky). The sun is not the only star that this works for, either. A medieval astrolabe can figure out [?] the position of other bright stars, such as Vega and Sirius, using the same methods. Celestial movements can be calculated from already knowing the date and location, or the astrolabe can be worked backwards [?] to figure out what the date and location are. The advantage is, you never have to plug in or download a map [!]; the disadvantage is that you need a somewhat clear sky."

One might be forgiven for thinking that even a medieval village idiot might have known that the length of daylight on the day of the equinox (no mention of this word in the text) was 12 hours. Our text continues:

> "While Chaucer's son Lewis may only have used an astrolabe to satisfy curiosity, astrolabes were vital to sailors [!] who navigated out of the sight of landmarks, and for traveling Muslims [!] who needed to determine the location of Mecca and the correct times to pray (incidentally, using an Islamic astrolabe is going to be

> Larsen's workshop next year at the ICMS [DAK says: أعوذ بالله *aʿūdhu bi-llāhi*]). Astrolabes at different latitudes required different geometry [?] to make precise calculations, so travellers who intended long journeys north to south (or vice versa) carried several plates to switch out when they changed latitude.
>
> "Far from being a primitive tool, the astrolabe proves our ancestors' deep knowledge of astronomy and geometry, as well as their immense skill in precise and delicate metalwork. Incidentally, it also requires [??] a concept of a three-dimensional, spherical Earth, another nail in the coffin of the myth of the flat Earth [!!]. (Otto Neugebauer suggests that the type of astrolabe medieval people would have used can be dated back to circa 375 CE, although similar devices are even older [?]. This article – **click here** – shares many stories as to what was thought to have been its origin.)"

Now the article clickable here is my own 1981 study "On the origin of the astrolabe according to the medieval Arabic sources", which deals mainly with legends and etymological considerations. This article, which is perhaps the least important of numerous publications of mine on the astrolabe or on individual astrolabes, has been pirated by medievalists.net, without mention of the source or date, and without permission of the author,[70] although that would have been forthcoming. I began that article by quoting Otto Neugebauer, the leading historian of ancient astronomy in the late 20th century, because he was the best authority on the actual history of the mathematical notions underlying the instruments.

Our author continues:

> "If you want to try making your very own astrolabe, James E. Morrison's website has printable patterns for many different locations, including Chaucer's Oxford. As Larsen mentioned in her workshop, bear in mind that Chaucer used the Julian calendar (not our current, Gregorian calendar), so there is a nine-day difference between Chaucer's indicated dates and ours (for example, Chaucer's March 12th is our March 21st). [DAK: It is still not too late to mention the word equinox.] Adjusting the date will give you an accurate reading on your homemade astrolabe, just as it would have for Chaucer. As the weather in the northern

> hemisphere makes it much more pleasant to be out at night these days, grab your homemade astrolabe and Chaucer's *Treatise* and impress your friends with your vast knowledge of medieval astronomy and ability to predict the sunrise. For Dr. Kristine Larsen's next project – a book on medieval astronomy – **click here**."[71]

Indeed your friends will be impressed to hell and back if you can use your astrolabe to determine the time of sunrise on the day of the equinox.

The book by Larsen that is here promised has the catchy title *Fiery Drakes and Blood-Drenched Moons: A Practical Guide to Astronomy in the Medieval World*. Its table of contents fortunately promises much more astronomy than mediaevistics. But, inevitably, a section on the astrolabe is threatened.

Cybulskie's report is illustrated with an image from 'Viewminder / Flikr' of "Chaucer's Astrolable [*sic*]". The instrument displayed is a modern copy of a Chaucer-type astrolabe. There are plenty of original 14th-century English astrolabes that she could have used.

The only points I wish to make regarding this circus performance are the following: The astrolabe is a complex device which takes a modicum of scientific, technical, historical, and artistic understanding to appreciate. To present the astrolabe to others without understanding what it is is a pedagogic travesty. A workshop on the astrolabe for medievalists by an astronomer who has obviously never seen an astrolabe but who takes it upon herself to introduce the instrument to medievalists? Shame on the International Congress on Medieval Studies for not seeking advice from any of the leading scholars of medieval astronomy and instrumentation – recognized academic subjects represented by several scholars in the UK, let alone in Europe and the US. It was in England that books such as *Astrolabes of the World* (1932), *Chaucer's Universe* (1988), and *Astrolabes from Medieval Europe* (2011) were published. And shame on medievalists.net for not realizing that astrolabes deserve as much respect as, if not more than manuscripts and psalters, armour and trebuchets, saints and relics, and all aspects of church and secular architecture.

European absurdities on the astrolabe

Not only in English do we find such fake news about the astrolabe. A German children's book on the Middle Ages[72] presents a picture of an 11th-century Andalusī astrolabe from the rich collection of the Germanisches Nationalmuseum in Nuremberg, which I actually catalogued over 25 years ago, with the following absurd caption:

> "Mit dem Astrolabium (11. Jh.) konnte man den Sonnenstand bestimmen [!] und bei Nacht [!] die Zeit messen, was die Orientierung auf See sehr erleichterte [!]." / "With the astrolabe (11th century) one could determine the position [?] of the sun and at night [!] measure the time, which much facilitated orientation [*i.e.*, finding one's way] at sea [!]."

This is the more sad because some of the best writings on the astrolabe are in German. Not only the catalogues of the principal collections in Germany, namely, Nuremberg and Munich, provide reliable overviews, but once there was also a German translation of the Greenwich booklet available at the Deutsches Museum in Munich. As already noted, the German *Wikipedia* article "Astrolabium" is acceptable, unlike those in other languages.

For example, the French *Wikipedia* article "Astrolabe" begins:

> "L'astrolabe (du grec *astrolabos* « instrument pour prendre la hauteur des astres » ou *Almincantarat* en arabe) est un ancien instrument astronomique, à vocation plutôt didactique depuis la Renaissance. Outil aux fonctions multiples, il permet notamment de mesurer la hauteur des astres et de lire l'heure en fonction de la position des étoiles ou du soleil. Sa conception et ses différentes constructions s'appuient à l'origine sur une double projection plane (le plus souvent une projection polaire) qui permet de représenter le mouvement des astres sur la voûte céleste." // "The astrolabe (from the Greek *astrolabos*, instrument for taking the altitude of the stars or Almincatarat in Arabic) is an ancient astronomical instrument, more didactic in function since the Renaissance. ... ."

The nonsense about the name is taken from a Hachette dictionary (where else?). The term المقنطرات , *al-muqantarāt* in Arabic refers to the altitude circles on astrolabe plates; it was <u>never</u> used for the astrolabe (except, perhaps, by Hachette). There is an awfully long period of time

between Antiquity and the Renaissance that is not mentioned here. I did not translate the rest of the paragraph as it would only confuse any reader. It is barely worth reading, and definitely not when the author starts quoting the German popularist writer Sigrid Hunke's *Le Soleil d'Allah brille sur l'Occident < Allahs Sonne über dem Abendland* (1960). The astrolabe illustrated at the beginning of the article is not an "astrolabe persan du XVIII siècle" as claimed, but a poor-quality late astrolabe from Morocco. This image was immortalized by some *manḥūs* who had photographed it in the Whipple Museum of the History of Science at Cambridge and then submitted it as an "18th-century Persian astrolabe" to *Wikipedia* to be "a featured picture, which means that members of the community have *identified* it as one of the finest images on the English *Wikipedia*, adding significantly to its accompanying article".[73] It could h a r d l y be that the Museum staff had chosen one of the least important astrolabes of their collection and told the hapless photographer that it was from a place 5,000 km away from its actual place of origin.

***

An anonymous French site labelled "Repérage terrestre – Savoir où nous sommes pour savoir où l'on va" / "Terrestrial tracking – To know where we are and where we are going" has the following information for us:[74]

> "Cet instrument, conçu dans l'Antiquité, permet de mesurer la hauteur d'un astre au-dessus de l'horizon et de déterminer rapidement la position de la Lune, du Soleil ou n'importe quelle planète par rapport aux étoiles. // "This instrument, conceived in Antiquity, enables one to measure the altitude of a celestial body above the horizon and to determine quickly the position of the moon, the sun, or any (old) planet relative to the stars. ...

This is brilliant start, and it gets better. You hold the astrolabe up with the alidade pointing towards the sun or any star and ...

> "On lit alors les degrés sur le disque et il ne reste plus qu'à les convertir en degrés de latitude. // One then reads off the degrees (of altitude) and there is nothing more to do than to convert them to degrees of latitude.

Such an operation, if conducted successfully, would merit admittance

to the *Légion d'honneur*. In conclusion,

> "L'usage de l'astrolabe a été très répandu par les astronomes arabes dès le VIIème siècle [!]. Il servait principalement pour l'astrologie, l'enseignement de l'astronomie et le calcul d'heure. Mais jusqu'à l'invention du sextant au XVIIIème siècle, l'astrolabe fut le principal outil de navigation." // The astrolabe was widely used by Arab astronomers starting in the 7th century [DAK: actually the 8th, but *ma'lesh*]. It served principally astrology, teaching astronomy, and finding the time. But until the invention of the sextant in the 18th century the astrolabe was the principal tool of navigation."

Oh dear! Finding the time of day or night, astronomy education, and astrology would be more appropriate. But the author is so confused that he also mixes up two different instruments. Why not just look up a French site compiled by people who know what an astrolabe is and how it works, such as that of the association called *Méridienne* at Nantes?[75] What is particularly sad is that one of the very best books on the astrolabe from a historical and a technical point of view is the *Traité de l'astrolabe* by the Belgian engineer Henri Michel. It was published some 70 years ago, and it contains all that most folk need to know.[76] It was not appreciated by the French academics in Paris for reasons that need not be discussed here, other than that they were interested essentially only in medieval texts on the astrolabe. Nevertheless, it remains the best general introduction to the astrolabe in French.

***

A somewhat serious Italian site on the history of astronomy[77] claims that the astrolabe was already in use in the 2nd century BCE and that it was used for celestial observations [meaning what?], for determining angular distances from the moon [a new one on me!], for finding the time [yes!], like a sextant for navigation [omg!]. We read:

> "L'astrolabio è uno strumento astronomico che ebbe notevole diffusione nel Medioevo, anche se le sue origini risalgono ai greci (tale strumento era già in uso all'epoca di Ipparco [!]), ed era legato principalmente all'osservazione celeste; veniva usato per determinare le distanze angolari con la Luna [!!], per la determinazione dell'ora, come sestante per la navigazione … in

> pratica oggi potremmo considerarlo un computer analogico per l'epoca." // "The astrolabe is an astronomical instrument which had noteworthy diffusion in the Middle Ages, even though its origins go back to the Greeks (such an instrument was already in use at the time of Hipparchus [!], and was principally associated with celestial observation; it came to be used for determining angular distances from the moon [!!], and for the determination of time, like the sextant for navigation ... in practice today we can consider it as an analogue computer of its age."

Our anonymous author continues:

> "Inizialmente portato in Andalusia grazie ai numerosi trattati divenuti noti con il nome di *saphea*, fu introdotto dapprima in Inghilterra e in seguito in tutta Europa, ove Ermanno di Reichenau scrisse ufficialmente il primo trattato europeo sull'uso di tale strumento." // "Initially brought to al-Andalus thanks to numerous treatises that came to be associated with the name *saphea*, it was first introduced in England and then in the whole of Europe, where Hermann of Reichenau officially (?) wrote the first treatise on the use of such an instrument."

This is all very nice, but the universal astrolabe (invented by ʿAlī ibn Khalaf in Toledo *ca*. 1100), not the plate known as the *saphea* (invented by Ibn al-Zarqālluh, also in Toledo *ca*. 1100), reappeared in England in the 16th century. The monk Hermann wrote his treatise on the standard astrolabe in Reichenau on Lake Constance *ca*. 1000.

Very flat astrolabes

A potentially useful Australian video on the astrolabe presented by one "Brother Abu Ismael" is somewhat compromised by the author's association with a Muslim "Flat Earth" group.[78] Abu Ismael overlooks, amongst other things, the geodetic measurements commissioned by the early-9th-century Caliph al-Ma'mūn, whose purpose was not to establish whether or not the Earth was flat, but rather to derive a value for its circumference more accurate than that derived by the Greeks.

The video presentation entitled "Astrolabe explained" by one "Truth Pion" (2017) is well informed on the astrolabe and planetary astronomy in general, if related in a somewhat unexciting fashion.[79] But it turns out at the end that this too is a "Flat Earth" production.

The universal astrolabe / The universal plate

A common error in the modern literature is to claim that the universal astrolabe is an improvement over the standard astrolabe. It is simply different. Besides, very few universal astrolabes exist: two medieval Islamic examples, two Renaissance examples, one English and the other Spanish. Few modern sources illustrate their brief mention with an illustration of any of these. And few modern sources differentiate between the various universal plates that ended up inside standard astrolabes – the *shakkāziyya* and the Ibn Bāso plate – and the universal plate for celestial coordinate conversion – the *zarqālliyya*.

A researcher Nimira Dewji, devotee of the Aga Khan, has recently written these charming words on Ibn al-Zarqāllu and his universal plate:[80]

> "Ibrahim al-Zarqali (d. 1987 [*sic*, read 1087]), known as Azarch[i]el in the West, introduced a universal plate capable of calculations at any latitude, thereby rendering the astrolabe usable in any part of the world – it did not need electricity, batteries or WiFi!''

Words fail me.

A heliocentric astrolabe

It was inevitable that the زورقي *zawraqī* or "boat" astrolabe should confuse modern writers. A celebrated Iranian historian of Islamic philosophy declared that al-Sijzī (Iran, *ca*. 1000):

> "was particularly noted for constructing an astrolabe based on the motion of the earth around the sun."

Here we see total confusion.[81] Fortunately, this assertion does not appear to have been repeated left, right and centre in the more modern literature. But in defence of the author we should mention that al-Bīrūnī's discussion of this astrolabe does occur in the middle of a discussion of Muslim statements about heliocentricity, such as would have made Copernicus jump.

The mariner's "astrolabe"

This device is not an astrolabe in the sense that it serves only one simple function, measuring solar or stellar altitude, whereas the astrolabe, besides being a model of the universe, is a multi-functional instrument.

However, the astrolabe is for landlubbers and the mariner's astrolabe is for mariners, preferably for those who know what to do with the solar altitude once they have measured it. Some folk think mariners only used it at midday. In fact, one can actually use it throughout the day to find the time of day, if one has the necessary wits and the appropriate astronomical tables. Very few modern discussions of the mariner's astrolabe mention the simple tables one needs to use it effectively; this is because people do not like tables.

The author of the *Wikipedia* article on the mariner's astrolabe is, this time round, correct in labelling it an inclinometer: it is, in fact, nothing more than that. He/she writes:[82]

> "The mariner's astrolabe, also called sea astrolabe, was an inclinometer used to determine the latitude of a ship at sea by measuring the sun's noon altitude (declination) or the meridian altitude of a star of known declination. Not an astrolabe proper, the mariner's astrolabe was rather a graduated circle with an alidade used to measure vertical angles. They were designed to allow for their use on boats in rough water and/or in heavy winds, which astrolabes are ill-equipped to handle. In the sixteenth century, the instrument was also called a ring."

The expression "noon altitude (declination)" is very misleading, not least because most readers of the W*ikipedia* article will not know how the meridian altitude is related to the latitude and the solar declination. Here, as elsewhere, there is no discussion of the way one can find the time of day using such a so-called 'astrolabe'. If one could not, there would be no use for the astrolabe when one was travelling due east or due west. People just do not like tables.

***

A specialist on marine history, who need not be identified here, has written recently about 'real' astrolabes:

> "Astrolabes were widely used for astronomical observations and calculations, **for nautical and land navigation**, for surveying, for time-calculation, and so on."

So there really is no hope that normal people can be expected to know that **'real' astrolabes were never used for navigation**.

The mariner's "astrolabe" appears out of nowhere in the 15th century.

It has no known Islamic predecessors. Thus it is rather surprising to read on the website of the Royal Museums, formerly Royal Maritime Museum, Greenwich:[83]

> "The mariner's astrolabe was a simplified version of an instrument originally developed by Arab astronomers for measuring the height of heavenly bodies above the horizon and came into use in navigation by about 1470."

Actually, Arab astronomers did not generally go to sea and they did not develop any mariner's astrolabe.

***

An American historian, Patricia Seed, in a recent article about 'celestial navigation', has written:[84]

> "(The standard astrolabe) required massive revision before it could translated into an instrument for navigation."

The steps by which Seed imagines the standard astrolabe was reduced to the mariner's astrolabe need not be repeated here. Alas her imagination has gone completely overboard, for all the instruments really have in common is, by historical accident, a name. Her text also includes some information about Islamic astronomy and mathematics that I never heard before, despite having worked on these disciplines for almost 50 years.

In 1995 Seed published a book *Ceremonies of possession in Europe's conquest of the New World, 1492-1640*,[85] in which she again mentioned the astrolabe. Her entire well-documented discussion is based on the writings of the most authoritative of modern scholars. Yet it is completely off the mark from an astronomical, an instrumental and a historical point of view. Consider the following:

> "Each day the sun reaches a maximum height in the sky relative to the equator which is called its zenithal latitude [!], or solar declination [!]."

On the astrolabe there is total confusion between the 'real' astrolabe and the simple 'mariner's astrolabe':

> "An instrument of nighttime [!!] observation probably [!] of Greek origin dating from the second or third century, the astrolabe was a circular disk [?] made of brass with a needle-like indicator attached

> at the center and a series of numbers [!] engraved on the side. In what (Owen) Gingerich calls the "Islamic era" – the eighth through fourteenth centuries – the astrolabe was transformed into a superb instrument of astronomical observation, equipped with sophisticated calculating devices that facilitated keeping track of the constellations [!] in the sky and the hours of the night [!!!]. By the fifteenth century, astrolabes were more popular on the Iberian peninsula than elsewhere in the Islamic world [!]. Their manufacture and use was a sophisticated science."

Again the instrument mentioned in the first sentence has nothing to do with the one mentioned in the second sentence. Note the charming statement that the astrolabe can only be used at night. Elsewhere, our author revels in the fact that a certain 15th-century Jewish astronomer calculated the solar declination for each day of the year, although how these could be of use to a nighttime sailor is not explained. It is also overlooked that solar declination tables were a feature of every serious Islamic astronomical work containing tables, from the 9th century to the 19th.[86]

***

What has been clear for a long time is that the mariner's astrolabe did somehow evolve. And just as I was writing these lines we found a missing part of the story. "Astrolabe ... ". Thus began a BBC article which I saw today (**25.10.2017**), as I write this. The word 'astrolabe' is being bandied about again in the press with the rediscovery in 2016 of an astronomical device recovered in the wreck of a Portuguese explorer named Esmeralda, which sank off Oman in 1503.[87] This is a circular bronze plate with a thjrone and two decorative protruding blazons on one side, which probably serve to counter-balance the now-missing alidade. On the other side traces of a 5° altitude scale have been identified, and the hole at the centre indicates that an alidade was once fitted there.

(Note added on **28.03.2018**: I hereby acknowledge that the British historian of science Thony Christie beat me by one day with a blog on **24.10.2018** about the way in which this discovery was presented in the British press, if only because he saw the BBC article on **24.03.2018**, a day earlier than I did. He referred to the news release as "patent rubbish",[88] and he took the trouble to inform the BBC of his opinion. I myself did not bother to do that, under the impression, most probably correct, that I would be wasting my time.)

Researchers at Warwick, when they found evidence of etchings around the edge of the disc, each separated by 5°, pronounced that this detail "proves it's an astrolabe",[89] because

> "these markings would have helped mariners measure the height of the sun above the horizon at noon – a strategy that helped them *figure out their location* while at sea."

The words in italics lead to another site which could help if a mariner knows only the solar altitude at noon. It is appropriately entitled "Why humans get lost".[90] On the other hand, the instrument was apparently so corroded when it was rediscovered that it was by no means obvious what it was.

This piece is not an astrolabe, of which we have over 1,000 examples with Arabic or Sanskrit or Latin inscriptions. This is not a typical mariner's astrolabe, of which we have over 50 examples. It is, in fact, a unique example of a proto-mariner's astrolabe, before it was realised that the instrument needed to be thicker and heavier to make it more stable on board a ship, with cutouts in the metal to lessen the effects of

wind, and with weight adjustments to ensure that it hangs vertically.

A sober article in *The Economist* of 26.10.2017 is headed "Navigational instruments: The oldest mariner's astrolabe yields to scientific scrutiny – Laser scanning shows how it worked".[91] A curious title, since it is obvious how it worked. As far as I am aware, the function, as opposed to the symbolism, of the two blazons has not been addressed in the press. They do serve a practical purpose.

Needless to say similarly careless announcements occurred in other news reports. In the French-language *Sciences et Avenir* / *Science and Future* of 26.10.2017[92] we are informed about ...

> "le plus ancien astrolabe du monde repêché sur une épave // the oldest astrolabe in the world fished out of the sea from a shipwreck",

and provided with

> "une photo d'un astrolabe, le plus ancien jamais découvert // a photo of an astrolabe, the oldest ever discovered".

Guaranteed that 90% of readers would not know the difference between an astrolabe and a so-called 'mariner's astrolabe' either before or after reading this news coverage.

What the discoverer David Mearns actually told the press was perfectly correct:

> "This is the oldest maritime astrolabe," he said, dating it to between 1496 and 1500 – around 30 years earlier than the previous oldest known astrolabe.

We learn this in an article in *The National*, Abu Dhabi, on 25.10.2017, apparently taken from Agence France Presse, announcing the discovery of the "world's oldest astrolabe".[93]

This report from Abu Dhabi is, of course, one of dozens that went around the world, and thanks to the carelessness of the original press report the stupid expression "world's oldest astrolabe" is now all over the internet.

The Abu Dhabi article inevitably contains the same old stuff as the British press, much watered down, but it is includes a photo of an object with the caption: “An astrolabe hangs on a wall as decoration during a VIP preview session at the official launch of AstroLabs Dubai ... .” The ridiculous object is a modern disc (made in India?) with four identical fake astrolabe retes attached to it. They are in fact poor copies of the rete of al-Khujandī’s astrolabe that is now in the Museum of Islamic Art in Doha. If al-Khujandī’s astrolabe represents the zenith of Islamic design for the standard astrolabe, then this AstroLabs ‘astrolabe’ represents the nadir.

•••

When the world’s actual oldest astrolabe disappeared in 2003 from the Archeological Museum in Baghdad there was no such kerfuffle, indeed there has never been any press coverage, not least because nobody realized that the Museum ever housed such an astrolabe from the 8th century.[94]

***

On an educational site owlcation.com we find the history of the mariner's astrolabe "invented 2000 years ago" as "an instrument of navigation used to measure celestial altitude".[95] The potted history of the instrument that follows relates however to the standard astrolabe, a different instrument altogether.

One might welcome a new project to document all surviving mariner's astrolabes, announced in 2015.[96] However, the organizers get off to a bad start by calling their undertaking "The Astrolabe Project", and they trip over at the starting line:

> "Marine astrolabes were a simplification of the existing Islamic calculating devices and were used during the sixteenth and seventeenth centuries to measure the height of the sun at noon on sailing ships. With this value and the proper tables, sea captains could calculate the latitude and estimate the position of their ships during the long oceanic voyages that characterized the first age of globalization."

The first half of the first sentence of this abstract is utter rubbish. With the right kind of tables, universal for all reasonable latitudes, one can measure the solar altitude at any time of day and read off the hours since sunrise or remaining to sunset. Now which instrument are we talking about?

> "Originally developed in Roman Egypt, later adapted by Islamic scholars, and passed into the neighboring Iberian states, astrolabes are part of an intellectual revolution that gave the world larger and sturdier ships and a sophisticated bureaucratic organization. The Portuguese and Spanish early modern states planned and implemented imperialist policies on a theater that encompassed a large portion of the known world. Astrolabes helped fifteenth and sixteenth century sailors find their way around the planet and allowed geographers and cosmographers to create the maps from which the Catholic, Protestant, and Islamic rulers planned their strategies and wars. Their form and style reflect the knowledge, skills, and taste of their makers and are a product of the cultural and economic environment within which they were cast."

Wow! Astrolabes gave the world larger and sturdier ships and a sophisticated bureaucratic organization. ما شاء الله , *Māshā'allāh*!

From no other source than NASA we have the following nonsense,[97] making one wonder how they navigate through space:

> "In particular, navigators used and improved upon [!] the early astrolabe and cross staff, two devices created in ancient times to measure the altitudes of celestial bodies. These devices enabled sailors to travel in an east-west direction [!] away from the sight of land. The astrolabe was a simple sphere [!!] made of brass, measuring about six inches in diameter. ... ."

Travel possible only in an east-west direction? The astrolabe a sphere? This really takes the biscuit, as they say.

As we have seen throughout Part II, various other websites confuse the astrolabe and mariner's astrolabe altogether, some presenting absurd historical overviews of both at the same time.[98]

Southern fried astrolabes

The website 'Southern Fried Science' is "a place to discuss marine science and conservation as we explore the oceans". These good people are, of course, interested in mariner's astrolabes, so that you can "look up at the sky and discern your place in the world", and a home-made one out of wood illustrates their discussion of the instrument.[99] We read further:

> "Developed in the Middle East to help traders chart their course through the desert, the (mariner's) astrolabe was the most popular western navigational instrument for centuries. ... The astrolabe allowed navigators to track their latitude as they explored the world. ... Astrolabes are a great tool for introducing students to celestial navigation and teaching trigonometry."

This is priceless! It inevitably brings to mind the fact that the camel is sometimes called "ship of the desert". It also brings to mind the fact that some modern writers (Gibson & Gallez – see below) have proposed that the Arabs in the 7th and 8th centuries knew of the astrolabe before they encountered Hellenistic scientific ideas and instruments, which would have been really very clever.

New potted histories of the astrolabe

On a site named interestingfacts.org.uk we learn something new about the early history of our instrument:[100]

> "It is not known when (the astrolabe) was invented but it widely used in the 6th and 7th century by Arab pilots at sea and also used by European navigators."

But the astrolabe was discovered by Muslims in Ḥarrān (now in S. Turkey) in the 8th century. Arab pilots at sea, if there were any, did not have astrolabes, even if Dan Gibson (see below) thinks they did. We should add, though, that of the two oldest surviving Islamic astrolabes, both from the 8th century, one was recovered off the coast of Malaysia from an Arab ship that had been on its way from Iraq to, most probably, China.[101]

***

A retired professor of the Department of History at Portland State University maintains a kind of blog named Quatr.us Study Guides (more than 2500 original articles on everything from Aachen to Zygotes). She presents the following charming answer to the question "What is an astrolabe?":[102]

> "About 140 BC, the Greek astronomer Hipparchus of Rhodes invented the science of trigonometry. Hipparchus figured out that you could use an imaginary right triangle [!!] whose corners were the sun, the earth, and the planets or stars [!!], to calculate the movements of the planets and stars. To measure the angles of these right triangles accurately, Hipparchus invented a metal tool called an astrolabe [!!!]. It's a kind of analog calculator, like a slide rule.
>
> "Later West Asian scientists, first Greek, then Christian [!], then Muslim [!], made gradual improvements to the astrolabe over the next thousand years. Islamic astronomers added markings so that you could find how far away from due north you were [??].
>
> "In the late Middle Ages, Chinese scientists shared the idea of making a magnetic compass with Islamic astronomers [!!] and from there the news spread to Europe. Then sailors – or at least highly skilled navigators – were able to combine the use of the astrolabe with the use of the compass to figure out where they were on the ocean when they couldn't see the land."

The text is illustrated with an astrolabe for which the caption reads: "An Islamic astrolabe (832 AD)". The illustration, however, shows the infamous undated Florence astrolabe from Abbasid – 10th-century –

Baghdad which we discussed in Part I.

This response should never have been written, and woe to anyone who would believe one word of it. Hipparchus' right triangles are not at all alright and he did not invent the astrolabe. The millennia are confused. The Christians before the Muslims were Greek. Muslim astronomers did not learn of the magnetic compass from the Chinese. The account of the astounding achievement of the Muslim scholars in adding markings to find how far away from due north one is, is curious indeed and unworthy even of an art historian. The European Middle Ages have vanished, and so has the Renaissance. And so will sailors who cannot use an astrolabe and a compass.

***

An article in the English-language *Sabah* newspaper in Istanbul dated 16.07.2015 gives a fairly reasonable overview of the instrument and its history culled from different non-academic sources,[103] but the author does not bother to go to any of several museums in the city to find an image of a Turkish astrolabe. She writes about the *muwaqqit*s or professional timekeepers associated with the major mosques, claiming that they used astrolabes to determine the time of day and night and particularly the times of prayer. But they did not; they used tables – of which we have several examples – and astrolabic quadrants – of which hundreds made for the latitude of Istanbul survive in museums around the world. The article is illustrated with an image of an unidentified astrolabe (actually by Abū Bakr ibn Yūsuf, Marrakesh, *ca*. 1200!). We also find an image of a very beautiful Miryam al-Asṭurlābiyya (see above) holding an astrolabe whose rete is actually a French design by Jean Fusoris of Paris, *ca*. 1400 (!!).

***

We now turn to an anonymous article at a would-be educational site "History 27012 Wiki" which is entitled "Islamic astrolabe discovered in Spain".[104] The astrolabe featured and illustrated actually has inscriptions in Hebrew, but *ma'lêsh*, this is not the only problem. The instrument is supposedly dated 1345-1355 CE, but, as we shall see, much of the information on the history and development of the astrolabe is unreliable. This is particularly strange since it gives the impression of being based on half a dozen scholarly writings on the

history of the astrolabe, including one of my own (an encyclopaedia entry listed under Selin). The following quotes are perhaps worth recording here, perhaps not:

> "The astrolabe is an ancient astronomical tool used to measure the position of the sun and the stars as well as solve problems of time. Inventors of the astrolabe re-created the sky on the face of the instrument and marked it so that celestial bodies were easy to find.
>
> " ... ... The plates, commonly called climates, are inserted into the mater and are engraved with circles of altitude and lines [!] of latitude [!]. ...
>
> "During the Dark Ages, many Greek astrolabes [!] and manuscripts were lost, specifically in the burning of the library in Alexandria, Egypt. This coupled with the sequestering of knowledge by the Church resulted in the loss of astronomical knowledge in the Western world. However, from 12 AD [?] to the 12th century [?], astrolabes were re-introduced [?] to the Western world as Islamic astronomers sought out and uncovered the remaining Greek astrolabes [!] and manuscripts. They expanded on the uses and technology of astrolabes and disseminated this knowledge as Islam was spreading throughout North Africa and southern Europe. ...
>
> "Dating back to 1345-1355 C.E., this astrolabe is made of brass and was found [?] in Spain, where it [?] was introduced by Islamic astronomers after the Muslim conquest of the Iberian Peninsula in the 8th century ... . [DAK: The author is writing about an astrolabe with inscriptions in Hebrew.] Muslims used astrolabes to find the times of the sunrise [!] and the rising of fixed stars and to help schedule morning prayers [?] facing Mecca.
>
> " ... Islamic astronomers primarily used the astrolabe to develop a calendar [!] of astronomical events important to the Islamic faith [!], determine exact moments of sunrise and sunset for prayer times [?], and position mosques and direction of prayer toward Mecca. ... "
>
> "By the 16th century, the astrolabe was a basic educational tool in mathematics and astronomy. It was largely replaced by the invention of the telescope [!], but those who were able to employ

an astrolabe were considered educated and well-schooled. As for time-keeping, the pendulum clock and the chronometer replaced the astrolabe, making it a thing of the past. However, the workmanship behind beautiful astrolabes was evidence of the advancements of technology in metalwork."

***

Nourane Khaled, an expert in nutrition, has ventured to write a short article on the astrolabe in Islamic civilization for the Biblioteca Alexandrina. Entitled "The Arabs and the advancement of astrolabes", the article contains a string of errors and misinterpretations.[105] It is illustrated with a modern copy of a medieval English astrolabe. The following extracts must suffice here:

"One of the Arab scientists' major contributions was in astrolabes. Astrolabes were primarily invented by the ancient Greeks in 225 BCE by Apollonius based on the theories and the findings of Hipparchus. The main uses of astrolabes were to tell time during day or night, to identify the time of sunrise and sunset, and the length of the day, and to locate celestial objects in the sky. These uses were essential for astronomers, astrologers, and of course navigators.

"The astrolabe was considered a highly valuable tool in Islamic civilization because of its ability to astrologically [!!] determine prayer times and find the Qibla, which is the direction of the city of Mecca, not to mention its uses in navigation and travelling for trade or war. Arabs upgraded astrolabes and innovated their usages in the different aspects of life.

... ... [Text confuses al-Battani and al-Farghani; it was the latter not the former who wrote on the mathematics of astrolabe construction. Also confuses altitude and latitude.]

"Arab women too played their role in this influence. In the 12th [!] century, a famous [?] woman in Aleppo from a family of engineers and scientists [read: instrument-makers], Mariam [*sic* – her name is unknown] Al-Ijliya (Al-Astrolabya), was constructing astrolabes. She made remarkable improvements to the tool [in fact, nothing whatsoever is known about her productions].

Arabs introduced the astrolabe to the European continent through

> Andalusia in the 11th century. The tool carried the knowledge of Muslim scientists and greatly affected astronomy studies in Medieval Europe, contributing to modern scientific progress."

In fact the Muslims were using astrolabes in al-Andalus at least from the 10th century onwards. They did this not to introduce the instrument to Europe or to the Europeans. They did it for themselves, because they liked astrolabes and knew how to use them. Some Europeans became curious about their neighbours in al-Andalus and their reputed scientific prowess. They came to Córdoba and other centres of Islamic learning and acquired the rudiments of scientific knowledge. It was these Europeans who introduced the astrolabe to Europe. We are fortunate to have some early Latin astrolabes from the 10th and 11th centuries, which are more revealing than the earliest Latin treatises on the instrument. The only known Muslim woman astrolabist has here jumped from the 10th to the 12th century.

***

An unusual Spanish presentation of the astrolabe from 2013 is part of a blog "Cosmos y Matemáticas" by one "Euclides59",[106] whose interests range from geometrical art to Hedy Lamarr. The author is Carlos Rodríguez Ipiens, a mathematician who has recently retired from teaching mathematics in a secondary school in Málaga. His history of the instrument is scanty but sound and it is beautifully illustrated. However, the labels are problematic. The instrument labelled "Persian astrolabe" is in fact late Maghribī. The Syrian astronomer who made a quintuply-universal astrolabe was Ibn al-Sarrāj not Ibn al-Shāṭir, as claimed. A discussion of the important 11th-century Andalusī astrolabe by al-Sahlī in the Museo Arqueológico Nacional in Madrid is illustrated by an unidentified astrolabe, which is in fact an electrotype from the Museo Naval in Madrid of the infamous anonymous 10th-century astrolabe from Baghdad preserved in Florence that has been misidentified as "the astrolabe of Pope Sylvester II". Towards the end of the text we find illustrations of the front and back of an unidentified and undocumented European astrolabe bearing the place and date Schmalkalden 1482, identifiable not only by the coat-of-arms on the image as being from the Czartoryski Collection in Cracow. The piece is by a rather mysterious Hans Bamann of Schmalkalden in Thuringia, of whom I have documented six other

astrolabes elsewhere.[107] Rodríguez concludes with the very accurate observation, of the kind I have so rarely encountered in the present endeavour:

> "El astrolabio náutico es un instrumento mucho más simple que el astrolabio astronómico." // "The mariner's astrolabe is a very much simpler instrument than the astronomical astrolabe."

***

A charming short history of the astrolabe was put on-line in 2008 by Rhiannon, "a self proclaimed museum junky, who spends her free time doodeling [?], curling up with a good book, or contemplating the meaning of the universe".[108] She admits that this is "a pint-sized wealth of useless information", but claims that her main source is the *Encyclopaedia Britannica*. Rhiannon writes:

> "Throughout the ages all cultures have had some sort of fascination with the sky and/or the celestial bodies. As this fascination grew people began to develop astronomical tools to help them study the sun, moon, stars, and other planets. The astrolabe, often referred to as the oldest scientific instrument in the world, has been used to measure/predict the location, height, and position of extraterrestrial bodies [!!!], to determine the time of day, and to navigate ships [!].
>
> "Around the 2nd century BC the astrolabe was developed in ancient Greece to determine the altitude of objects in space [?]. However the instructions for this tool's construction were supposedly lost in the fire at the Library in Alexandria [!!!]. During the approaching Dark Ages astronomical information was further lost to the western world as the Christian churches banned such knowledge. The preservation of astrolabe technology is credited to the Islamic cultures, as they collected as many remaining Greek astrolabes as possible [!], thus preserving and improving the uses of the astrolabe. In 12 AD [!!], as Islam migrated though southern Europe [!!], the astrolabe was reintroduced [!!] to the Western World."

Somehow in 2012 we were not called upon to celebrate 2,000 years of Islamic civilization. But numbers, unlike words, do not lie, and the date 12 CE was also mentioned in the previous site above. It does not appear

to have been taken from the *Encyclopaedia Britannica*. Where it comes from *Allāhu a'lam*, God knows best.

***

Consider also this description of an actual astrolabe, this a 13th-century Andalusī piece preserved in a museum in Istanbul:[109]

> "Astrolabes are astronomical instruments used for measuring time and distance [?]. Their plates bear engraved concentric circles, meridians and astrological terms and numerals. Invented in the 2nd century BC [!], the most advanced astrolabes were used by the Muslims in al-Andalus and the Maghreb [!!]."

Here we have the fiction that the Muslim astronomers of al-Andalus and the Maghrib used the most advanced astrolabes. This contradicts all that we know about Islamic astrolabes, the most sophisticated having been made in Iraq, Iran and Syria (9th-14th centuries). The inclusion of the Maghrib goes beyond the popular myth that the most important scientific advances were made in al-Andalus rather than anywhere else. The invention of the universal plate by the Andalusī astronomer Ibn al-Zarqālluh is not to be hailed as the greatest achievement in the history of the astrolabe, and he proposed two different plates anyway. And how can you measure "distance" with an astrolabe, distance of what? The writer means "heights" of inaccessible buildings and depths of uninviting wells. Astrolabic plates have more circles than a few ones, only one meridian, no "astrological terms", whatever that may mean, and certainly numerals, not to confuse but to guide the perplexed.

***

Interesting twists to the nature and history of the astrolabe are provided in an article in study.com.[110] To the question: "What is an astrolabe?", the answer is:

> "The astrolabe was a two-dimensional, movable disc with a sighting arm used to line up celestial bodies above the horizon to determine their altitude. Knowing the altitude made it possible to predict the locations of the sun, moon, stars, and planets [!]. It could also be used to calculate the time of day, time of the year, and other astronomical measurements."

Another section is entitled "Arabic astrolabe: Definition, navigation &

history", which in itself augurs ill, but it is the subtitle "The Astrolabe in the Arabic world" which merits our attention. It begins:

> "The astrolabe was first invented in North Africa and it quickly spread throughout the Middle East. Astrolabes were first introduced to the Islamic world in the 8th century, and as Islam spread throughout the Middle East, North Africa, and Asia, the astrolabe went with it. Eventually, the astrolabe would reach Europe in the 1100s through Islamic settlements [!] in southern Spain. Throughout the next few centuries, astrolabes continued to be refined and improved by Arabic scholars, and turned into true works of art. Many astrolabes were produced during this time period, and some Arabic astrolabes that were made in the 10th and 11th centuries are still around today!"

It is sad that people actually pay money to access this kind of nonsense.

Museums beyond hope

Many museums are more concerned with administration than with the artefacts in their care, and most have more pressing concerns than worrying about astrolabes. Yet it is a fact of life that in most museums a vase or a potsherd has a better chance than an astrolabe of being appropriately displayed and described. What has happened to certain historically-important astrolabes in their present domiciles is a disgrace. In this and the subsequent section I give some examples.

***

In 2016, I was approached by an art-historian colleague from a museum in a small town near Frankfurt for help in obtaining an astrolabe for an upcoming general historical exhibition. I told her that to liberate an astrolabe quickly from any local museum would be time-consuming and possibly difficult. But I could offer two modern astrolabe copies: one of a 10th-century Iraqi astrolabe given to me by my colleague, the late Prof. Fuat Sezgin, and the other a model of a 16th-century German astrolabe actually made in that very town in which the museum was situated. It had been made by a former instrument seminar participant who lived in that same town and who had kindly presented the instrument to me. My condition for lending them was that they should display a text which I had written. The label that actually appeared in the show-case was quite different:

> "The astrolabe, an instrument for measuring angles, was developed already in Antiquity. With it one can aim at a celestial body and measure its altitude in angular degrees. The oldest known European astrolabe is a copy of an Islamic one from Moorish Spain. The astrolabe is a two-dimensional model of the heavens, as seen from a particular latitude."

Again, here we go:

The astrolabe is not an instrument for measuring angles. Such a device is called a protractor.

- Having measured the altitude of a 'celestial body' – why not say the sun or any bright star – what does one do with the result?
- The oldest known European astrolabe, from 10th-century Catalonia, is not a copy of anything Islamic. Not does it resemble any other medieval European astrolabe. It is so 'different' that it was declared a fake by scholars with no experience with actual astrolabes. It has now been reinstated to its rightful position (see below).
- 'The heavens' is problematic here. It makes more sense to think of an imaginary celestial sphere of arbitrary radius, centred on the observer.

Even when an astrolabe collection has been catalogued, we can find people innocent of what an astrolabe is being called upon to describe what it is. Thus, for example, we find our favourite Judaeo-Arabic astrolabe[111] featured as an instrument:

"used to make astronomical measurements and in navigation".

***

I now mention four other astrolabes which have suffered at the hands of the museums that house them.

(1) The most exquisite astrolabe of the early period of Islamic instrumentation, that of the 10th-century astronomer al-Khujandī, was offered to the Oxford Museum of History of Science in 1929 by a dealer in London (#111). The leading Arabist in Oxford misread the date as 778 Hijra [= 1376], and the vendor had rightly considered it much older, having read the date properly as 378 Hijra [= 960]. In any case, Oxford lost this spectacular piece.[112] Half a century later the instrument was acquired by a Paris dealer and eventually sold to a Kuwaiti

collector, who was keen to have it properly documented, and then to the new Museum of Islamic Art in Doha. The Museum has nothing of consequence on this astrolabe on its website, and no bibliography. And none of the websites devoted to al-Khujandī makes any mention of it. Sad!

(2) Once a historical instrument has been branded as fake or suspicious by folk who do not understand it, it is never possible to fully reinstate it. One good example is the Destombes astrolabe, the earliest known European astrolabe, the vicissitudes of whose struggle have been related above. Destombes deliberately donated the piece to the Institut du Monde Arabe in Paris, not wishing for it to land in a French national museum. There it languished until it was restored to its rightful place in history, but now the Institute seems to have forgotten about it. Perhaps this is because it is not "Arab" but more probably because "some people" used to say it was a fake. Their bookstore has neither anything sensible on the Destombes astrolabe nor the catalogue of their rich collection of Islamic astrolabes, but it does offer a new novel for children entitled *Le secret de l'astrolabe* and with a fake or imaginary astrolabe on the cover.

On a different level, we have an overenthusiastic *Wikipedia* article "Barcelona astrolabe" which in an amateurish way associates the instrument directly with the city of Barcelona and a new, fictitious "engraved" date of 980, and more ... .[113]

(3) In 2005 I published an astrolabe preserved in the Museum of Islamic Art in Cairo in a chapter entitled "Some astronomical instruments from Medieval Syria". This was an unsigned, undated piece on which the astronomical parameters used on the plates – latitude for Damascus and obliquity of the ecliptic – can be uniquely associated with the early-14th-century Damascus astronomer al-Mizzī. In the light of various minor defects – orthography of some star-names – the astrolabe cannot be by the master himself (compare his splendid quadrant in the British Museum), so, *con tutti rispetti*, I have attributed this fine Mamluk Syrian astrolabe to one of his students.[114]

Now the piece is on display at the new(ish) Biblioteca Alexandrina and is featured on its website.[115] It is happily assigned to the "Ottoman era (1517-1922)" without location. Its function is fancifully summarized as follows:

> "The astrolabe is a precise astronomical instrument to measure the location of the sun, planets and some stars in the hemisphere. It measures angles, shape [?], size [?] and height as well as the course of celestial objects around the celestial pole. ... ... The astrolabe is used to solve many astronomical issues. It played a big role in the navigation of military and commercial ships [!]. It was also used to calculate time of night and day, while Muslim astronomers used it to determine prayer time, the direction of the Qibla and the eclipses of the sun and the moon [!!]."

There is no description of any part of this particular instrument, which is of primary historical importance, rather, a few general remarks on the astrolabe are presented, including that:

the universal astrolabe of al-Zarqālī "can be used from anywhere on earth (!)";

- Ibn al-Shāṭir invented the first astrolabic clock called "*al-basseet*" to determine prayer time(s), thereby confusing his magnificent sundial (بسيطة *basīta*) on the minaret of the Umayyad Mosque with the astronomical clock he had erected at his home; and

"Ahmed ibn al-Sarrāg" developed an astrolabe "which combined all the advantages of previous inventions".

- The dialectal orthography of the name of Ibn al-Sarrāj (*g* for *j*) confirms that the author was an Egyptian. Ibn al-Sarrāj, on the other hand, was from Aleppo.

(4) A historically important Maghribi astrolabe signed by Ḥusayn ibn ʿAlī in 709 Hijra (1309/10) is preserved in the Whipple Museum for the History of Science at Cambridge. It is described on a Museum website on which almost every sentence is incorrect:[116]

> "The earliest surviving Arabic astrolabe treatises are from the seventh and eighth centuries and are often translations of earlier Greek or Syriac texts."

Now the *Qur'ān* survives from the 7th century, but no Arabic texts on the astrolabe. The earliest surviving Arabic text on the construction and use of the astrolabe, by al-Khwārizmī, dates from *ca*. 825, and it is not, funnily enough, based on earlier Greek or Syriac texts. Earlier works, such as treatises by al-Fazārī *ca*. 750, are lost, but they probably were dependent on earlier Greek or Syriac texts.

> "Eighth century literary references from Baghdad and Damascus indicate that by this time the use of the astrolabe was widespread throughout the Arab world. ... ... "

I know of no such literary references from the 8th century. From 10th-century Baghdad we have Ibn al-Nadīm's list of 30-odd instrument makers but these are mainly from Baghdad. By the 10th century we know that astrolabes were being made in Tunis and by the 11th century in Isfahan, Córdoba, and Ghazna.

> "This astrolabe is signed "Husain b. Ali" and dated 1309/10 AD. It is probably North African in origin, and is made of brass."

The instrument is not "probably" North African in origin; it is obviously North African, most probably, Tunisian in origin. But the piece has a replacement rete, not mentioned here, which is not Maghribi in origin, but rather Iraqi or Iranian. Who cares? Actually the rete is of considerable historical interest. Anyone who can read Arabic could list the star-names.

> "It has four plates (for the front of the astrolabe, representing the projection of the celestial sphere and marked with lines for calculation), each for a specific latitude, and 21 stars marked on the rete (the star map, with pointers, fitting over the plate)."

This is very strange. Plates having "lines for calculation"? The latitudes used on the plates, which are not mentioned here, can tell us the most likely places where the piece was made. In this case it is Tunis.

> "I have chosen this astrolabe since it is right in the middle of the time frame for Islamic astrolabe use (*ca*. 600 to *ca*. 1800) and because it demonstrates many of the features common to Islamic astrolabes.

Muslims using astrolabes *ca*. 600? This kind of misinformation paves the way for the crack-pot theories of Gibson and Gallez (see below). Muslims made astrolabes up to *ca*. 1900, especially in Iran, India, Turkey and Morocco.

> "On the back is a shadow square for measuring the heights of inaccessible things and other similar calculations (shadow squares are quite common, but not on all astrolabes), and scales for calendrical calculations and calculation of the qibla (the direction to face during prayers)."

Indeed we find a shadow square and calendrical scales. But there is no means whatsoever of finding the *qibla* with this instrument.

Now the fact that the astrolabe contains an additional or replacement plate with a special universal projection bearing an inscription by the renowned 14th-century Damascus astronomer Shams al-Dīn al-Mizzī is inevitably not mentioned in this account. In all, this is a shoddy description of an important historical object, proof that only people who cannot read the inscriptions on an instrument should not be allowed to 'publish it' on a serious museum website.

The Toledo astrolabe

The remarkable astrolabe recently acquired by the Aga Khan Museum in Toronto is perhaps the most historically important medieval European astrolabe.[117] It is an elegant 14th-century quatrefoil astrolabe, most probably made in Toledo. It bears the latitudes scratched on each of the plates in Hebrew, clearly maker's marks, then most of the inscriptions are in Latin, with a later overlay of inscriptions in Arabic showing that it was acquired by a Muslim intent on taking it to Algiers. We read on the Museum webpage:[118]

> "Planispheric astrolabe, from the Iberian peninsula, 1300s. ... The inscriptions on the astrolabe bear the names of constellations [!] in both Arabic and Latin, with additional inscriptions in Arabic [?]. Later [!!], Hebrew was added to one [!] of the plates."

Another problem is that this piece has been associated with Toledo, for lack of any feasible alternative. There are no names of any 'constellations' on astrolabes; the author means 'zodiacal signs'. Who cares? There is no hint of the fact that this astrolabe has been published in the greatest detail in a monograph accessible on the internet.[119]

Now if the latitudes on every plate scratched in Hebrew characters, normally out of sight since they are hidden by the rim of the rete, were made by the maker, then he was a Jewish craftsman. If, as is now claimed, the Hebrew scratches were added later, after the Latin and Arabic inscriptions, then they are entirely superfluous because the latitudes in Hindu-Arabic numerals would have been already engraved, properly at that. The Museum now makes the Hebrew inscriptions last, which completely distorts the delicate history of this monument to *convivencia,* which in this case means something like handing over an

astrolabe to someone of different religion better equipped to handle it.

***

A former staff member at the Aga Khan Museum, Patricia Bentley, has just published an account of the Toledo astrolabe in an academic journal.[120] This is a singularly amateurish account of the instrument which contains nothing that is not already in my earlier publications on the piece but much that is new and simply incorrect. For example, it repeats the fiction that the Hebrew inscriptions (actually, scratchings) were added last (!!), which is important for demonstrating that the astrolabe was not made by a Jew. In one of the illustrations supposedly

> "the latitude of Mecca in Hebrew script [!!] is faintly visible on the bottom rim of the Mecca plate,"

but the plate shown is for latitude 45° (for the sixth climate and, for example, Lyon), and it has nothing to do with Mecca. The number '45' in Hebrew script on this plate was put there by the Jewish maker of the astrolabe before the Latin inscriptions were engraved on it. In the caption to this plate we are told it represents

> "Mecca [!!] longitude [!!] 45 degrees".

***

None of the other exciting features of this instrument – such as the earliest attested use of fractions, and the only example of the use of a 'new' letter of the medieval Latin alphabet, to mention just two – are mentioned either in the Museum website or in Bentley's article. The engraving holds the key to the exact provenance of this piece, but that is not to be established by guesswork. Toledo seemed a reasonable choice, the Museum now introduces Saragossa, inevitably without any explanation. The Museum has yet to do justice to its prize possession.

***

The 2012 novel by Gerhard Behrens entitled *The Toledo Fake*, in which an 11th-century astrolabe sells for £2.8M at auction in London and a few days later an eccentric expert of Islamic art and science is murdered in his modest London flat, and more. The book is a work of fiction because there is no 11th-century astrolabe from Toledo, no astrolabe ever sold for £2.8M, and there are no British experts on both Islamic art and Islamic science. Nevertheless, the book has surely attracted

more attention than the real Toledo astrolabe.

More museums beyond hope

In the Science Museum in London there is a geared astrolabe from N. France *ca*. 1300.[121] This has for decades thought to be unique amongst medieval European astrolabes, but some 20 years ago another one, more skilfully produced, showed up from the same milieu. The London instrument has been described in the literature (Robert Gunther and John North), but the Science Museum has prepared a splendid set of images for their on-line catalogue. Whilst the instrument gets three short lines of description (!) without any bibliography (!) the photos are first-rate and could be useful to any future researcher. Unfortunately in their enthusiasm for the gears on the front, someone forgot to photograph the back, which is also important, since it features an error in construction enabling us to identify a distinctive tradition of astrolabe-making in N. France.[122]

***

An invitation to a special attraction at the Royal Observatory in Greenwich[123] promises much but delivers only confusion:

"Measuring time by the stars:
Astrolabe − What is it and what does it do?"

The announcement is illustrated with an image of the front of a 13th-century astrolabe from Damascus, which is of singular interest because its maker, al-Sarrāj, was a muezzin, a man who called the faithful to prayer from the minaret of the mosque:

> "It's beautiful, sure, but can you imagine what it is used for? An astrolabe is an impressive instrument which was used by astronomers for centuries to measure and predict [?] the positions of the Sun and stars (in order) to calculate the observer's time, location [already known!] and date [already known!]. Some versions were also used by Islamic astronomers who would use one to accurately calculate the time for prayers and other events [?] for the faithful.
>
> "If the dating on this [??] astrolabe is correct, then it (*sc*. this astrolabe) belongs to the later period of Muhammad Khalil's activities. ... [DAK: It transpires that the text relates to different

> astrolabe from Iran *ca*. 1700.] ... . Engraved along the rim of the mater is an invocation to the Prophet, his mother [*sic*, read: daughter] Fatima and the 12 Imams of Twelver Shi'ism."

Oy weh! This from the museum with the second largest astrolabe collection in England, pretending to inform the public what an astrolabe is, and what it can do!

***

How should museums present websites on astrolabes in their collections? Two different pages on the British Museum's 'Sloane Astrolabe', a magnificent early 14th-century English astrolabe, are exemplary.[124] They are accurate and informative, and there is a very fine image of the front (if not the back). Missing is the most important bibliographical reference; at least Gunther's *Astrolabes of the World*, should have been cited, or better, simply, reproduced. Also missing is a plea for someone qualified to work on this astrolabe seriously. But fortunately such a scholar has appeared in the guise of John Davis.

Many museums will devote more space to the dimensions of an astrolabe than to its description. And invariably more space to all the exhibitions in which it has featured than to any publications on the instrument. Publications that are favoured are those by museum staff and/or art historians who illustrated the piece or mentions in local newspapers, seldom detailed descriptions by experts.

As already noted, but worthy of repetition, is the fact that the bibliography on most astrolabes featured on serious museum sites is usually altogether lacking or hopelessly inadequate. This is the more shameful when the astrolabe collections in those museums have been catalogued by specialists, sometimes invited by the museums to catalogue their collections.

The auction houses

In the "good old days" – I think of the 1990s – the major auction houses in London and Paris had consultants who knew what an astrolabe was and who themselves had contributed to the history of the subject. This has certainly changed, for nowadays astrolabes with false descriptions can realise almost six-figure sums (pounds), astrolabes can be auctioned without reference to other known and documented pieces by the same maker, manuscripts of astrolabe-treatises are offered that are

incompetent scientifically-erroneous copies, ... Also, it is often clear that the people who write the catalogue descriptions, or the "expert" at Christie's who wrote the blurb:

> "Astrolabes, the beautiful objects that were the 'medieval iPhone ... ."

have but limited understanding of what an astrolabe is, illustrating their accounts with late astrolabes of limited historical interest and a fake astrolabe manuscript.[125] Alas, in general, nobody should any longer trust the information on astrolabes coming from the major auction houses.

Even Sotheby's of London in 2017 prefaced a serious description of an 11th-century Andalusī astrolabe from Córdoba with the following:[126]

> "Astrolabes are elaborate instruments designed to determine the solar or stellar hour at a specific location, allowing the user to make a number of astronomical or astrological observations. They were used by astronomers and navigators from classical antiquity to the Renaissance."

What on earth (or in heaven) is a "stellar hour"? Now we have "astronomical and astrological observations". And then the "navigators" make their customary appearance.

In 2017 a 17th- or 18th-century Maghribī astrolabe was auctioned as a 13th-century Andalusī astrolabe at Bonhams of London for close to £100,000.[127] A Parisian auction house had tried to sell it some ten years previously with the same incorrect attribution (which I had corrected for them). No action was taken by Bonhams when I pointed out this gross error. The piece was introduced in their auction catalogue with the following further misinformation:

> "Astrolabes were widely used in the Islamic world both for navigation and for finding the qibla, or the direction of Mecca. They were also used to find the times of sunrise in order to help schedule morning prayers."

But, I need to keep repeating, **astrolabes were not used in the Islamic world for navigation**. Nor were they used for finding the qibla, except in a very few cases. One has to be pretty thick to need to determine the time of sunrise, which is 0 o'clock in medieval Arabic usage, but without the clock. To be sure one can determine the duration of twilight

with an astrolabe, and tables displaying this throughout the year were also available, at least in the major Muslim cities.

***

A respected auction house in a certain European city recently offered a unique example of a very rare astronomical instrument that was neither signed nor dated but was in fact made by the leading astronomer in Europe over 500 years ago at the time when that same city was the principal centre of astronomy in Europe, activity reasonably well documented in the scholarly literature.[128] The 'experts' , inevitably art-historians, obviously had no idea about any of this, asserted a wrong date and a wrong provenance (!), and set a starting sum at €10,000. Of all the serious instruments known from the work-shop in that city at that time, of which some 20 years ago I made an inventory, published in that very city, not one is preserved in any museum in that city today. *Schade*!

***

As I write these lines in the summer of 2018 a leading auction house in London is offering in its next sale a "Spanish or French astrolabe". In fact, it is Italian. Who cares? And there is even another Italian astrolabe in an important London collection that exhibits some of the unusual features of the 'new' piece. Oy weh!

***

Some very important astrolabes have been auctioned over the past 50 years with detailed expert descriptions. It is distressing to find certain museums ignoring such descriptions and having their staff write 'Mickey Mouse' descriptions of their own. This happened most recently with what is arguably the most important medieval European astrolabe, which stems from 14th-century Toledo and is now housed at the Aga Khan Museum in Toronto, but one could cite other examples. Likewise annoying are the situations in which catalogues of museums full of copies of instruments written by people who have never seen a real instrument are cited by authors who have never seen a real instrument in their life, ignoring the fact that such catalogues are sometimes based on information taken from scholarly studies. The latter are then cited by the new authors in their bibliographies even though they have never seen these original descriptions. I refrain from

giving examples.

The encyclopaedias

The article "Astrolabe" in the *Encyclopædia Britannica* and britannica.com, written by "the editors", is something of a national disgrace.[129] It is very uninspired and is illustrated with a ridiculous, totally unrepresentative 16th-century iron astrolabe and a reasonable Islamic one, stated to be "11th century", but in fact 11th century Hijra, thus, 17th century:

> "Astrolabe, any [?] of a type of early scientific instrument used for reckoning time and for observational purposes. One widely employed variety, the planispheric astrolabe, enabled astronomers to calculate [?] the position of the Sun and prominent stars with respect to both the horizon and the meridian. It provided them with a plane image of the celestial sphere and the principal circles – namely, those representing the ecliptic, celestial equator, and tropics of Cancer and Capricorn. Because of such features, the planispheric astrolabe can be regarded as a kind of rudimentary [!] analogue computer.
>
> "Although astrolabes have been traced to the 6th century [?], they appear to have come into wide use from the early Middle Ages in Europe [first ??] and the Islamic world [second ??]. By about the mid 15th century, astrolabes were adopted [?] by mariners and used in celestial navigation [?]. The so-called mariner's astrolabe was later supplanted by sextants. ... "

The reader may be forgiven for thinking that the astrolabes in the first sentence of this quote are the same as the astrolabes in the second sentence, which is not the case. And just how, pray, does one calculate the position of the sun and stars? The sloppy reference to the Islamic world after Europe is inappropriate since Europeans were totally indebted to the Muslims for their first contacts with the astrolabe. The only correct information in this quote is that the mariner's astrolabe is a "so-called mariner's astrolabe", for, in fact, it is not an astrolabe at all.

The author of this page has the audacity to state that "the astrolabe can be regarded as a kind of rudimentary analogue computer", whereas there is nothing rudimentary about the astrolabe. It is precisely an

analogue computer in the original sense of this expression, of which our author has not learned or understood the rudiments. The corresponding article in the 1911 edition of the *Encyclopædia Britannica* is inevitably better informed.[130]

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The article "Astrolabe" in the *Encyclopædia Americana*, surely an old edition, has no inkling about planispheric astrolabes:

> " ... an instrument for measuring the degrees, minutes, and sometimes even the seconds, of angles. It generally consists of a horizontal circular plate of metal, having those divisions on its extreme circumference. The utmost accuracy may be obtained in the measurement of angles, by means of a peculiar contrivance (vernier) ... ."

Oops! the author is talking about an instrument completely different from our beloved astrolabe. He/she is talking about the "plain" or "plane table", an instrument used in surveying, not in astronomy. But no, what am I saying? Our author continues – now talking about the sextant without mentioning its name – and concludes by mentioning the first application of the astrolabe to navigation – now we are talking about the mariner's astrolabe – by Martin Behaim of Nuremberg in the 15th century.

***

Likewise, the article "Astrolabe" in simple.wikipedia.org is pathetic:[131]

> "The astrolabe is a tool using [?] the positions of the stars or sun. It was formerly [?] used in navigation to help explorers and sailors figure out where they were. They found the distance north and south of the equator by measuring the distance of the sun and stars above the horizon [this would be really clever!]. Astronomers used other kinds of astrolabes, usually larger ones [actually they were mainly smaller!]."

According to the *Collins English Dictionary* (2009), an astrolabe is:

> "An instrument used by early astronomers to measure the altitude of stars and planets and also as a navigational aid. It consists of a graduated circular disc with a movable sighting device."

We read in *The American Heritage Science Dictionary* (2005) that the

astrolabe is:

> "An ancient instrument used widely in medieval times by navigators and astronomers to determine latitude, longitude and time of the day. The device employed a disk with 360 degrees marked on its circumference. Users took reading from an indicator that pivoted around the center of the suspended device like the hand of a clock. The astrolabe was replaced by the sextant in the 18th century."

The *Random House Dictionary* (2013) explains an astrolabe as:

> "An astronomical instrument for taking the altitude of the sun or stars and for the solution of other problems in astronomy or navigation; used by Greek astronomers from about 200 B.C. and by Arab astronomers from the Middle Ages until superseded by the sextant."

Clearly things are not improving.

Sometimes the information on the astrolabe is in "new-speak", unintelligible to this author and probably to most readers. The article "Astrolabe" on encyclopedia.com maintains:[132]

> "Astrolabes depict the visual reference points of stars on the night sky as a function of time. As such, an observer can also set the time to predict the visible star pattern expected."

The mind boggles. I just feel sorry for anyone who reads this kind of nonsense. Just one more quote ...

The entry for "astrolabe" in the on-line *Cambridge Dictionary* deserves a mention:[133]

> "a circular device used from ancient times until about the 18th century for measuring the position of stars, and on ships for calculating the ship's position."

I love it. Talk about clueless!

The new Islamic connection

There is a new study by some Malaysian scholars of the history of the astrolabe in Greek, Islamic and European civilisation, based entirely on secondary sources. The authors make no reference to surviving instruments, although a few pictures without captions have been added from the internet.[134] Another study deals with the astrolabe as an

"astrofiqh instrument", *fiqh* being the Arabic term for Islamic law and referring here to the *qibla* and prayer-times.[135] However, this study omits any reference to the well-documented history of the determination of the qibla and times of prayer by complicated tables and instruments for well over a thousand years and makes no mention of any surviving astrolabes.

A woman astrolabist

Of all the 30-odd Muslim astrolabists from the 8th, 9th and 10th centuries whose names are known to us from the 10th-century Baghdad bibliographer Ibn al-Nadīm,[136] only one has made it into the popular literature, and she is a woman. All that we know of her is that she was called simply al-ʿIjliyya, that she made astrolabes, and that her father, al-ʿIjlī, made astrolabes, and that both of them, father and daughter, were students of the famous instrument specialist of Baghdad called Nasṭūlus. In addition, she went on to work for the Syrian ruler Sayf al-Dawla, founder of the Emirate of Aleppo. This is not much to go on, but it has been embellished dozens of times and now she is the best-known Muslim astrolabist in the world. For example:[137]

> "Mariam [!] Al-Astrulabi [*sic* for الاسطرلابية , *al-Asṭurlābiyya*, a female astrolabe-maker] was a Muslim scientist [?] born in Syria [*sic* for Baghdad] in the (early) 10th century who is famous for developing astrolabes, navigational devices [!!] used to locate and predict the position of the sun, stars *etc* and the determining of latitudes [!] using local time and *vice versa*. ... ... Her genius level intellect [!] made her designs superior to others [?] and the astrolabes designed by her were more intricate [!] and innovative [!] and thus more useful."

The name 'Mariam' is fictional. The name al-ʿIjliyya has been suppressed probably because readers will not understand it. Surely she bore the epithet al-Asṭurlābiyya, but please spell it right, because astrolabe is اسطرلاب , *asṭurlāb* in Arabic. Her greatest claim to fame was that she was a student of Nasṭūlus, as was her father. He was, as we have said, the leading instrument-maker in Baghdad *ca*. 900. But his name is strange and was massacred by medieval copyists. It is even more strange to a modern Arab ear. He did not bother to dot the first letter of his name on any of his instruments (surely because he was so

well known in his time): thus his signature could be read نسطولس , Nasṭūlus (one dot above) or بسطولس , Basṭūlus (one dot below). So when the first of his astrolabes came to light in the 1970s his name was falsely misinterpreted as Basṭūlus (supposedly related to Greek αποστολος / *apostolos*, hardly a good name for a Muslim). It took considerable effort to reinstate the name Nasṭūlus, which is related to نسطورس , Nasṭūrus and the Nestorians). Here and elsewhere on the internet he now has the ridiculous name 'Bitolus'.

In an article in the English-language *Sabah* newspaper in Istanbul dated 16.07.2015, to which we shall return below,[138] the author woffles on about the ways in which she thinks the Ottoman astronomers used to tell time, concentrating on the astrolabe, which they did in fact not use. (They preferred to use tables and quadrants and sundials rather than astrolabes.) But almost as a consolation we are presented with an image of a very beautiful Miryam al-Asṭurlābiyya holding an astrolabe whose rete is actually a French design by Jean Fusoris of Paris, *ca*. 1400. عونك يا رب , *'awnak yā rabb*!

Our al-ʿIjliyya has given rise to a trilogy of science fiction novellas in an Afrofuturist setting where the main character is from a family that allegedly makes astrolabes, although these are mainly of use in making phone-calls:[139]

> "In Nnedi Okorafor's Nebula Award-winning novella *Binti*, the eponymous main character is a young woman who is an expert at crafting Astrolabes, a device that was used to discern the position of the stars and planets around us in ancient times, useful for everything from astronomy to time keeping to horoscopes. ... Recently on Twitter, Okorafor cited this woman as an inspiration for her protagonist Binti, saying that she learned of Al-Ijliya at a book festival in the United Arab Emirates. ... Mariam "Al-Astrolabiya" Al-Ijiliya lived in Aleppo, Syria, daughter of a man who apprenticed with a famous astrolabe maker named Bitolus [!!] before she became his student as well. Her designs were so innovative and complex that she was employed by Sayf al-Dawla – the ruler of Aleppo – from 944 to 967. Astrolabes could be used to determine time of day, as well as location, and were often used in Muslim society to determine Qibla, prayer times, and the days to start Ramadan and Eid."

The claim that astrolabes could be used to determine the days to start Ramadan and Eid is pure fiction.

On the internet there are now dozens of other citations of the woman astrolabist called Mariam. These two must suffice here. In view of all this dubious information in circulation it is comforting to find a voice of reason, namely, that of Raya Wolfsun, a specialist on astrolabes unlike many historians of science:[140]

> " ... ... Unfortunately, there are many unsupported details widely circulating about her: that her name was Mariam "Al-Asturlabiya" Al-'Ijliya; that she was born in 945 and died in 967 AD; and most notoriously that she invented the astrolabe, or at least made such beautiful astrolabes that she had regular royal commissions.
>
> "First of all, I have no idea why so many people think her name was Mariam. (If anyone can shed light on this, please reach out to me!)
>
> "The most glaring error is the claim that she invented the astrolabe. There is a mountain of evidence that she did not – for example, the known existence of at least three astrolabe treatises ... written centuries before she was born. Furthermore, all three use the term 'astrolabe', which is noteworthy because I've encountered people who think that 'Al-Asturlabiya' was part of her name and that the astrolabe was named after her. ...
>
> "Regarding the claim that her work was especially "beautiful" or "intricate" or "ingenious": we have no idea. We have no surviving instruments attributed to her, nor descriptions thereof. The closest we get is some work attributed to her teacher, Nastulus ... ."

Perhaps one day some Muslim sites will take interest in the other 30-odd astrolabists mentioned by Ibn al-Nadīm, or even in their surviving instruments. Google Arts & Culture has Nasṭūlus' earliest dated astrolabe, preserved in the Islamic Art Museum in Kuwait, dated too early by some 200 years to a time long before the Muslims came into contact with the astrolabe.[141] *Ma'lêsh*. The actual date of this piece is 927/28, but it is not – *contra* many claims – the oldest surviving astrolabe, for the Archaeological Museum in Baghdad has, or had, one datable to the mid 8th century. On the other hand, the same site has a commendable description of the early-14th-century "Sloane astrolabe"

in the British Museum, the most spectacular surviving astrolabe from medieval England.[142]

For the time being, the site mosaicofmuslimwomen.com informs us that:[143]

> "Astrolabes were global positioning instruments [!] that determine the position of the sun and planets [!], so they were used in the fields of astronomy, astrology and horoscopes [!]. They were also used to tell time and for navigation [!] by finding location by latitude and longitude [wow!]. The Muslims used them to find the Qibla [!], prayer times, and determine starting days for Ramadan and Eid [!!]. Basically, an astrolabe is an old fashioned smart phone."

Actually not old-fashioned but at least smart enough to serve as a model of the universe.

A man with an astrolabe

Some light relief for a change. Proof that leading European scientists even in the early 17th century still used astrolabes is perhaps provided by the following story, for whose authenticity I cannot vouch. The story supposedly concerns John Keill (1671-1721), the Scottish mathematician and disciple of Isaac Newton, whilst at Oxford. He apparently preferred "the conviviality of jolly and learned Gownsmen" in a local tavern to "the confines of the Senior Common Room". Whilst staggering home after "relaxing and refreshing draughts from pots of ale", he collapsed into a ditch by the Rotunda. "Thereupon he whipped out his Astrolabe with intent to obtain a fix on the fading moon, but finding the heavens whirling above him, fell senseless into a drunken stupor." At daybreak, he was discovered by two Proctors who carried him to safety in his own chambers. All's well that ends well.

Differences between academic colleagues

One problem for the History of Science can be the modern scientists who with no historical training get interested in historical scientific objects or ideas. Even worse than the scientists might be philosophers and art historians. Some of these colleagues have no idea that there is a discipline called History of Science. This is a broad discipline, and at one end are those concerned with "Quellen und Studien", "historical

sources and studies thereof". Your local museum has an astrolabe. You go there, study it, every detail of it. You read up on astrolabes. You write up your astrolabe. You publish it. At the other end are those devotees of "Wissenschaftsgeschichte", for which there is no polite translation, but this is a newly-established discipline which has replaced "Geschichte der Naturwissenschaften", "History of Science". Your local museum has an astrolabe but you do not go to look at it because you know what an astrolabe looks like; you feel inspired to write a paper philosophizing about the social context of astronomical instrumentation in such and such a milieu in such and such a century.

These days it is necessary to add a bit of hype. How about a university course entitled: "The astrolabe as a source for pre-modern astronomy and astrology"? Or how about: "For Latin scholars around the year 1000, the astrolabe became the earliest, non-verbal channel to access and assimilate mathematical knowledge from the Arabic culture, and could be seen as representing a divine 'architectonical rationality' which humans could share in the mathematical experience."? I am translating here from two European languages; I am not making this up.

***

When a modern astronomer turns his attention to a historical instrument, he is possibly capable of understanding the mechanics of the instrument, as well, perhaps but not necessarily, the use. Consider this extract from an article on instruments before the telescope authored by an astronomer for other astronomers:[144]

> "Some of the problems solved with astrolabes were:
>
> finding the position of the sun on the ecliptic on a given date;
>
> finding the azimuth of the sun at sunrise on a given date;
>
> - finding the time of sunrise and sunset on a given date;
> - finding the sun's altitude at transit on a given date;
> - finding the length of daylight on a given date;
>
> finding the rising azimuth of a star;
>
> - finding the altitude of a star at transit;
> - finding the length of time a star would be above the horizon on a given date.

- In addition to the predictions [?] above, the astronomer could use the astrolabe to measure the altitude of the sun, moon [!], or stars. Not a bad set of abilities for an instrument that does not use electricity or have even one computer chip!"

All this is more or less correct. I would just change "on a given date" to "on any day of the year", and change "altitude at transit" for the sun or a star to "altitude" at any time of the day or night. And please drop the moon. But I would add the principal practical use of the astrolabe: "finding the time of day or night throughout the year", even without a single chip. And why not illustrate such an important article with some real instruments, instead of cheap imitations?

***

An American university student of History published in 2014 an article "The Portal of the Universe: The astrolabe as a site of exchange in medieval and early modern knowledge".[145] He began:

> " ... although the astrolabe may seem foreign and inaccessible today, for Chaucer in medieval England, the tool was so crucial to understanding one's place in the universe that he wrote an essay describing how to use the instrument".

The author then proceeded to cite a few museum catalogues, but his article gives the impression that he had never actually seen a single astrolabe. Or that he thought that Chaucer's treatise was the only one, or the best one, ever compiled? It certainly was not. And is the astrolabe really so foreign and inaccessible today? Are we today incapable of comprehending an instrument that was known and appreciated in the Middle Ages amongst educated people? And can one really with an astrolabe begin to understand one's place in the Universe?

Various other sites purporting to deal with the astrolabe do not achieve the aspirations of their titles.[146]

An astrolabe made out of stone

A stone column some 2 meters high from the monastery of St. Emmeram outside Regensburg carries on the top a vertical disc, also in stone. This object, unique of its genre, was fashioned in the 11th century, and is now in the Historisches Museum in Regensburg. On one side of the disc is a meridian circle, which defines the plane of an

orthogonal projection of the celestial sphere (from infinity). We see an ensemble of straight lines representing the celestial equator and the circles of Cancer and Capricorn, as well as the celestial axis, and more. The whole is devised for latitude 48°, which was surely intended to serve the seventh climate as well as Regensburg (latitude *ca*. 49°). On the other side is a sculptured image of the poet Aratus (d. 240 BCE) kneeling; this Roman author was in later life associated with simple notions of folk astronomy and meteorology, rather than the kind of serious mathematical astronomy depicted here, but he is so much more photogenic than the astronomical markings that only postcards with the side with him on it are available at the Museum shop, forget about the 11th-century images of the heavens on the other side.

The first serious investigator of this piece was the distinguished German historian of astronomy and astronomical instruments, Ernst Zinner, who in 1923 published it as the "*Regensburger Lehrgerät*", that expression indicating that is was a "teaching device".[147] Previously, and again more recently, it had been called an 'astrolabe' and a 'sundial' or a 'sphere'; it is, of course, none of these. It is just a *Lehrgerät*. Why it was made and for whom it was intended is a mystery. Its practical uses are indeed limited, and we know that in the 11th century some monks in Germany were starting to understand the basic of the standard astrolabe. The piece is indeed unique of its genre amongst objects surviving from Antiquity and the Middle Ages. I also wrote about this charming piece in a comparativistic study of astronomy in mosques and monasteries.[148]

Now in 2017 we have a new study of this piece, couched in the dismal jargon of art-historical "comparativism".[149] The author persists in referring to it as an astrolabe throughout his paper, without seeming to realize what an absurd name this is for an instrument that has nothing to do with an astrolabe. He inevitably cites neither the classic study of Zinner nor my own humble contribution, and he claims that the object:

> "presented the semblance of an astrolabe [!], embodying the relevant technology and knowledge [?] even without functionality [!]. We can put to one side technological debates about possible functionality. For the historian of art focusing on the medieval world, the fact that the object was nonoperational indicates that its significance lay not in its functionality but rather in its place and

> monumentality [!]. The object *did* function but as a marker, a signifier for the reception of technology, rather than as an object that could inform about the place of the stars or the time of the day."

In fact the piece, which has no semblance of an astrolabe, is perfectly functional, but only for those who have eyes to see. It is nothing more or less than a *Lehrgerät*. It has nothing to do with the stars and nothing to do with time-keeping. Now our author starts talking about real astrolabes, citing the "plethora" of available literature, although it is highly doubtful whether he has consulted any of it since he obviously has no idea what a real astrolabe is or does. His next paragraph reads:

> "The astrolabe was a tool with which one gazed into the celestial flow [!] in order to determine the time. A comparison can be made with earlier examples of astrolabes produced in Spain or in the eastern Mediterranean, such as the earliest Latin astrolabe, known as the "Carolingian Astrolabe", a device probably made in Muslim Andalusia [DAK: nuts!] and then engraved in Latin in a monastery in northern Spain. The marking of the latitude at 38°30′ [DAK: there is no plate for this latitude!] which could indicate either Barcelona or Paris [!!], two cities that are in the same latitude [!!], has generated uncertainty about where the piece was made."

The Destombes astrolabe was not made in Islamic al-Andalus. It was made in what is now Catalonia and it resembles no other known Islamic astrolabe and no other Latin astrolabe from Spain. There is no plate for latitude 38°30′. In the description here we are confronted with some severe geographical problems since our author confuses the notions of latitude and longitude. The latitudes used on the Destombes astrolabe are:

$$36° – 39° – 41°30′ – 45° – 47°30′,$$

and I have devoted several pages to interpreting these in my description of this instrument for the 1994 Saragossa symposium. Actually, latitude 38°30′ corresponds to Córdoba, with 41°30′ associated with ROMA ET FRANCIA, the latter surely referring to "the land of the Franks". And that is where this astrolabe was made, unless it was made in Rome.

Let us return to safer ground and move to our author's statements about the use of the standard astrolabe:

> "An astrolabe such as the Carolingian astrolabe would have been held up high into the sky, making the person holding the astrolabe into the center of the celestial sphere [!]. That person would then adjust the rete according to the position of the tip of the moving alidade, find a star, and calculate his own place in the world [!]. He would then adjust the astrolabe horizontally [!], fixing the rete according to that calculation, and have the celestial sphere projected through the astrolabe [!], with every zodiac [?] and star placed according to the display on the astrolabe. We can be quite certain that this practice was not carried out for the Regensburg astrolabe [!], not simply because it lacks an alidade [!] but because the stone astrolabe could not be flipped horizontally [!]."

The mind boggles at this art historian's fanciful but nonsensical approach to using an astrolabe. Enough of this, but alas there is more – page after page – in the article presenting more about the "Regensburg astrolabe" for comparativist art historians. They may be comforted with the author's assurance:

> "The comparativist approach to such objects may be innovative, but it will surely be informative",

However, I'm not so sure about that. In defence of the author, I have to say that some of the modern literature still valiantly refers to the object as an "Astrolabium", a term used in the museums in nearby Nuremberg and Munich only for 'real' astrolabes. When I was planning to pass though Regensburg in June 2018 I phoned the Historisches Museum beforehand to ask about the *Lehrgerät* (and make sure it was still there): the staff-member had trouble understanding my inquiry and thought I was asking about a *Hörgerät* (hearing aid). Only when I clarified *astronomisches Lehrgerät* did he tell me that the "Astrolabium" is still there.

Astrolabes as early garden accessories

The following new information is provided by Abby Cessna, an author for universetoday.com:[150]

> "The astrolabe is a predecessor of the sundial, which is still common today as an ornament in many gardens."

Oy weh! Nobody will be more surprised at this than the many lovers of sundials, who know that the sundial has its own history stretching back

to Antiquity, parallel to and essentially distinct from that of the astrolabe.

Nabataean astrolabes

Since the 1950s several researchers have proposed that Islam started in N.W. Arabia rather than Mecca. The latest of these, Dan Gibson, believes that he has established that Islam started in Petra. Proof of this, he maintains, is that the majority of early mosques face Petra rather than Mecca.[151]

The problem is that these early mosques were not laid out to face Petra, and they do not face Mecca either, in the modern sense of being actually and deliberately aligned toward Petra or Mecca. You cannot begin to find the direction of a distant location in modern terms unless you know where it is and where you are. In fact, it is well established, and confirmed by medieval Arabic texts, that early Muslims faced the astronomically-aligned Kaaba in Mecca by means of folk astronomical procedures, that is, using astronomical horizon phenomena.[152] If they do happen to face Petra, it is by coincidence. Gibson conveniently ignores all of this evidence, and all that has been written on the subject in the Western sources (nothing has been written on historical mosque orientation in 'Eastern' sources in modern times).

Gibson further claimed that these early mosques face Petra so accurately that the earliest Muslims must have had the necessary mathematical and technical skills to achieve this, namely, spherical trigonometry and astrolabes and stuff (by stuff I mean pigeons and things). Of the astrolabe Gibson writes:[153]

> "The astrolabe in Islam. The astrolabe was introduced early on in the Islamic world. Some historians believe that this might have been later in the eighth and ninth centuries when Arab treatises on the astrolabe were published. However by the ninth century these writings indicate a long familiarity with the instrument. The oldest existing instruments are Arabian [*sic*, read Iraqī] from the tenth century [*sic*, read 8th century], and there are nearly 40 instruments from the 11th and 12th centuries. The astrolabe gave Muslims the ability to determine the time of day, and therefore prayer times as well as the Qibla direction. Early astrolabes were based on the Arab compass [!!] that used the rising and setting of different stars.

> The astrolabe ... has both a front side and rear side, so that calculations can be made [!]. The astrolabe was also known as a Windrose [!]. ... On the astrolabe, latitude was still [*sic*, read 'never'] determined by the height of the pole star using the *iṣba'* and *zām* measurements [of Arab navigational astronomy]. Astrolabes were quite difficult to use at sea because of the rolling of the ships, which made it hard to determine the vertical line accurately. ... ."

The problem with this is that the Muslim encounter with the astrolabe took place on the northern border of the new realm, in the city of Ḥarrān, where astrolabes were already being made by folk who knew what they were doing. And that took place in the mid 8th century. Another problem is that early Islamic astrolabes were not used to find the qibla. And they have nothing to do with navigation, let alone with the windrose.

When I ventured to mention this in a review of Gibson's book I was viciously attacked by a French Catholic priest and fundamentalist theologian Père Édouard-Marie Gallez,[154] who came out in support of Gibson and of the 7th- and 8th-century Muslims and their astrolabes in the Hejaz:

> "King prétend que les Arabes ne savaient pas se servir de ce qui tenait lieu alors d'astrolabe. Il est difficile de penser qu'ils étaient incultes à ce point – et ils pouvaient au moins le demander à d'autres." // "King claims that the Arabs [of the 7th and 8th centuries] did not know how to use what took the place of the astrolabe in those times. It is difficult to imagine that they were so illiterate / unschooled at that time, and they could not at least have asked some other folk."

One has to imagine these Hejazi Arabs running around trying to find the *pibla* to Petra, asking any passing Bedouin or surviving Nabataean or defunct Hagarene or visiting Judéo-Nazaréen (Gallez' favorites) if they have an appropriate tool.[155] With this remark of Gallez, singularly unschooled (*inculte*) in the history of science, we have, so to speak, reached the bottom of the barrel, but not quite.

The astrolabe in press releases

When the Regiomontanus astrolabe of 1462 was auctioned by

Christie's of London in October, 1989, a report by the art historian with the pseudonym Joseph Roy appeared in *L'Exprès* (Paris, 3-19 octobre, 1989), commenting on the "*latin de cuisine* / kitchen Latin" of the dedication by Regiomontanus to his patron Cardinal Bessarion; the "*ange étonnant* / funny angel" and "*ange surprennant* / surprising angel" on the back; and the six-pointed star on the throne, a "*symbole musulman* / Muslim symbol". Of course, the astrolabe was deemed highly suspicious. But the author knew nothing about astrolabes, and certainly missed the point on the decoration of this one. In the light of this article, as well as the infamous report from 'experts' in England (see Part I), the new owner returned the piece to Christie's and asked for his money back.

In fact, the Latin inscription is an acrostic with multiple vertical axes, perhaps the most brilliant epigram of the European Renaissance. Regiomontanus intended the angel to relate to Bessarion, who was named after an early St Bessarion, venerated as an angel in the Byzantine liturgy. The six-pointed star, a hexagram, is a perfectly reasonable symbol for a mathematician to use and appears here with five-petalled roses, symbols of the Virgin Mary, ignored by our art historian. And so on ... .

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"Sale of rare astrolabe halted", read the title on the British magazine *Science* article on 14.12.2008.[156] You might think that there was an astrolabe involved here, but that would be to expect too much. For the author of an article in *Science* did not know the difference between an astrolabe and a quadrant (!). Or rather, he/she did not take the trouble to find out what an astrolabe was before writing a pathetic article about a quadrant. The quadrant was of great interest, being a 14th-century English example of a universal horary quadrant fitted with an astrolabic ecliptic and horizon for latitude 52°, that is, an example of the so-called 'quadrant of Profatius'. On 30.07.2008, the London-based *Telegraph* announced under the title "Unique medieval astrolabe saved by the British Museum", that the "medieval astrolabe" had been purchased by the BM for £350,000.[157] The illustration referred to the piece as an "astrolabe quadrant", which it is also not. But at least someone realized it was in fact not an astrolabe. The British Government had intervened to ensure that the owner of the quadrant did not sell it to "a foreigner".

The many claims in the literature that the Islamic astrolabic quadrant is identical with the European Profatius-type quadrant are false,[158] and the universal horary quadrant with or without a cursor is an Islamic invention anyway. A competent description of one such device can be found on a British Museum site.[159]

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In Part I, we have drawn attention to the "astrolabe" which the BBC announced in October 2017 had been discovered in a ship-wreck off Oman. It was, inevitably, not an astrolabe. When one of the two oldest surviving astrolabes, from 8th-century Baghdad, came to light in a ship-wreck, there was no press coverage and no hype. Now it has a web-page in the Museum of Islamic Art in Doha, on which it is incorrectly attributed to the 9th century, and inevitably no reference is given to any publication on it (or to any publication on any astrolabe).[160]

Locally-made astrolabes as a potential source of national pride

The Moroccan researcher Abdelmalek Terkemani has for several decades been trying to arouse national interest in the splendid astrolabes made by Abū Bakr ibn Yūsuf in Marrakesh around the year 1200.[161] He located some four of these instruments in francophone museums; in fact, seven are known worldwide. They are characterized by their accuracy and a distinctive rete design whose inspiration seems to be original to Abū Bakr. They constitute a significant episode in the history of astronomy in the Maghrib, which subject has been documented mainly by the historians of astronomy at the University of Barcelona and the present writer. Most of this documentation, which is in English, is sadly out of reach to Maghribi investigators.

This sad tale reminds me of the splendid exhibition "*Syrie – mémoire et civilization*" which was held at the Institut du monde arabe (*IMA*) in Paris during 1993-94.[162] A particularly rich selection of medieval Syrian astronomical instruments from museums all over the world was displayed and described in detail in the catalogue. At the time few people in Paris and even fewer in Syria knew that in the 14th century Damascus and Aleppo were home to some of the world's leading astronomers – Ibn al-Sarrāj, al-Mizzī, Ibn al-Shāṭir and al-Khalīlī. The exhibition was a monumental success in Paris and was to go thereafter

to Damascus, but the Syrian government could not get its act together and the display was disbanded. Thus the Syrian public was deprived of being able to witness this most vivid testimony to their splendid past. And now Syria itself has been destroyed.

Before anybody might seek to capitalize on this proof of stupidity on the part of a non-Western government, we should remind readers that even the BBC does not even know what an astrolabe is: witness their releases on newly-discovered quadrants and mariner's astrolabes cited above.

Of authors and dates and translations and influence

The German architecture historian Felix Arnold, Director of the German Archaeological Institute in Madrid, published in 2018 the results of his investigation of the internal geometry of the Grand Mosque in Córdoba. To set the scene, and at some risk, he ventured an introductory summary in one paragraph of the history of mathematics and astronomy in al-Andalus.[163] He mentioned the astrolabe in the following terms:

> "The astronomer Ibn al-Ṣaffār (d. 1035) wrote a commentary on the astronomic tables of al-Khwārizmī and composed a treatise on the treatise on the astrolabe, used until the 15th century to determine a geographic location based on the position of stars."

Here it will not be clear to the average reader whether the astrolabe was used until the 15th century, which it was, and indeed beyond until say the 17th century, or whether Ibn al-Ṣaffār's treatise was in circulation until the 15th century, which it was also. (In the Wikipedia article on Ibn al-Ṣaffār it is stated that his astrolabe treatise even "influenced the work of Kepler", which is nice but false.) In fact, Ibn al-Ṣaffār's treatise did have the good fortune, some might say, to be translated into Latin in the medieval period, twice at that, but there were several other equally important Andalusī treatises on the astrolabe that were not translated. Europeans had their own treatises on the instrument in Latin and then the vernaculars, albeit of varying quality, starting from the 10th century and continuing up to the 17th. (As for the astronomical handbook of al-Khwārizmī, one could argue that the history of astronomy might have progressed more steadily if it had not left Baghdad.) All that is certain is that one does not use an astrolabe to:

> "determine a geographic location based on the position of the stars".

What is not certain is how long it will take to stop people talking about the one unexciting Andalusī astrolabe treatise that was translated into Latin and reflect instead upon the **50 surviving Islamic and Latin astrolabes that survive from Spain before *ca*. 1500** (and which were catalogued recently in Madrid).

The metaphorical significance of the astrolabe

The beauty and mystique of the astrolabe have been demonstrated by Raya Wulfsun (see Part I). Others less familiar with the instrument have tended to go overboard. One such is María González de Léon, author of a webpage on a site faena.com/aleph:

> "Welcome to Faena Aleph, an editorial pulse which, we warn you, will try to transform you. We are a digital magazine that acts as an agent of that precise, perhaps omnipresent, moment that triggers inspiration."

Forewarned, we turn to the title of the page that concerns us, which reads:[164]

> "On the beauty and metaphor of the astrolabe, ... a powerful object worked simultaneously as a guide to the cosmos and to the infinite within ... ."

Now we embark on an odyssey for the mind:

> "If it's true that we're made of the stars, the artifacts created by people to measure and approach those same stars are not only indispensable but an essential part of the great narrative of humanity. The astrolabe (one of the first computers, really) and the uses to which it's been put over centuries show strong symbolic implications. Likewise, it's also been one of the best visual metaphors, often circular, for both being and infinity. ... ...
>
> "Circular in form, the astrolabe is related, symbolically and essentially, with the perfect wheel, one encompassing both the eternal and the infinite. From the earliest representations of the universe to the many ways humankind has found to represent time, the power of the geometrical circle works as a map and a visual metaphor for the graphic explanation of all kinds of information:

> scientific, theological, and philosophical, among many others. Thus, the astrolabe's cartographic function is primordial, deriving an infinity of metaphysical implications by its very nature.
>
> "Another use of the astrolabe was as an astrological tool. This was especially true during the Middle Ages when there was no clear division between astronomy and astrology. Curious devices that they are, astrolabes have been used to make all kinds of decisions, including whether or not to go to war. The astrolabe then takes on a fascinating dimension as a guide not only to the geographic and the maritime worlds but to the spiritual, as if the map implied by the instrument guides both the universe outside and the one inside, too.
>
> "The beautiful astrolabe – a labyrinth, a clock-compass, a mirror of the sky and of ourselves – is always simultaneously a magical object. For centuries, it's allowed us to decipher the world, and consequently, to decipher ourselves and the universes quietly inhabiting us."

What a load of poppycock! Not surprisingly this text is illustrated, or, should we say, illuminated, by an image of a modern sub-standard fake "Iranian" astrolabe – with London, Paris and other European cities, included on the gazetteer! – taken from *Wikipedia Commons*. As far as the metaphors are concerned, one could wish the astrolabe was square.

Astrolabes for Christmas

In an article by Veronica James on the origin and use of the astrolabe for hunker.com, a site for 'easy living',[165] we read, after the usual fare of planets, horoscopes, and navigators, that:

> "Symbols marked on (European astrolabes) for Western religion replaced those of Islam, providing a way of predicting saints' days and the calendar feast days, such as Easter and Christmas. The year, months and weeks were calculable, compared to previous civilizations in which time was based on days and seasons. ... ... "

But the crunch comes in the final paragraph:

> "In the same way that the Internet has brought the world even closer together, the astrolabe pushed boundaries and horizons, making the entire globe navigable."

The article features a single illustration, not of an astrolabe, but of an armillary sphere. Ouch!

Fake astrolabes

The faking of Islamic astrolabes began in Iran in the 19th century and in the past 40 years has moved to India. Far fewer medieval European fakes have been produced. There has been a tendency amongst certain colleagues when confronted with an instrument that they do not understand – notably in Paris and Oxford – to pronounce: "It must be a fake." This happened to the Destombes astrolabe and the Regiomontanus astrolabe, two of the most historically important astrolabes. In both cases, it was possible, with a great deal of work, to reinstate them. The problem is that the instruments, even after they have been understood and reinstated, never recover from the disgrace, and those who doubted the authenticity of the instruments will never publicly retract their original opinions. "So-and-so said it was a fake" lingers on, "so-and-so didn't like the inscription", ... , one can really feel sorry for the poor instruments abused in this way.

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Now "fake" means not genuine and intended to deceive. A 19th-century astrolabe with an inscription purporting to be from the 14th century. A signature of a man whose name is not proper Arabic. Astrolabes in the tradition of a famous astrolabist, astronomically incorrect markings with incorrect Arabic inscriptions and a signature of sorts of the master. Such were the astrolabes which Owen Gingerich showed on photos to George Saliba and myself in Beirut in 1971: we sorted out the real ones, little jewels, from the fake ones, rubbish but still looking reasonable at first sight.[166]

***

One day in the 1990s I spent the morning at Christie's in London just looking at dozens of fake astrolabes in the hope of finding a genuine plate or rete or whatever. Whilst I was there a man came in with an astrolabe which he wanted to have auctioned. I was consulted and I told him it was a piece of trash for tourists; he was not happy. That afternoon I spent at Sotheby's with the same intention. Lo and behold, the same fellow came in with his fake astrolabe. I was consulted again, but now the man was despondent. "I need the money", he said to me in

confidence, "what can I do?". He was a pleasant fellow and I was moved to help him. I told him: "Take it to Paris." Long gone are the days when Alain Brieux in the Rue Jacob could also have told him immediately that it was a fake, for it was Alain who had landed a modern European instrument faker in prison.[167] Nowadays it is possible for a fake astrolabe to flourish in Paris. Also in London.

***

Large-scale fake and fantastic instruments of multiple components were made in certain workshops in India in the 1990s for unsuspecting tourists with bulging purses.[168] We should add ill-advised museum curators, because some of this trash was acquired by the Miraj Museum in Abu Dhabi, who are so proud of it that they even prepared a video of it.[169] One of these objects is being or has been hawked by Barakat Gallery:[170]

> "This piece heralds from India during a period of British occupation and is likely to have been produced in one of the northern Indian workshops that are known to have produced Islamicate style globes as early as 16th-17th centuries and continued well into 20th century."

This is unexpurgated rubbish, and it is an insult both to the serious astrolabists of Lahore and even to the much-maligned British colonialists.

The monstrous thing that we shall describe in the next section reminds me of this fake Indian junk.

Astrolabes as a must-have gimmick

Concerning the 2016 season six finale of "The Game of Thrones", *Radio Times* editor Paul Jones writes:[171]

> "As an awestruck Sam makes his way into the vast library at the Citadel, hanging from the ceiling is this device … ... . At first glance it looks as if its function is to reflect sunlight from the window high above around the room via those mirrors ... . But ... ... could the device have a second function? Well, yes, it's called an astrolabe – or more accurately an armillary sphere. And you can actually buy one … ... .
>
> *Game of Thrones* Astrolabe and Pop-up Book Set!

> So what does it do? Well, an armillary sphere is a model constructed from revolving hoops representing celestial bodies, their lines of longitude and latitude and so on, usually with the sun or the earth at its centre. It was used to track the movement of the stars and planets and could therefore also show the changing of the seasons. Given that the Maesters at the Citadel determine when the long seasons of Westeros officially begin and end – sending out white ravens to share the news – it seems likely they are using the armillary globe to help make those decisions."

Here we have three different instruments combined into one, the first two completely misunderstood, and the third, an armillary globe, an ingenious figment of the author's crass commercial imagination.

Here's another explanation from Angus Wall, Creative Director at *Elastic*, "the company that created the opening credits map intro":[172]

> "Astrolabes have historically been used by everyone from explorers and navigators to astronomers and even astrologers to locate and predict positions of the planets [does he really mean Mercury, Venus, Mars, *etc*., which are usually called "planets"?] in order to provide local time, latitude, and more. The astrolabe the team at *Elastic* created is much more complex than traditional astrolabes and has intricate rings around it telling the history of Westeros."

There you go.

So what is an astrolabe and what can one do with it?

Perhaps we need a statement for the record, in plain English, which people can quote and be assured that everything in it is correct. Well, here it is, from a page on the instrument from scienceislam.com.[173] I do not know who wrote it, but he/she hit the nail on the head, several times over:

> "What is an Astrolabe? The astrolabe is an astronomical computer for solving problems relating to time and the position of the Sun and stars in the sky. ... Astrolabes are used to show how the sky looks at a specific place at a given time. This is done by drawing the sky on the face of the astrolabe and marking it so positions in the sky are easy to find. To use an astrolabe, you adjust the moveable components to a specific date and time. Once set, the

> entire sky, both visible and invisible, is represented on the face of the instrument. This allows a great many astronomical problems to be solved in a very visual way. Typical uses of the astrolabe include finding the time during the day or night, finding the time of a celestial event such as sunrise or sunset and as a handy reference of celestial positions. Astrolabes were also one of the basic astronomy education tools in the late Middle Ages. Old instruments were also used for astrological purposes. The typical astrolabe was not a navigational instrument although an instrument called the mariner's astrolabe was widely used. The mariner's astrolabe is simply a ring marked in degrees for measuring celestial altitudes."

Of course it is not all the sky that is visible on the rete, and one should add daybreak and nightfall to sunrise and sunset; also, for astrological purposes it does not matter whether the instrument is old or new. This statement from scienceislam.com belongs in Part I, and it is far superior to everything that has been cited here in Part II.

Concluding remarks

Fake news on astrolabes will continue to flourish because a little astronomy, a little history, a little imagination, is perhaps too much to ask for, yet it is necessary before one can begin to understand what an astrolabe is. This is, alas, not the only topic which suffered in this way. For example, the whole field of the history of Islamic science, a field in which I have been involved for half a century. Let us not forget that Muslim scientists were the leaders in their field from the 9th to the 15th century. Yet much of what is now found on the internet written by amateurs or eager university students is an insult to the memory of those scientists. The damage these people have done is, of course, irreparable. And now we have reached a time when professors of this and that can publish a scholarly-looking, apparently well-documented overview of the history of Islamic science without even being aware of any fundamental contributions of the Muslim scholars and being clueless about the basic research that has been done on the subject over the past 200 years.[174]

But in this new age, anything goes. And now we have a new buzz phrase "astrolabes in context". Where astrolabes belong is of course in

the history of astronomy in Islamic or medieval European society. But the world is not interested in what astronomers did in times of yore with observations, tables and calculations. Calculations and tables are not sexy, but astrolabes most certainly are. And it is hard to convince people that astrolabes constitute but a small part of astronomy in those societies. Or to convince them that a mariner's astrolabe is not an astrolabe but an inclinometer.

***

I have certainly not exhausted the fake news about astrolabes. And I know that a study similar to the present one could be prepared on quadrants. The reader can look for more on a site of the Mariners' Museum in Newport News, Virginia.[175] Or how about the fake news of an Islamic astrolabe having been discovered in Spain,[176] the Islamic astrolabe in question being a Hebrew one and not having been discovered at all! I was fairly confused by a so-called 'Haiku Deck' presentation promising to display an ordered series of images of a Hebrew astrolabe.[177] In fact, images of bits and pieces of three Hebrew astrolabes, each of which I had published, were presented, along with some astronomical and mathematical snippets that, like the astrolabe snippets, could not, with an appropriate commentary, conceivably serve any educational purpose. Yet the Deck apparently serves over a million *innocenti* worldwide. One of their images shows a Fusoris astrolabe, from Paris *ca*. 1400, labelled 'ASTROLOBE', which endeared them to me so much that I have included it at the beginning of Part II.[178]

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Close to 20 astrolabes, Islamic and European, genuine and fake, are featured on a Greek website without any indication of which are genuine and which are fake.[179] Sorting them out might be an interesting exercise for any student. Alternatively, any interested person can find quite a bit more on the discoverislamicart.org site.[180] Here there are a few Islamic astrolabes presented from various museums. For most pieces, only the fronts can be seen, which is not a good start. But for each piece we get a statement, usually absurd but at least novel, about what an astrolabe is, and some strange information about each piece, with many Arabic names incorrectly spelled. One of the pieces illustrated is a worthless fake, and it bears no relation to the genuine

instrument whose description accompanies it. The descriptions are written by museum curators, who, with few exceptions, have no idea about the state of the field regarding astronomical instruments or the regional history of Islamic astronomy.

The internet is now abuzz with images of astrolabes without proper captions put up by such outfits as artsandculture.google.com, googleart.com and pinterest.com. This is a very useful source for authors who can now take any old image they find and insert it into their own writings about the astrolabe when they have never seen one except on pinteret.com, and, frankly, it doesn't matter whether it's a Maghribī astrolabe or a Persian astrolabe, or one of either sort posing as the other in a caption prepared by a total incompetent. As a colleague once said to me of astrolabes: "If you've seen one, you've seen'em all."

Perhaps one day somebody will write a thesis about the way in which the idea that the 'real' astrolabe was used in navigation came into circulation and how it spread like a virus through the literature. Or a thesis on the way authors of the tertiary literature mentioned in Part II simply copied unwittingly the rubbish they found in other tertiary or n-ary sources. Computer investigations of word patterns and phrases might enable the reconstruction of paths of such false information in the literature, who had copied whom and who first put the false information into circulation.

***

CNN these days has a cute reminder, call it a warning, about fake news in this age of mindless tweets and uncontrollable tweeters.[181] It runs something like this:

> "An apple is an apple, whether you look at it from the left or from the right. Some people might say that it is a banana, but that does not change the fact that it is an apple."

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Note: The sources used for Part II are not listed here but are given in the appropriate footnotes. The following items relate solely to Part I. **All of the works listed here are reliable.** The individual entries are not ordered alphabetically or chronologically in order that the reader can spend more time surveying them. The general works on the history of astronomy provide the context for instruments in general and astrolabes in particular. Works containing a substantial number of relevant articles are dissected. The selection of works is prejudiced by the author's preference for early instruments. The two dozen most significant works for astrolabes to *ca*. 1500 are printed bold. A more detailed bibliography for secondary literature up to *ca*. 2005 is given in King, *In Synchrony with the Heavens*, vol. 2.

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Johannes Thomann, "Astrolabes as eclipse computers: Four early Arabic texts on construction and use of the *ṣafīḥa kusūfiyya*"

Josefina Rodrīguez-Arribas, "The astrolabe finger ring of Bonetus de Latis: Study, Latin text, and English translation with commentary"

Emilia Calvo, "Some features of the Old Castilian Alfonsine translation of ʿAlī Ibn Khalaf's treatise on the *Lámina universal*"

Flora Vafea, "From the celestial globe to the astrolabe: Transferring celestial motion onto the plane of the astrolabe"

Petra G. Schmidl, "Knowledge in motion: An early European astrolabe and its possible medieval itinerary"

Sreeramula Rajeswara Sarma, "A monumental astrolabe made for Shāh Jahān and later reworked with Sanskrit legends"

Miquel Forcada, "*Saphaeae* and *hay'āt*: The debate between instrumentalism and realism in al-Andalus"

Laura Fernández Fernández, "Astrolabes on parchment: The astrolabes depicted in Alfonso X's *Libro del saber de astrología* and their relationship to contemporary instruments"

John Davis, "Fit for a King: Decoding the Great Sloane Astrolabe and other English astrolabes with 'quatrefoil' retes"

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VIII "Remarks regarding the terminology of the astrolabe"
IX "al-Khwârizmî as a source for the *Sententie astrolabii*"
X "On the authenticity of the treatise on the composition and use of the

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XII	"Al-Ṣūfī and the astrolabe stars"
XVI	"Traces of a tenth-century Spanish-Arabic astrolabe"
XVIII	"The stars on the rete of the so-called 'Carolingian astrolabe'"
XXII	"On six kinds of astrolabe: a hitherto unknown Latin treatise"
XVIII	"The stars on the rete of the so-called 'Carolingian astrolabe'"
XXII	"On six kinds of astrolabe: a hitherto unknown Latin treatise"

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III	The origin of the astrolabe according to the medieval Islamic sources
IV	A note on the astrolabist Nasṭūlus/Basṭūlus
V	Nasṭūlus the astrolabist once again (with Paul Kunitzsch)
VI	The ʿAbd al-A'imma astrolabe forgeries (with Owen Gingerich & George Saliba)
VII	On the early history of the universal astrolabe in Islamic astronomy and the origin of the term *shakkāzīya* in medieval scientific Arabic
VIII	The astrolabe of ʿAlī al-Wadāʾī
IX	The astronomical instruments of Ibn al-Ṣarrāj: A brief survey
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II	A survey of tables for regulating the times of prayer
III	A survey of arithmetical shadow-schemes for time-reckoning
VIII	Aspects of practical astronomy in mosques and monasteries
X	Astronomical instrumentation in the medieval Islamic world
XI	An approximate formula for timekeeping (750-1900)
XIIa	On the universal horary quadrant for timekeeping by the sun
XIIb	On universal horary dials for timekeeping by the sun and stars
XIII	Selected early Islamic astrolabes, preceded by a general overview of astrolabes
XIIIa	The neglected astrolabe – A supplement to the standard literature on the favourite astronomical instrument of the Middle Ages
XIIIb	The oldest astrolabe in the world, from 8th-century Baghdad
XIIIc	The earliest astrolabes from Iraq and Iran (*ca*. 850 – *ca*. 1100)

XIIId	A medieval Italian testimonial to an early Islamic tradition of non-standard astrolabes
XIIIe	On the origin of the astrolabe according to medieval Islamic sources
XIV	Selected late Islamic astrolabes
XIVa	An astrolabe made by the Yemeni Sultan al-Ashraf
XIVb	Some astronomical instruments from medieval Syria
XIVc	A monumental astrolabe for the Ayyubid Sultan al-Muʿaẓẓam
XIVd	An astrolabe for the Sultan Ulugh Beg
XIVe	Two astrolabes for the Ottoman Sultan Bayezit II
XIVf	Brief remarks on astronomical instruments from Muslim India
XIVg	A universal astrolabe from 17th-century Lahore
XV	An astrolabe from medieval Spain with inscriptions in Hebrew, Arabic and Latin
XVI	The geographical data on early Islamic astronomical instruments
XVII	The quatrefoil as decoration on astrolabe retes
XVIII	A checklist of Islamic astronomical instruments to *ca*. 1500, ordered chronologically by region

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Medieval European astrolabes

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- Preface - Introduction (Wesley Stevens)
- Destombian discovery and doubt, the problem of the 'oldest Latin astrolabe' (Anthony Turner)
- La provenance de l'astrolabe 'Carolingien' de Marcel Destombes (Jan de Graeve)
- Latin planetary studies in the IXth and Xth centuries (Bruce Eastwood)
- La littérature astrolabique latine jusqu'au XIIIe siècle (Emmanuel Poulle)
- Roma et Francia (= Ifranja) in M. Destombes' Carolingian astrolabe (Julio Samsó)
- Paleographical studies of letter forms on the mater and tympana of astrolabe AI. 86-31 (Wesley Stevens)
- Analyse paléographique de l'astrolabe 'carolingien' (Anscari Mundó)
- Traités byzantins sur l'astrolabe (Anne Tihon)
- The earliest known European astrolabe in the light of other early astrolabes (David King)
- Étude comparative entre l'astrolabe dit 'carolingien' et l'astrolabe d'Abu-Bakr ibn Yusuf de Tou1ouse (Raymond d'Hollander)
- The craftsmanship of the 'Carolingian' astrolabe, IC 3042 (Gerard Turner)
- Nouvelles analyses de l'astrolabe latinAI.8631 (B. Gratuze & J. N. Barrandon)
- L'authenticité de l'astrolabe dit 'carolingien' (Guy Beaujouan)

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quadrant and dials):

I Astronomical instruments between East and West
II The earliest European astrolabe in the light of other early astrolabes
III Rewriting history through instruments: The secrets of a medieval astrolabe from Picardy
IV The medieval Catalan astrolabe of the Society of Antiquaries, London
V A remarkable Italian astrolabe from *ca*. 1300 – Witness to an ingenious Islamic tradition of non-standard astrolabes
VI An astrolabe from Einbeck datable *ca*. 1330
VII The star-names on three 14th-century astrolabes from Spain, France and Italy
VIII A *vetustissimus* Arabic text on the *quadrans vetus*
IX 14th-century England or 9th-century Baghdad? New insights on the origins of the elusive astronomical instrument called the *Navicula de Venetiis*
X The astrolabe depicted in the intarsia of the *Studiolo* of Archduke Federico in Urbino
XI The astrolabe presented by Regiomontanus to Cardinal Bessarion in 1462
XII An ordered list of European astrolabes up to *ca*. 1500

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The construction and use of the astrolabe (David Proctor)
The literature of the astrolabe to 1450 (Richard Lorch)
From brass to text: the European astrolabe in literature and print (Anthony Turner)
The stars on the astrolabe (Paul Kunitzsch)
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Kurt Maier, "Bemerkungen zu den romanischen Monatsnamen auf mittelalterlichen Astrolabien"
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Elly Dekker, "A close look at two astrolabes and their star tables" (the medieval English lion astrolabe from Salzburg and the Great Sloane astrolabe)
King, "The star-names on three 14th-century astrolabes from Spain, France and Italy"
David Pingree, "A Greek list of astrolabe stars"
Julio Samsó, "Maslama al-Majrīṭī and the star table in the treatise de mensura astrolabii"
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Anthony J. Turner, "Interpreting the history of scientific instruments"
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Detailed studies of individual astrolabes (selected)

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Byzantine

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Burkhard Stautz, "Die früheste bekannte Formgebung der Astrolabien", in *Frankfurt IGN Festband*, pp. 315-328 (comparison of the 1062 Byzantine astrolabe and the 8th-century Baghdad one)

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Islamic

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Hüseyin Sen, "The al-Khujandi astrolabe and some later derivatives" (2011), at http://islamicartandscience.blogspot.de/2011/09/al-khujandi-astrolabe-and-some-later.html (accessed 2017)

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Azucena Hernández (Pérez), "Arte y ciencia en al-Andalus: el astrolabio nazarí de Alcalá la Real", *Boletín de Estudios Giennenses* 215 (2017): 259-284

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Joshua Nall, "Finding the fakes – Collections of historic scientific instruments are full of forgeries – and metallurgy offers one way to weed them out", at https://www.chemistryworld.com/opinion/how-to-spot-fake-scientific-instruments/3008560.article (article too short!)

Boris Jardine, Joshua Nall, James Hyslop, "More than Mensing? Revisiting the Question of Fake Scientific Instruments", *Bulletin of the Scientific Instrument Society* No. 132 (2017): 22-29, available at https://static1.squarespace.com/static/54ec9b40e4b02904f4e09b74/t/58f8d3c944024341b370612c/1492702155316/Jardine_Nall_Hyslop_March.pdf (deals with post-medieval European instruments)

Non-relevant titles

Jean Aubin, *Le latin et l'astrolabe*, 3 vols., Paris, 1996-2006 (not what one would expect from the title)

Addenda:

Note: The following sites were noted after this study was completed.

Other reasonable sites

Jacqueline Ronson, "How to build an astrolabe like John B. McLemore from 'S-Town' – It's the universe in the palm of your hand" (2017), at https://www.inverse.com/article/30002-john-mclemore-s-town-astrolabe-clock-ancient-astronomy (includes the Florence MG video)

http://www.bbc.co.uk/ahistoryoftheworld/about/transcripts/episode62/ (on the Hebrew astrolabe in the British Museum)

https://blogs.ucl.ac.uk/researchers-in-museums/2018/02/09/time-and-astronomy-in-the-petrie-museum/ (on a wooden astrolabe in the Petrie Museum)

More less informative sites

https://www.historymuseum.ca/cmc/exhibitions/tresors/treasure/222beng.shtml

http://www.kuriositas.com/2011/04/astrolabe-magnificent-computer-of.html

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It is a pleasure to acknowledge my debt to Shefayet Chowdhury for help in obtaining relevant literature. Various colleagues made useful suggestions to improve drafts of this paper, none of whom should be held responsible for what it now contains or what I would not remove. So my thanks to Silke Ackermann, Thony Christie, John Davis, Azucena Hernández, Günther Oestmann, Raja Sarma, Giorgio Strano, Hüseyin Şen, Anthony J. Turner, and Raya Wolfsun. To Thony Christie in particular I owe various suggestions concerning what one could do with materials in Part II. I hope that he will find the time to write a new article "Astrolabe" for Wikipedia.

The author

David A. King (b. 1941) is a British-born orientalist and historian of astronomy. He studied Mathematics (Cambridge), Education (Oxford), and Near Eastern Languages & Literatures (Yale). His first appointment was with the Sudan Government Ministry of Education (1964-67), and later he directed a project in the history of medieval Islamic astronomy sponsored by the Smithsonian Institution and based at the American Research Center in Egypt (72-79). He has been Professor of Near Eastern Languages & Literatures at New York University (79-85) and thereafter Professor of the History of Science at the Johann Wolfgang Goethe University in Frankfurt.

King has researched thousands of medieval Arabic scientific manuscripts and hundreds of medieval astronomical instruments in libraries and museums around the world. Most of his writings are based on such primary sources that have not been studied previously in modern times.

His *World-Maps for finding the direction and distance to Mecca* (1999) and other writings on the sacred direction or *qibla* and the sacred geography of Islam have surveyed the ways in which Muslims for well over a millennium – astronomers and scholars of the sacred law – have determined the sacred direction towards the astronomically-aligned Kaaba in Mecca. This research has helped to explain the often curious orientations of medieval mosques. The first volume of his 2,000-page *magnum opus* entitled *In Synchrony with the Heavens – Studies in astronomical timekeeping and instrumentation in medieval Islamic civilization* (2004/05) contains the first description of the ways in which Muslims have regulated the astronomically-defined times of the five daily prayers for well over a millennium. A second volume deals with the instruments that Muslim astronomers used. His unfinished catalogue of medieval Islamic and European instruments from the 1990s is now available online.

Other studies have been reprinted in the Variorum series: *Islamic mathematical astronomy* (1986/93); *Islamic astronomical instruments* (1987/95); *Astronomy in the service of Islam* (1993); *Astrolabes from medieval Europe* (2011); and *Islamic astronomy and geography* (2012).

King stresses the regional nature of Islamic astronomy after the formative period. There were different schools from al-Andalus and the Maghrib to Central Asia and India, with different interests and different authorities, hence also distinctive regional schools of instrument-making. The first of his several regional studies was a book *Mathematical astronomy in medieval Yemen* (1983); his last was an article "Astronomy in medieval Jerusalem" (2018).

Many of his publications on the history of astronomy in Islamic civilization as well as on astronomical instruments can be downloaded from davidaking.academia.edu.

Endnotes:

[1] The name al-Andalus and the adjective Andalusī refer to that part of the Iberian Peninsula under Muslim domination at a given time.

[2] King, "The origin of the astrolabe in the Arabic sources".

[3] See my March 2018 lecture at the Al-Furqan Foundation in London on instruments from the European Renaissance and earlier examples of Islamic instruments of the same kind at www.youtube.com/watch?v=KmsixNDb7oo (2018), starting at 50 minutes (following my lecture "Astronomy in the Service of Islam").

[4] Reprints of studies on Islamic instruments from the 19th and early 20th century – a monumental total of over 5,000 pages (!) – are found in Frankfurt publication *AIOS*: *Arabische Instrumente in orientalistischen Studien*, 12 vols., 1990-98.

[5] The record was set in Salzburg where Dr. Christa Svoboda of the Museum Carolino-Augusteum let me work in her office several hours after closing time and served my wife and me dinner there when I was finished.

[6] See the description of the Met, half of which is devoted to the dimensions of the piece (!), in www.metmuseum.org/art/collection/search/444408 (accessed 2018), and now Diana Rosenthal Roberson, "Yemeni astrolabe", timeinart.wordpress.com/delineating-time/1-yemeni-astrolabe/ (accessed 2018).

[7] I owe this charming expression to Fernando Arce-Sainz, "The alleged Basilica of Saint Vincent of Córdoba: From a historical myth to an obstinacy of historiography", *Al-Qantara* 36 (2015): 11-14.

[8] See King, I*n Synchrony with the Heavens*, XI: 111-198 "An approximate formula for timekeeping (750-1900)" and XII: 199-336 "On universal horary quadrants and dials".

[9] Nir Shafir, "Forging Islamic science", at https://aeon.co/essays/why-fake-miniatures-depicting-islamic-science-are-everywhere (accessed 2018).

[10] http://www.astrolabes.fr/index.html.

[11] Thony Christie, "The astrolabe – an object of desire" (2017) at https://thonyc.wordpress.com/2016/04/28/the-astrolabe-an-object-of-desire/ (accessed 2018).

[12] At New York University in the early 1980s, I had some students ask people on Washington Square: "On which day of the year is the sun directly overhead in New York?". The replies were fortunately never published.

[13] In 1971 I gave a lecture at the American University of Beirut entitled "Islamic Prayer Tables". After I started speaking, a young lady in the front row got up and walked out. I found out later that she was interested in Near Eastern furniture.

[14] http://kotsanas.com/gb/exh.php?exhibit=1301005 (accessed 2017).

[15] King, "On the origin of the astrolabe according to the medieval Islamic sources" (1981), with a new version in *In Synchrony with the Heavens*, XIIIe: 575-611.

[16] The illustration with ASTROLOBE is from www.haikudeck.com/astrolobe-uncategorized-presentation-eadf4a7632.

[17] https://qm.org.qa/en/mia-school-workshops-0.

[18] "A rare Andalusian brass astrolabe, Islamic Spain, 13th century, probably before 1238", at https://www.bonhams.com/auctions/24197/lot/116/?category=results&length=90&page=1 (accessed 2017.

[19] Nimira Dewji, "Astrolabe, one of His Highness the Aga Khan's favorite artifacts at the Museum'', https://ismailimail.wordpress.com/2014/12/22/astrolabe-one-of-his-highness-the-aga-khans-favorite-artifacts-at-the-museum/ (2014).

[20] *Khalili Collectiion Catalogue*, p. 186.

[21] The special plate for determining eclipses (*ṣafīḥa kusūfiyya*) is, of course, an exception: see Johannes Thomann, "Astrolabes as eclipse computers: Four early Arabic texts on construction and use of the *ṣafīḥa kusūfiyya*", in *London 2014 Conference Proceedings*.

[22] Father William (Sean Connery) in the film *The Name of the Rose*.

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