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The Armillary Sphere:

A Concentrate of Knowledge in Islamic Astronomy

Author: Samia Khan
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Associate Editor: Dr. Salim Ayduz

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FSTC Limited
27 Turner Street, Manchester, M4 1DY, United Kingdom
Web: http://www.fstc.co.uk Email: info@fstc.co.uk

THE ARMILLARY SPHERE:
A CONCENTRATE OF KNOWLEDGE IN ISLAMIC ASTRONOMY

Samia Khan*

Background

The armillary sphere is one of the three types of three-dimensional celestial models which also include the spherical astrolabes and celestial globes. The development of the armillary spheres reached an advanced level of sophistication during the 10th century, appearing in two main varieties[1].

The Demonstrational Armillary Spheres were earth-centered models where the circles of the ecliptic, equator, tropics and polar circles are represented by rings which encompass a tiny model of the earth. This structure is held in place by a graduated meridian ring and is pivoted about the equatorial axis. A horizon ring forming part of the base also holds the structure in place including the meridian ring. The moon, planets and stars did not constitute part of the model for these spheres.

The second type is the Observational Armillary Spheres which differ from the above by the absence of the earth globe in their center and having mounted sighting devices on the rings. These spheres are tools used to determine coordinates and other values, and the demonstrational spheres appear to just give relative motion of bodies about earth.

Muslim astronomers used and constructed armillary spheres as early as the 8th century, the first being the treatise of '*dhāt al-halaq'* or "the instrument with the rings" of al-Fazārī which is considered as the earliest known treatise on the subject[2]. Sources also indicate that 'Abbās Ibn Farnās who lived in 9th century Cordoba (d. 887 CE) constructed one but was unfortunately lost without a trace. There are no early Islamic armillary spheres which survive, and thus this document is based on information obtained from treatises.

There were many Muslim astronomers who wrote about the observational armillary spheres, an example of which is a discussion by Jābir b. Aflah (d. mid-12th century) also known as Geber. They built on the works of Ptolemy's *Syntaxis*, known as the *Almagest* (written in the 2nd century) in the Islamic world. The use of armillary spheres for observations is well evidenced by observatories such as the Maragha observatory (13th century), the Samarkand observatory (15th century) and the Istanbul observatory (16th century) (Mosley, 1999).

* Researcher at the FSTC. The research conducted for this article benefited greatly from interviews with Professor Emilie Savage-Smith (University of Oxford) and Emily Winterburn (Royal Observatory, Greenwich). Some of the drawings were done by Jonathan Chang, ex-researcher at FSTC.
[1] Emilie Savage-Smith, *Islamicate Celestial Globes: Their History, Construction and Use*, Smithsonian Institution Press, 1984. See also online Jonathan Chang, *Celestial Globes: Armillary Spheres* at: http://www.muslimheritage.com/uploads/CelestialGlobes.pdf, where the author provides a brief information about the types of the armillary spheres.
[2] David A. King, "Astronomical Instruments in the Islamic World", in *Encyclopaedia of the History of Science, Technology and Medicine in Non-Western cultures*, edited by Selin Helaine, Dordrecht: Kluwer Academic Publishers, 1997, pp.86-89; see p. 86.

Figures 1 and 10 are two of the few known illustrations of demonstrational armillary spheres of Islamic origin. Figure 1 is from an 18th century Ottoman manuscript while Figure 2 shows an illustration by the 15th century Cairo astronomer al-Wafā'ī.

The armillary sphere in Figure 1 was published in an edition of Jihannuma in 1732 by the Ottoman publisher, printer and diplomat Ibrahim Muteferrika (d. 1745). Muteferrika had brought book-printing to Turkey and had updated the original work. The original Jihannumma was a large geographical work written in the 17th century by the famous scholar and bibliographer Katib Celebi (Hajī Khalīfa). This work was an attempt to combine traditional Islamic wisdom with Western geographical knowledge.[3]

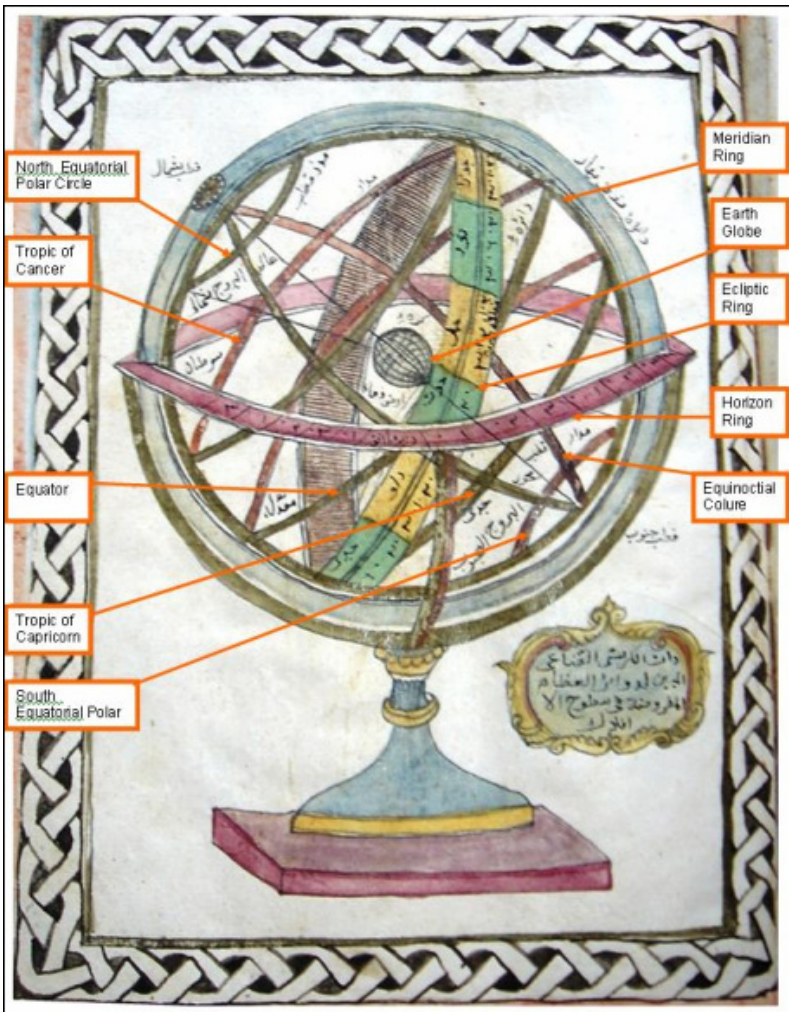

Figure 1: An armillary sphere in *Ma'rifatname* of Ibrahim Hakki Erzurumi. Adapted from the original manuscript held in the Suleymaniye Library in Istanbul, Haci Mahmud collection, MS 5616, fol. 1b.[4].

[3] O. Kurz, "European clocks and watches in the near east", London/Leiden, 1975, p. 69.
[4] O. Kurz (1975), "European clocks and watches in the near east", op. cit., fig. 21.

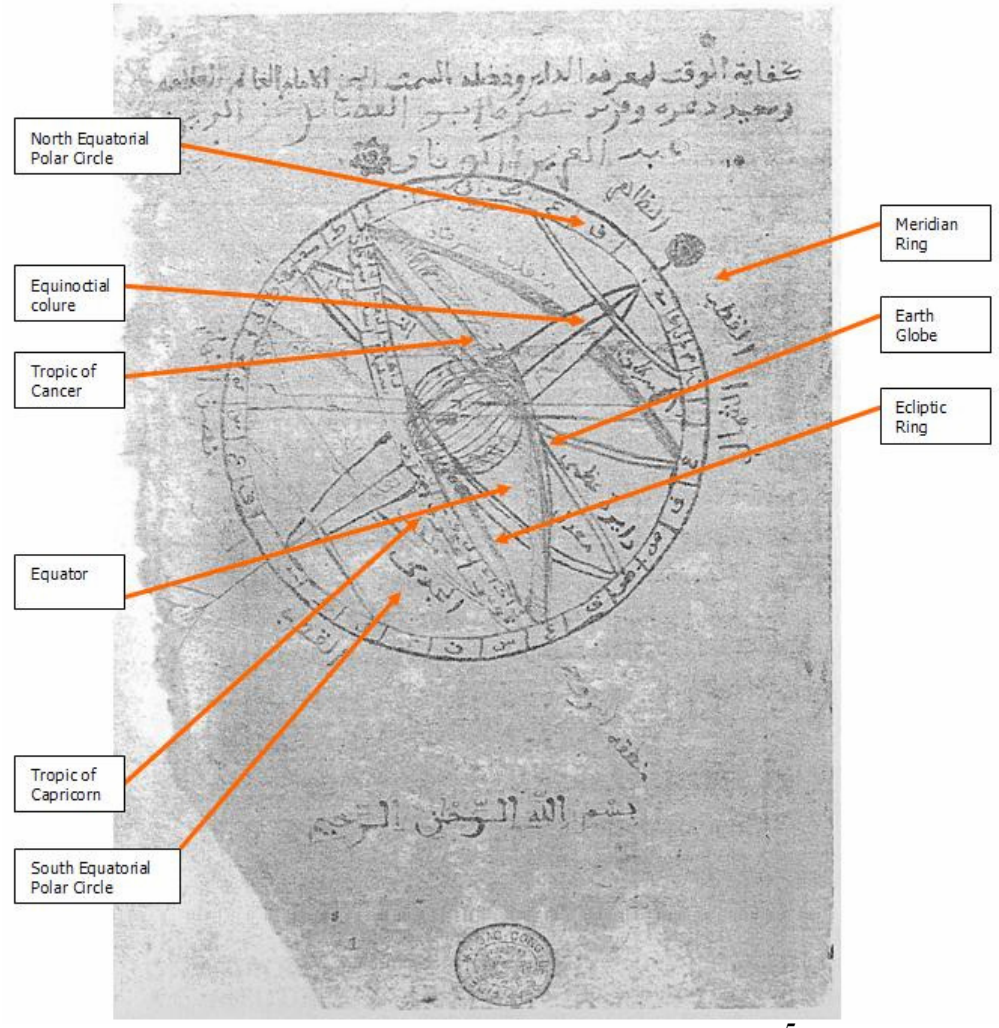

Figure 2: Annotated Diagram of the Cairo Manuscript[5].

Description of the Armillary Sphere

The armillary spheres in Figures 1 and 2 depict demonstrational armillary spheres and are composed of similar components, with only slight differences. The spheres consist of the following elements:

1. The Earth (kurat ardh wa mā')

Figures 1 and 2 have an earth globe in the middle of the structure (only found in demonstrational armillary spheres. This represents a geometric point and is absolutely at rest, i.e. it does not rotate along with the rest of the skeletal structure representing the celestial sphere.

Markings: In Figure 1, the earth is marked with lines of latitude and longitude whereas in Figure 2, the earth is only marked with lines of longitude.

[5] Emilie Savage-Smith (1992),"Celestial Mapping", op. cit., figure 2.32, p. 50.

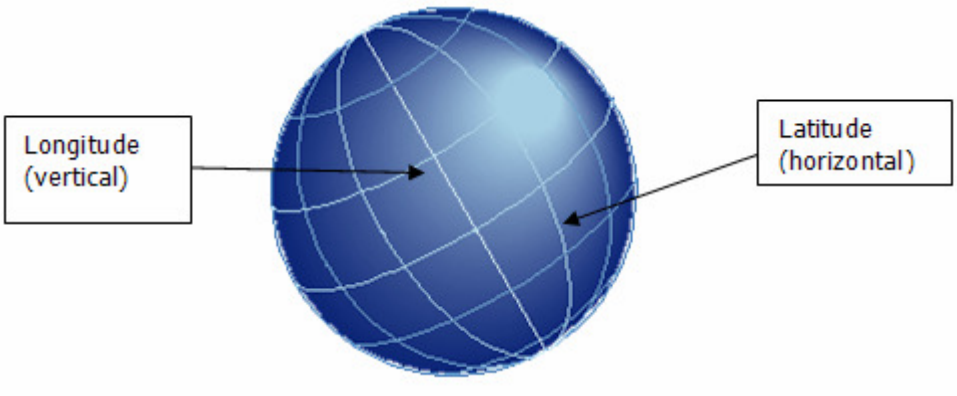

Figure 3: Globe with lines of latitude and longitude.

2. The Rings[6]

The rings which make up the armillary spheres are indicated below. The most important are the horizon, the meridian, the equator and the ecliptic rings.

2.1. The Horizon Ring (not illustrated in Figure 2)

2.2. The Meridian Ring

2.3. The Ecliptic

2.4. Rings making up the inner skeletal globe

2.1. The Horizon Ring (*dā''irat 'ufuq*)

The horizon ring is a fixed ring which, along with the meridian ring, forms the base or stand for the revolving sphere. This ring is clearly illustrated in Figure 1 as the illustration also includes the base and stand, while Figure 2 depicts just the armillary sphere without any such stand.

What does it represent? The horizon is a plane which is tangent to the observer's position on the earth. This can be seen in Figure 4. The observer is positioned at a particular latitude which is defined by the angle between the equator and the observer's location. Note that in Figure 10, the earth has been made large for purposes of clarity, whereas when compared to the celestial sphere, the earth is of negligible size. The horizon plane, thus, bisects the celestial sphere: one half of the celestial sphere is above the horizon and the other half below.

[6] For more see J. Evans, *The Armillary Sphere*, Seattle: University of Washington Press, 1986, pp. 4- 7.

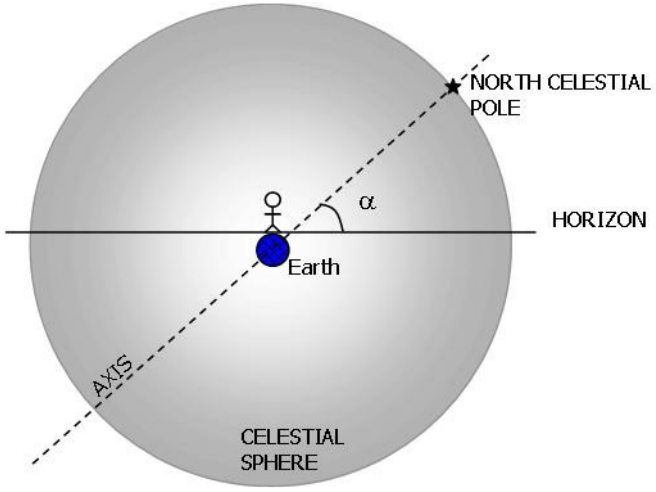

Figure 4: The horizontal plane bisecting the celestial sphere.

Scales and Markings :

In Figure 1, the horizon ring is divided into ten degree intervals with lines across the flat ring. These ten degree intervals are marked 10, 20 and 30 in Arabic numerals, anti-clockwise.

These ten degree intervals are further sub divided into two degree steps. These are marked by a strip towards the inside of the horizon ring in alternating dark and light graduations each indicating two degrees.

Armillary spheres are also typically marked with cardinal points (north, east, south and west) on the horizon ring but no such markings are visible on the manuscript in Figure 1.

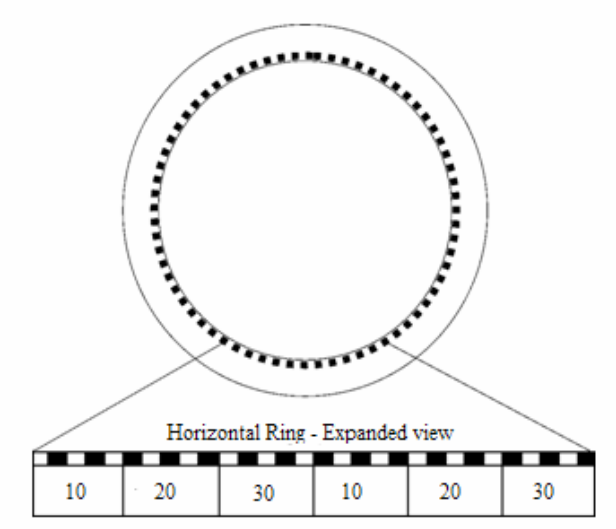

Figure 5: Markings on the Horizon Ring.

2.2. The Meridian Ring (*dā"irat nisf nahār*)

The meridian ring is a vertical fixed ring which forms part of the base and stand along with the horizon ring. It does not participate in the revolution of the celestial sphere about the axis of the universe, although it should be able to rotate in the direction of its circumference. This is to allow the altitude of the pole above the horizon to be changed. This ring is clearly illustrated in Figures 6 and 7 which are drawn from Figures 1 and 2.

What does it represent?

The meridian ring is a vertical circle. It is similar to meridians of longitude drawn on globes of earth, but this meridian ring represents a similar circle for the celestial sphere.

Scales and Markings

The meridian ring is also divided, in similar fashion to the horizon ring, into ten and two degree intervals. These are degrees of celestial latitude, based on the angle "α" as shown in Figure 3. The two degree intervals are also marked with alternating dark and light graduations towards the inner side of the meridian ring.

The markings in Figure 1 and Figure 2 are in Arabic. The markings on Figure 1 start at 90 degrees at the north celestial pole, and are marked in ten degree intervals (80, 70, 60, 50 … 10) till 10 degrees at the celestial equator, covering a quarter of the meridian ring. The numbering starts again at 10 degrees and goes on to 90 degrees at the south celestial pole. In Figure 2, instead of Arabic numerals, the 10 degree divisions are marked by Arabic letters representing the ten degree intervals, but are not symmetrical in terms of layout on either side of the meridian ring.

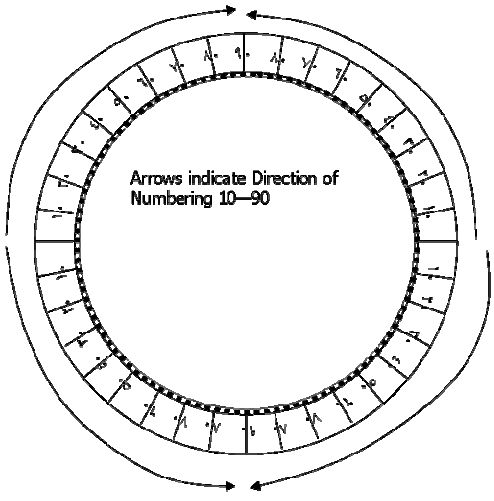

Figure 6: Numbering on the Meridian Ring of an Ottoman Manuscript.

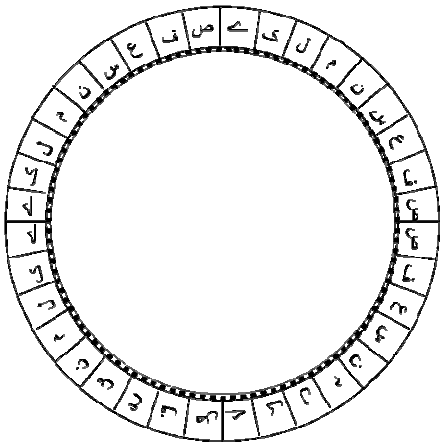

Figure 7: Lettering on the Meridian Ring of a Cairo Manuscript.

2.3. The Ecliptic (*mintaqat al-buruuj*)

A band going around the celestial sphere at an angle of 23.5 degrees to the equator is marked with signs of the zodiac. The line running through this band is the Ecliptic.

The ecliptic intersects the equator at two places:

The vernal equinoctial point (the sun passes through this point on March 21)

The autumnal equinoctial point (the sun passes through this point on September 23)

What does it represent? The ecliptic is the path of the sun in its annual motion around the earth

Scales and Markings

The width of the band is ideally +/- 9 degrees.

In both Figures 1 and 2, the ecliptic has three markings incorporating; the degrees of celestial longitude, the signs of the zodiac and the date on which sun enters each sign. The zodiac signs, usually of Arabic names, are as given in Table 1. The zodiacal signs are 30 degrees segments of the ecliptic, starting with Aries which makes up the first 30 degrees segment, then comes Taurus and the rest of the sings. Please note that the figure below represents the markings on the Ottoman script in Figure 1.

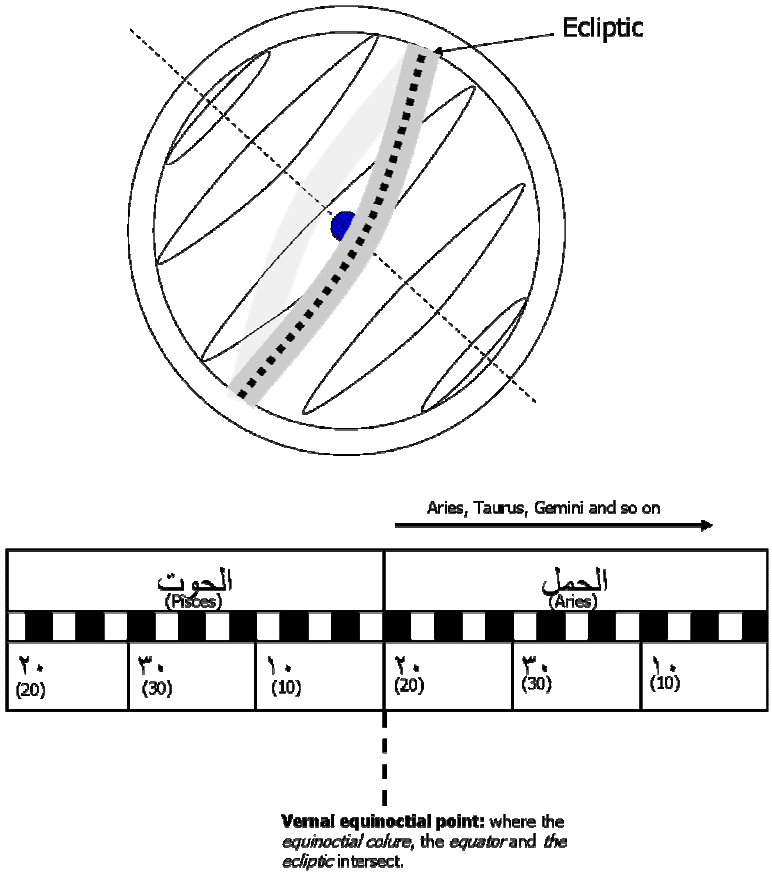

Figure 8: Markings on the Ecliptic Ring.

Latin	Arabic
Aries	Al-Hamal
Taurus	Al-Thawr
Gemini	Al-Jawzā’
Cancer	Al-Saratān
Leo	Al-Asad
Virgo	Al-Sunbula
Libra	Al-Mīzān
Scorpio	Al-‘Aqrab
Sagittarius	Al-Qaws
Capricorn	Al-Jadiy
Aquarius	Al-dalw
Pisces	Al-Hūt

Table 1: Signs of the Zodiac in English and Arabic.

2.4. Rings making up the inner skeletal globe:

They consist of the following:

A. The Equator (*dā'ira mu'addala*)

The equator, along with the ecliptic, participates in the daily revolution of the celestial sphere.

The equator is generally marked with hours on armillary spheres, but in this case both the manuscripts in Figures 1 and 2 are left unmarked.

B. The Tropics and Polar Circles

The illustrations in Figures 1 and 2 include the rings of the Tropic of Cancer and Tropic of Capricorn as separate rings.

What do they represent? The tropic of Cancer is tangent to the ecliptic in the north. This line marks the limit of the sun's progress towards the North Pole each year.

The tropic of Capricorn is tangent to the ecliptic in the South. This line marks the limit of the sun's progress towards the South Pole each year.

	Celestial Latitude	**Arabic Name**
Tropic of Cancer	23.5ºN	مدارسرطان
Tropic of Capricorn	23.5ºS	مدارجدی
North equatorial polar circle	66.5 ºN	مدارقطب البروج الشمالی
South equatorial polar circle	66.5 ºS	مدارقطب البروج الجنوبی
North celestial Pole	90 ºN	قطب الشمالی
South celestial Pole	90 ºN	قطب الجنوبی

C. The Colures

Generally in armillary spheres, there are two types of colures included: the Solstitial Colure, and the Equinoctial Colure. These are the circles passing through the northern and southern celestial poles and have little theoretical importance. The Solstitial Colure passes through the two solstitial points similarly to the equinoctial colure which passes through the two equinoctial points (the vernal equinoctial point and the autumnal equinoctial point.) The Equinoctial Colure is included in both Figures 1 and 2, whereas the Solstitial Colure is not illustrated.

3. The Base

The armillery sphere has a base, characteristic of common hexagonal based designs. The design is based on the extrapolation of lines of a ten-point star.

Figure 9: Western style of the armillary sphere.

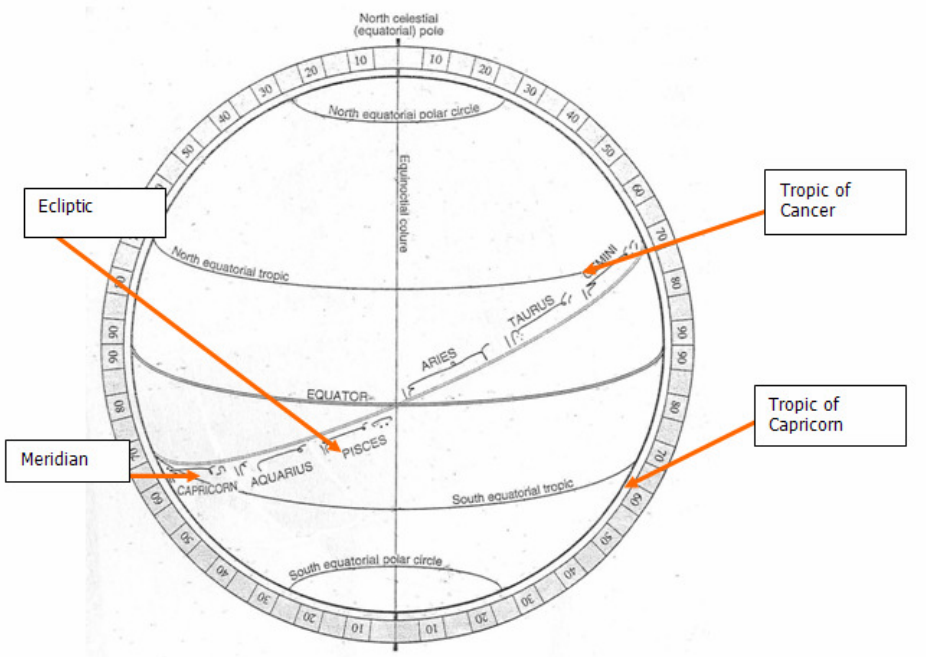

Figure 10: Diagram illustrating the various elements of the celestial sphere[7]

[7] Emilie Savage-Smith (1992),"Celestial Mapping", op. cit., pp. 12-69

4. Important Astronomical Facts

There are a number of important astronomical facts required for understanding the armillary sphere including:

Celestial Sphere – If the sky is regarded as a hollow sphere on which the stars are fixed, it is called the Celestial sphere.

Celestial Poles – The stars appear to behave exactly if they were attached to a single revolving sphere (the celestial sphere). The two points where the axis of rotation pierces the celestial sphere are known as the celestial poles

Celestial Equator – The celestial equator is the great circle located midway between the two celestial poles. This may be considered as a projection of the Earth's equator.

Ecliptic – The path of the sun around the Earth. The ecliptic is tilted and the angle between the plane of the ecliptic and the plane of the celestial equator is about 23 degrees.

Tropic Circles – Circles parallel to and equidistant from the celestial equator

Meridian – A vertical circle on the celestial sphere which is analogues to the meridians of longitude that one sees drawn on globes of the earth. (Please note that in the above diagram the numbering is different from the manuscripts.

Vernal Equinox/Vernal Equinoctial point – the point on the celestial sphere where the path of the sun (ecliptic) crosses the celestial equator, in the constellation of Pisces. This is also intersected by the equinoctial colure.

Appendix – Annotated manuscript images

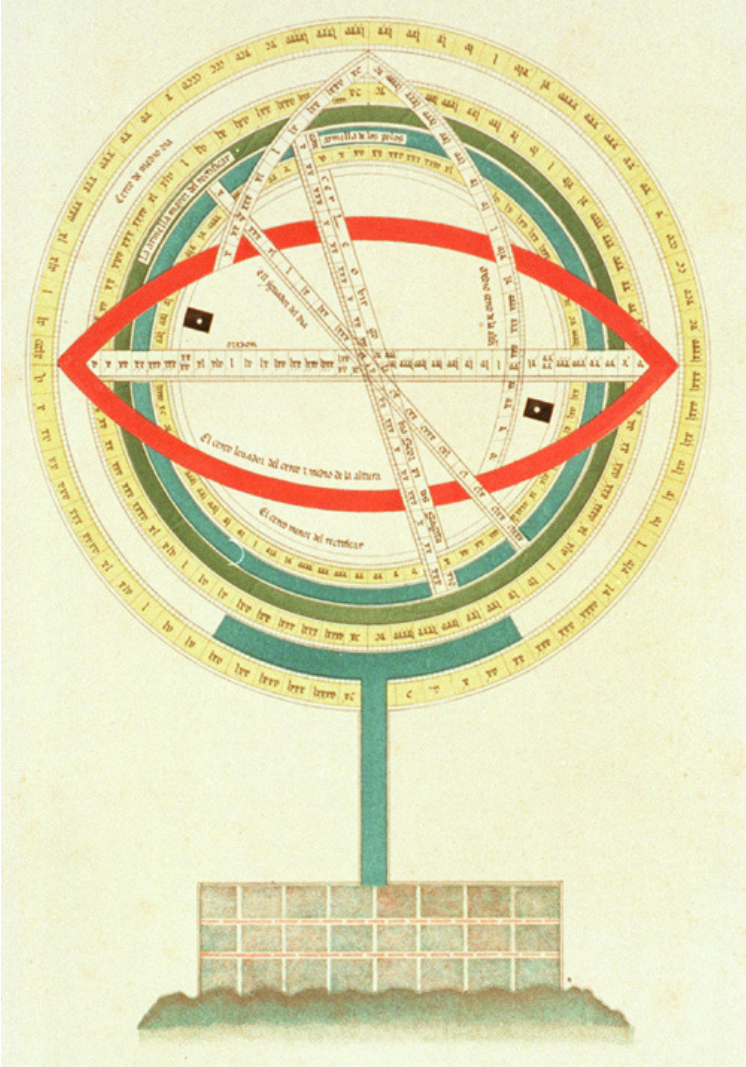

Figure 11: A drawing of a demonstrational armillary sphere, from *Libros del saber de astronomia del rey D. Alfonso X De Castilla*, a compilation of sixteen treatises translated from Arabic upon the instigation of Alfonso X in Spain in 1276 -1277. Source: **http://www.hps.cam.ac.uk/starry/armillary.html**.

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