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İSAM

Zodiac on Earth: The Ecliptic on two sixteenth-century Ottoman World Maps*

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Yeryüzündeki Zodyak: Osmanlı Onaltıncı Yüzyılından İki Dünya Haritasında Ekliptik

Özet ■ Ali Macar Re'is atlası ve Walters Deniz atlasında yer alan ve Osmanlılarca hazırlanmış iki dünya haritası, ekliptik çizgisini (Zodyak) düz iki dilim şeklinde göstermeleri açısından emsalsizdirler. Her iki harita da onaltıncı yüzyılda, o sıralarda oldukça popüler olan "oval" diyebileceğimiz kartografik projeksiyonla çizilmiştir. Zodyak, bu atlasları hazırlayanlar için önemli olmuş olsa gerek, zira her iki haritada da göze çarpacak bir şekilde ve en son yapılan eklentiler arasında çizilmiştir. Ancak geometrik bir araştırma, her iki haritadaki (bilhassa Walters Deniz atlasındaki) ekliptik çizgilerinin de doğru olmadığını ortaya koyuyor. Oysa aynı dönemde Batı Avrupa'da hazırlanmış birçok küresel ve göksel düzlemküre, aynı astronomik çizgiyi geometrik olarak doğru bir şekilde gösteriyor. Bu fark, haritaları hazırlayan Osmanlılar'ın hedeflerinin, geometrik doğruluktan ziyade sembolizm ya da estetikle ilgili olduğunu düşündürüyor. Bir dünya haritasına çizilen Zodyak'ın pek bir pratik uygulaması olmadığını düşünecek olursak, haritayı çizenlerin aynı anda hem yeri hem de göğü temsil etmek istemiş olabileceklerini söyleyebiliriz. Bu da, bu iki Osmanlı dünya haritasını, üzerlerinde Zodyak'ın sıklıkla görüldüğü kozmografik diyagramlara benzetir. Ayrıca, ekliptik çizgisinin her iki haritada da aynı şekilde hatalı çizilmiş olması, çizenlerin ortak bir kaynaktan ilham almış olabileceklerini düşündürür. Zodyakı dört düz dilimle gösteren bir Arap kozmografik diyagramının bulunması, her iki haritanın çiziminde de ortak bir prototip diyagramın kullanılmış olabileceği ihtimalini güçlendirir.

Anahtar kelimeler: Walters Deniz atlası, Ali Macar Re'is atlası, ekliptik, Zodyak, oval projeksiyonlar, kozmografik diyagramlar, Battista Agnese.

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Introduction

Among the very limited number of Ottoman world maps made in the sixteenth century, two present a unique characteristic: they show the Ecliptic line as two straight segments, a configuration that I have not found on any other map. These two world maps are contained in two manuscript atlases produced in the Ottoman Empire in the second half of the sixteenth century. One of them is named after its presumed author, Ali Macar Re'is, dated 1567 (more precisely one of the portolan charts it contains is dated in the month of Safer of 975 AH) and currently located in the Topkapi Palace Library.[1] The other one is part of an anonymous and undated atlas that Thomas D. Goodrich located in the Walters Art Museum in Baltimore, USA, and named the Walters Sea Atlas.[2]

The shape of the two maps is quite similar. Both show the entire world in a single, elongated figure framed by two straight segments at the Poles and two semicircumferences at the Eastern and Western edges. The central meridian is located on the Atlantic Ocean, close to the westernmost tip of Africa. This way of representing the world was quite frequent in the sixteenth century.

I have attempted to understand why the authors of these world maps decided to draw the Ecliptic and why in that particular manner. For this I have studied in detail the geometry of the grid of parallels and meridians and of the main cartographic lines (equator, ecliptic, tropics and polar circles), while disregarding the coastlines drawn on the maps. I have also carried out a survey of other cartographic works from the sixteenth century that represent the Zodiac in different manners, trying to grasp the intentions of their respective authors.

I had the chance to use a very-high-resolution facsimile of the Walters Sea atlas that was recently made available online at the website of the Walters Art Museum.[3] For the Ali Macar Re'is Atlas I used the paper facsimile published by Kemal Özdemir.[4]

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1 Topkapı Sarayı Kütüphanesi, H 644. Color reproductions of the world map can nowadays be found in the internet, for example at http://www.turkiye-rehberi.net/harita/resim/dunya/ali_macar_reis_dunya_haritasi.jpg

2 Thomas D. Goodrich, "The Earliest Ottoman Maritime Atlas: The Walters Deniz Atlası," *Archivum Ottomanicum* 11 (1986): 25-50.

3 "W. 660, Maritime atlas," The Walters Art Museum: http://www.thedigitalwalters.org/Data/WaltersManuscripts/html/W660/

4 Kemal Özdemir, *Ottoman nautical charts and the Atlas of Ali Macar Reis* (Istanbul: Marmara Bank Publication, 1992); for a reproduction of the *mappa mundi* in this atlas, see p. 58, Figure 1, in this volume.

Geometric survey

Grid measurement

The measurement of the grid of parallels and meridians leads to the following five observations:

1. Parallels are straight horizontal lines.

2. The central meridian is a straight vertical line half as long as the equator.

   The value of the equator / central meridian length ratio is not exactly equal to 2.0 in the two maps considered but the difference is unimportant.

   For the Walters map the equator measures 1.94 times the length of the central meridian.

   For the Ali Macar map the measurement is a bit more complicated because on this map the easternmost and westernmost edges of the equator appear to have been cut off, at least on Özdemir's facsimile and all the reproductions I have been able to consult. I have not been able to check the original as the Topkapı Palace Library was closed for maintenance. Taking the length of the equator as shown on the available facsimiles gives an equator / meridian ratio of 1.94, whereas if we extrapolate the map's grid to include the equator in its full extension then the ratio increases slightly to 1.97.

3. The central meridian is evenly graduated in latitude.

   Parallels are drawn at intervals of 10 degrees in the Walters map and of 15 degrees in Ali Macar's. In addition, the central meridian of the Ali Macar map is more finely divided by dots into intervals of 5 degrees each.

   In fact the spacing between consecutive parallels is quite homogeneous on both maps but not completely. On the Ali Macar map the distance between the 75°S parallel and the South Pole is 9% smaller than the average interval between consecutive parallels. Aside from the southernmost interval, the spacing of parallels is very homogeneous (relative deviation = 1.4%). Similarly, on the Walters map the southernmost interval is the narrowest too, around 7% shorter than the average. Excluding that interval, homogeneity is quite high (relative deviation = 2.4%).

4. The equator is evenly graduated in longitude.

   Meridians are drawn at intervals of 20 degrees in the Walters map and of 15 degrees in Ali Macar's. In addition the Equator of the Ali Macar map is more finely divided by dots into intervals of 5 degrees each. A similar subdivision, with dots spaced every 10 degrees, can be observed in the Walters map but curiously only in its Western half.

As is the case with the central meridian, the graduation of the equator is not perfectly homogeneous. The relative deviation of the lengths of intervals between consecutive meridians is low for both maps: 3.6% for Ali Macar's and 2.2% for the Walters'.[5] That said, an attentive observer can detect with the naked eye slight discrepancies in meridian spacing on the Ali Macar map. For example the distance between 45°W and 30°W at the equator is 19 mm whereas between 30°W and 15°W it measures a noticeable 1.5 mm less (values measured on Özdemir's facsimile).

On the Walters map, the faint traces of two extra meridians can be observed between meridians 80 and 100° East and West respectively. Based on the points at which these extra meridians cut the Equator, their longitudes are roughly 94°E and 93°W. The purpose of these extra meridians is not clear to me; they may just have been used at some intermediate stage of the geometric construction of the grid.

5. Meridians are arcs of circumference drawn in two different ways: for longitudes greater than 90° East or West from the central meridian, they are semicircumferences with center on the equator and radius equal to half the length of the central meridian; for longitudes less than 90°, they are arcs that pass through the two extremities of the central meridian and through the appropriate point on the equator.

   The meridians of the Ali Macar map are actually not perfect arcs of circumference. I took 10 random measurements of the radius of the 180°W and 180°E meridians, i.e. the edges of the map, and found discrepancies of up to 6 mm over an average radius of ca. 108 mm. The relative deviation of this sample is small, around 2%, which explains why to the naked eye these meridians do look like circumferences.

   On the Walters map the meridians seem to have a much more perfect circularity, which suggests that a compass was used by the draughtsman. This impression is reinforced by the fact that at the Poles the arcs of the meridians sometimes continue beyond the point of tangency with the horizontal line, an imperfection that typically occurs when drawing with a compass (see Figure 1).

5 The following intervals have not been included in the computation of relative deviation because they do not appear complete on the facsimiles used for this study: 180°W – 165°W and 165°E – 180°E for Ali Macar; 20°W – central meridian for Walters.

Figure 1: Detail of the North Pole line on the Walters Atlas world map (for the source, see fn. 3).

Partial conclusions

Overall the grids of meridians and parallels of both the Ali Macar and the Walters world maps form a clearly-defined pattern that leaves no doubt about the cartographic projection used for both works. This projection, which I will discuss in detail in the following section, was correctly identified by Tom Goodrich as the same one used on other sixteenth-century world maps by Italian cartographers Gastaldi, Camocio and Porcacchi.[6]

The small inaccuracies in the spacing between meridians and parallels rule out the use of a pre-defined template grid. Visual inspection indicates that the Walters map's lines may have been traced with ruler and compass. On the other hand, the slight imperfection in the circularity of the meridians of the Ali Macar map hints at some kind of free-hand drawing, as has been suggested by Sonja Brentjes for several later Ottoman maps.[7] In actual fact, with the information available it is rather difficult to reach a definitive conclusion on how these maps were drawn.

Cartographic projection

The geometric survey has shown that both the Ali Macar and the Walters world maps satisfy to a high degree the following six conditions:

1. Parallels are straight horizontal lines.
2. The central meridian is a straight vertical line half as long as the equator.
3. The central meridian is evenly graduated in latitude.

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6 Thomas D. Goodrich, "Old maps in the library of Topkapi Palace in Istanbul," *Imago Mundi* 45/1 (1993): 120-33.

7 Sonja Brentjes, "Mapmaking in Ottoman Istanbul between 1650 and 1750: a domain of painters, calligraphers, or cartographers?" in *Frontiers of Ottoman Studies*, eds. Colin Imber, Keiko Kiyotaki, and Rhoads Murphey, vol. 2 (London: I.B. Tauris, 2005), 125-56, http://us.academia.edu/SonjaBrentjes/Papers/635291/Mapmaking_in_Ottoman_Istanbul_between_1650_and_1750_a_domain_of_painters_calligraphers_or

4. The equator is evenly graduated in longitude.
5. Meridians of longitudes greater than 90° are semicircumferences with centers on the equator and radiuses equal to half the length of the central meridian.
6. Meridians of longitudes less than 90° are arcs that pass through the two extremities of the central meridian and through the appropriate point on the equator.

The six conditions above define unequivocally a specific cartographic projection that can be also expressed by explicit algebraic equations (see Appendix 1). Given this set of six instructions, any sixteenth century draftsman would have been able to draw the grid of parallels and meridians corresponding to such projection. His only choices would have been how many parallels and meridians to draw, i.e. the spacing between two consecutive parallels and between two consecutive meridians; and on which geographical location to position the central meridian.

This projection was used quite frequently throughout the sixteenth century. Appendix 2 lists all the twenty-seven pre-1600 maps drawn based on it that I am aware of. Not surprisingly, the table includes the world map printed by Gastaldi (ca. 1561) and currently preserved at the British Library, which is extremely similar in its coastlines to Ali Macar's world map. Given that this projection has not been given a specific name in cartographic literature,[8] in order to make the following discussion easier to follow I propose to call it the "Agnese Oval Projection" (AOP), after the cartographer that seems to have used it first.[9]

Other sixteenth-century world maps were based on a very similar projection that differs only in the fact that the Equator has been compressed in length, thereby reducing the equator / central meridian ratio to a value close to 1.7 or 1.8. According to Shirley's *The Mapping of the World*,[10] there exist 15 pre-1600 printed

8 Anthiaume called it "canevas symétrique" but the name did not catch on; Albert Anthiaume, *Cartes marines*, 2 vols. (Paris: E. Dumont, 1916), 421: http://gallica.bnf.fr/ark:/12148/bpt6k57844542/f433.image

9 Battista Agnese worked in Venice and between 1536 and 1565 made a series of manuscript atlases, of which at least eighty are extant, that always include an oval-shaped world map drawn in the projection described above; Marica Milanesi, "La cartografia italiana nel Medioevo e nel Rinascimento," in *La cartografia italiana: Cicle de conferències sobre Història de la Cartografia – 3er curs: 17, 18, 19, 20 i 21 de febrer de 1992* (Barcelona: Institut Cartogràfic de Catalunya, 1993), 15–78, at 59-60.

10 Rodney W. Shirley, *The Mapping of the World: Early printed world maps, 1472-1700*, 4th ed. (Riverside: Early World Press, 2001).

world maps based on this projection, which I will call the "Compressed Agnese Oval Projection" (CAOP). The earliest CAOP world map seems to be Gastaldi's *Universale Novo* printed in 1548.[11]

Aside from these, there exist many other world maps with a shape that may be generally called "oval," a term for which a strict definition is rarely given but that we can take to mean as the representation of the whole Earth in a continuous figure that is symmetric both across the Equator and across the central meridian. Well-known examples from the sixteenth century are the world maps printed by Rosselli (1508 reprinted in 1532),[12] Bordone (1528),[13] Cabot (1544) [14] or Gastaldi (1546).[15] The projections used by these four authors are all different between them and different from the AOP, with which they should not be confused.

The precise knowledge of the cartographic projection used for the Ali Macar and Walters world maps will allow us to theoretically calculate the shape of the Ecliptic, plot it on each map and therefore compare it with the Ecliptic lines actually drawn.

11 The "Universale novo" was one of the two "modern maps" of a compact edition of Ptolemy's *Geographia*, entitled *La Geografia di Claudio Ptolemeo Alessandrino... di Meser Iacopo Gastaldo...* (Venice, 1548) ; see Shirley #87, plate 74.

12 The 1508 map was printed in Florence and only four exemplars are extant (see Shirley #28, plate 32S). The later reprint appeared in Bartolommeo dalli Sonetti, *Isolario, Carte del mare Egeo* (Venice, 1532); see Shirley #67A, plate 61A.

13 Contained in *Libro di Benedetto Bordone… de tutte l'Isole del mondo…* (Venice, 1528) ; see Shirley #59.

14 Sébastien Cabot (Antwerp, 1544) ; preserved in a single copy at the Bibliothèque Nationale de France [BNF hereafter], GE AA- 582 (RES); see Shirley #81.

15 Giacomo Gastaldi, "Universale" (Venice, 1546); see Shirley #85, plate 72.

Ecliptic and Zodiac

Definitions

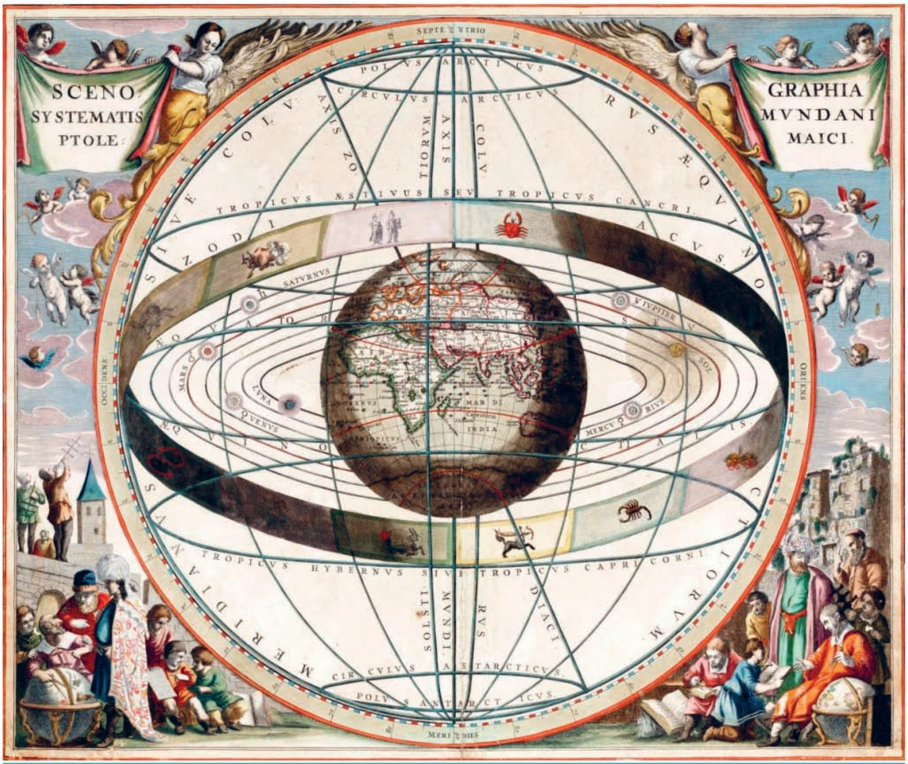

Figure 2: Cosmographical scheme showing the Earth in the center of the Universe and the Zodiac on the outer "sphere of stars," according to Ptolemy's theory; from Andreas Cellarius, *Harmonia macrocosmica*, ed. Johannes Janssonius (Amsterdam, 1660). Image courtesy of the National Library of Australia and Wikimedia Commons.

Astronomers define the Ecliptic as the imaginary curve formed by the intersection of the "ecliptic plane" with the "celestial sphere." The ecliptic plane is nowadays defined as the geometric plane that contains the mean orbit of the Earth around the Sun, which forms an angle of around 23.4 degrees with the axis of rotation of our planet.[16]

16 The exact value of the obliquity of the Ecliptic is not constant with time. In 1567 the obliquity was 23.493 degrees , according to the algorithm provided in NeoProgrammics.com, based on data published by Jacques Laskar, "Secular terms of classical planetary theories using the results of general theory," *Astronomy and Astrophysics* 157 (1986): 59-70.

The celestial sphere is an imaginary sphere concentric with the Earth. Back in the times of geocentrism, the Ecliptic was defined as the path of the Sun across the celestial sphere along the year.[17]

The band of sky about eight degrees above and below the Ecliptic is called the Zodiac and was particularly important for ancient astronomers / astrologers because it encompasses the apparent trajectories of the seven "planets," i.e. Mercury, Venus, Mars, Jupiter, Saturn, the Sun, and the Moon. Since Antiquity the Zodiac has conventionally been divided into 12 segments of equal size called the zodiacal signs.

The Ecliptic on terrestrial maps

Figure 3: Detail of Andreas Cellarius' diagram shown in Figure 2. Cellarius drew the projection of the Ecliptic on the Earth surface as a "Liniea Zodiaci," with the same graphic treatment as the Equator. Cellarius chose to draw the Ecliptic with its tangency point with the Tropic of Cancer located at longitude 90° East.

If the Earth is assumed to be spherical (instead of its actual ellipsoidal shape) and if the celestial sphere is assumed to lie exactly on the planet's surface, the Ecliptic then takes the shape of a great circle that is tangent both to the Tropic of Cancer and to the Tropic of Capricorn.

Due to the Earth's movement of rotation, the Ecliptic changes place continuously, moving around the planet approximately once every day. So, if somebody

17 David P. Stern, "The Path of the Sun, the Ecliptic," *From Stargazers to Starships*, 2004, http://www-istp.gsfc.nasa.gov/stargaze/Secliptc.htm

wants to draw the Ecliptic on a world map he or she must choose arbitrarily the position of the points of tangency of the Ecliptic with the Tropics. By convention, mapmakers have always tended to draw the tangency points either at 0° and 180° or at 90° and 270° longitude. Both the authors of the Walters and Ali Macar world maps chose to make the Ecliptic tangent to the Tropic of Cancer at 0° longitude.

Like any other cartographic line, the shape that the Ecliptic adopts on a map depends on the cartographic projection used. In a world map drawn using the Agnese Oval Projection the Ecliptic adopts the shape of the smooth curve that can be observed in Figure 4. It looks much like a sinusoid but is in fact a slightly different curve. The algebraic equations of the Ecliptic in this projection can be found in Appendix 1.

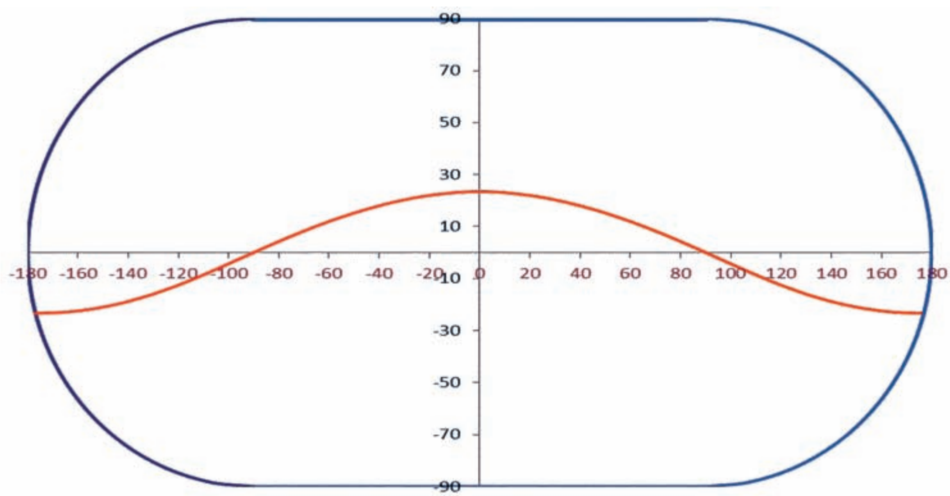

Figure 4: True shape of the Ecliptic in the Agnese Oval Projection.

How accurate is the shape of the Ecliptic on the Ottoman world maps?

a) Walters world map

On the Walters world map the Ecliptic is drawn as two straight segments highlighted in gold color. Neither the Tropics nor the Polar Circles appear on this map. The Ecliptic is divided into 12 sections, on each of which the name of a sign of the Zodiac is written in Arabic, i.e. in the usual way of naming Zodiac signs in the sixteenth-century Ottoman Empire. The sign names and most of the rest of the text on the map were written with the map oriented to the south (i.e. south at top).

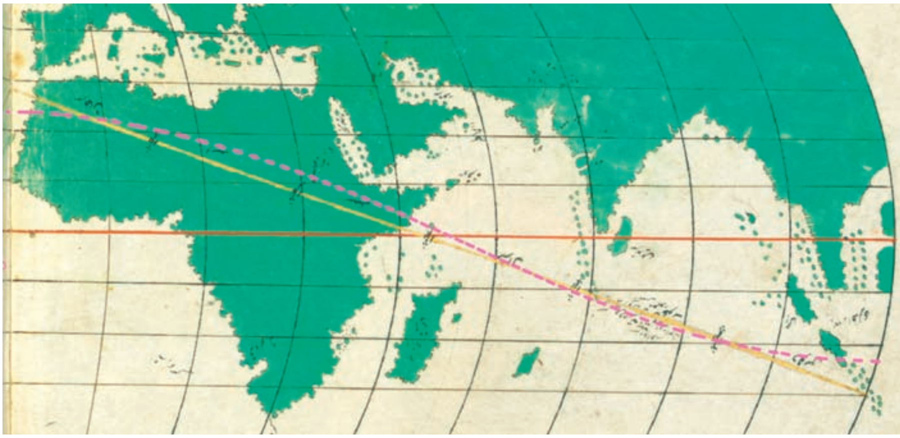

Figure 5: Superimposition of the theoretically exact shape of the Ecliptic (dashed pink line) on the Eastern hemisphere of the Walters world map.

Figure 5 shows that the shape of the Ecliptic drawn on the Walters world map is rather inaccurate. The most obvious difference is that the Ottoman chart displays the Ecliptic as straight lines instead of a curve. There is, however, another more subtle inaccuracy: the points of tangency with the Tropics are incorrect in latitude. The northern one is apparently placed at around 28°N whereas the southern one is at 30°S, i.e. more than 6 degrees to the south of its true position.

For anybody attempting to draw the Ecliptic on a world map, even without knowing the actual shape of the line, it is always theoretically possible to plot at least four points on their exact locations: the points of tangency with the two Tropics and the two intersections with the Equator (see Table 1).

	Real values	*Walters map*	*Ali Macar map*
Latitude at point of tangency with Tropic of Cancer	23.4° N	28.3° N	23.9° N
Longitude at intersection with Equator, Eastern hemisphere	90° E	84.3° E	87.1° E
Longitude at intersection with Equator, Western hemisphere	90° W	86.7° W	87.5° W
Latitude at point of tangency with Tropic of Capricorn	23.4° S	30.0° S	24.3° S

Table 1: Longitudes and latitudes of the four "fixed points" of the Ecliptic.

I find it difficult to believe that the error on the Walters map may be due to an erroneous estimate of the value of the obliquity of the Ecliptic. First of all, astronomers and cartographers have known the angle of the obliquity with very good approximation since Antiquity. Quite accurate values like 23 or 23½ degrees are widespread in sixteenth century cartographic and astronomic works.[18] Furthermore, adopting different values of latitude for the northern and southern points of tangency is a conceptual error; whatever the value of the obliquity, those two latitudes cannot be different in any case.

One possible explanation of the Walters map's error would be that the person who drew the Ecliptic on it was ignorant of its astronomic meaning and just made a mistake when copying the line from some other map where it was correctly drawn. Maybe the draughtsman mistook parallels 30°N and 30°S on the Walters map for the Tropics drawn on the hypothetical model map. Another possibility is that he just wanted to draw a symbolic Zodiac and did not worry much about the accuracy of its geographic position.

b) Ali Macar world map

On the Ali Macar world map the Ecliptic appears as two straight segments in the same red color as the Equator, the Tropics and the Polar Circles. The Ecliptic is divided into the usual twelve Zodiac signs, named in Arabic. The name of each sign was written with the map oriented to the East. Furthermore the Ecliptic is graduated by dots at intervals of five degrees, like the Equator.

Table 1 shows that the points of tangency of the Ecliptic with the Tropics of Cancer and Capricorn are correctly located on the Ali Macar chart, at their right latitudes and 180 degrees away from each other. However, the intersections of the Ecliptic with the Equator (which should naturally lie at 90°East and 90° West) are misplaced by between 2.5 and 3.0 degrees. This error is just the natural result of having drawn the Ecliptic by joining with a straight line the two points of tangency with the Tropics. If the author of the map had chosen to respect the true positions of the intersections with the Equator, the result would have been a four-segment Ecliptic.

18 Arabic-speaking scientists revised the exact value of the obliquity of the Ecliptic quite often, keeping it always somewhat less than Ptolemy's value of 23°51'. Raymond P. Mercier, "Geodesy," in *The History of Cartography*, vol. 2, book 1: *Cartography in the Traditional Islamic and South Asian Societies*, ed. David Woodward and John Brian Harley (Chicago: University of Chicago Press, 1992), 175.

Order of the Zodiac signs

In both the Ali Macar Re'is world map and the Walters world map, the Arabic names of the twelve signs of the Zodiac are written along the Ecliptic. The series starts with Capricorn in the west and ends with Sagittarius in the east. The two northernmost signs, therefore closest to the Tropic of Cancer, are Gemini and Cancer. The two southernmost ones are Capricorn and Sagittarius. This arrangement of Zodiac signs follows the predominant convention used in astrological and cartographic works in the sixteenth century, which has its origin in classic Antiquity. However, due to the astronomical movement called precession of equinoxes, the signs of the Zodiac move slowly along the Ecliptic; and, as a result, their true position in the firmament in the sixteenth century in fact did not correspond any more to the convention established many centuries earlier.

Walters map	جدي دلو	دلو	حوت	حمل	ثو[ر]	جوزا[ء]
Ali Macar map	جدي	دلو	حوت	حمل	ثور	جوزا[ء]
Modern English names	Capricorn	Aquarius	Pisces	Aries	Taurus	Gemini

Table 2: Zodiac signs in the Western half of the maps, from southwest (Tropic of Capricorn) to north (Tropic of Cancer).

Walters map	سرطان	أس	سنبله	ميزان	عقرب	قوس
Ali Macar map	سرطان	?	سنبله	ميزان	عقرب	قوس
Modern English names	Cancer	Leo	Virgo	Libra	Scorpio	Sagittarius

Table 3: Zodiac signs in the Eastern half of the maps, from north (Tropic of Cancer) to southeast (Tropic of Capricorn). In the Walters map numerous diacritic signs are missing.

A curious mistake in the Walters atlas reveals, in my opinion, that the scribe wrote the signs from West to East: right after the name of the first sign, Capricorn (جدي), he wrote the name of the following one, Aquarius (دلو). He then realized that he had misplaced the latter word and thus wrote it again in its correct Zodiac interval. As a result, the Arabic name of the Aquarius sign appears twice on the map.

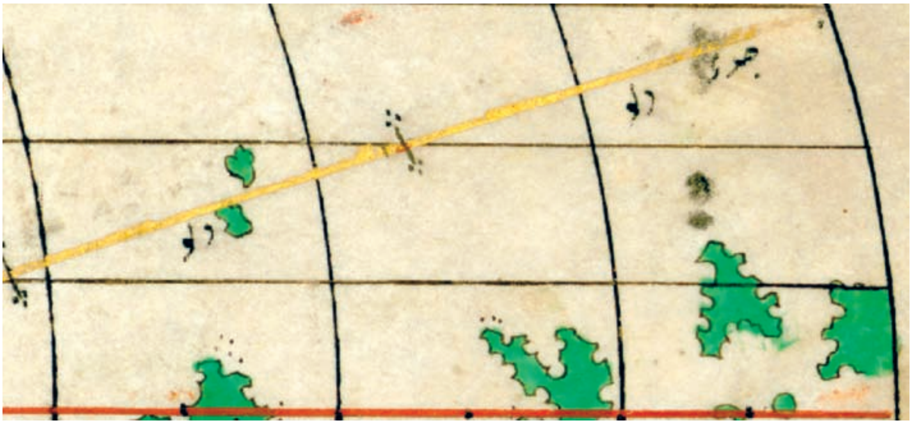

Figure 6: Westernmost section of the Zodiac in the Walters map, with South at top. The name of the sign Aquarius (دلو) appears twice.

When was the Ecliptic drawn?

The high resolution of the facsimile of the Walters Atlas world map allows deducing the relative order in which the different elements visible today on the map – lines, color, text – were added, just based on the way the different layers of color overlap on each other. I have inferred the following chronology:

0. Early stages that left no visible traces

1. Coastlines (black lines)

2. Continents and islands filling (green solid color)

3. Toponyms and legends (black text)

4. Meridians and parallels (black lines)

5. Equator (red line)

6. 10-degree division marks on Equator (black dots, only on Western half of map)

7. Ecliptic (gold line)

8. Zodiac sign names and divisions (black text and lines)

In the same manner the stages of the making of the Ali Macar world map can be ascertained, albeit with a lower degree of confidence because in this case the resolution of the facsimile is not so high:

0. Early stages that left no visible traces

1. Coastlines (thin black lines)

2. Continents and islands filling (green solid color)

3. Toponyms and legends (black text)

4. Meridians and parallels, including Equator and central meridian (black lines)

5. Rivers (blue lines)

6. Equator (thick red line over previously-drawn black one), Tropics and Polar Circles (thick red lines)

7. 10-degree division marks on Equator (black dots)

8. Ecliptic (thick red line)

9. 10-degree division marks on Ecliptic (black dots)

10. Zodiac sign names and divisions (black text and lines)

11. Central meridian (faint red line over previously-drawn black one)

For the purpose of this article, it should be emphasized that the Zodiac was the last element added to the Walters map and almost the last one in the case of the Ali Macar map.

Partial conclusions

The precise reason why the Zodiac was drawn on these two Ottoman maps is unknown but this line seems to have been important in the mind of their authors, as evidenced by the prominent graphical treatment it received in both charts.

Given the complicated mathematical expression of the equation of the Ecliptic in the Agnese Oval Projection, it is hardly surprising that its shape had to be simplified for any graphic representation. Nevertheless, reducing it to just two straight segments is an extreme simplification. Finding the same inaccurate shape of the Ecliptic on two different maps suggests that the authors of both maps may have had in mind a common prototype image. A mistake made when copying from a now-lost prototype could also explain the positional error of the Ecliptic on the Walters map.

At the same time, the fact that the Zodiac was the last (or almost the last) element added to the map raises the possibility that it may have been drawn *a* *posteriori* by somebody who was not the original author of the map. This person may have been a painter, not necessarily familiar with cartographic projections or with the shape that the Ecliptic adopts in each of them.

In any case, the simplified straight shape of the Ecliptic on these Ottoman maps hints that its function is more linked to symbolism or aesthetics than about geometric accuracy. The following section will explore the presence of the Ecliptic and the Zodiac on other sixteenth-century cartographic works in an attempt to understand the possible reasons that inspired the authors of the Walters and Ali Macar atlases to add the Ecliptic on their world maps.

The Zodiac in sixteenth-century cartographic works

Oval celestial planispheres

The world maps in the Ali Macar Re'is and Walters Sea atlases are, as far as I know, the two only terrestrial planispheres based on the Agnese Oval Projection that depict the Ecliptic. There exist however two oval *celestial* planispheres that show the Ecliptic in an exact manner.

Painted on the ceiling of the *Stanza delle Geografiche* (also known as *Sala della Cosmografia*) at the Palazzo Farnese (Caprarola, Italy) there is a celestial planisphere drawn in the AOP that has been dated to between 1573 and 1575. The Ecliptic appears as a smooth curve that matches very accurately its real shape. The Zodiac is shown in the position of the Winter solstice with each sign located not on its conventional position but on its correct apparent position on the sky at that date.[19] A very similar star chart, in the same projection and also showing the Ecliptic, was painted around those same years on the ceiling of the so-called *Sala bolognese* of the Vatican palace (Rome, Italy).[20]

These frescoes are approximately contemporary with the Ali Macar and Walters atlases and prove that at least in Italy there existed at that time the necessary astronomical and geometrical knowledge to plot the Ecliptic correctly on an AOP map. They also show that sixteenth century astronomers were well aware of

19 See reproduction in M. Quinlan-McGrath, "Caprarola's Sala Della Cosmografia," *Renaissance Quarterly* 50/4 (1997): 1050. A virtual 360° view of the whole Stanza, including the ceiling, is available online at http://www.futouring.it/web/filas/biblioteca-ricerca?fedora–item=turismoCulturale:3661.

20 This part of the Vatican palace is closed to visitors nowadays. A rather distorted reproduction of the celestial planisphere can be found in Jacob Hess, "On some celestial maps and globes of the sixteenth century," *Journal of the Warburg and Courtauld Institutes* 30 (1967): 406-9, plate 49.

the shift of Zodiac signs due to precession and were capable of locating each sign correctly on a star map. This stands in contrast with the straight-line Ecliptic and conventional sign position that characterize the Zodiacs of both the Ali Macar and Walters world maps.

Terrestrial globes and world maps with the Zodiac

Numerous terrestrial globes include the Ecliptic line. For example, the earliest preserved terrestrial globe – by Martin Behaim, ca. 1492 – shows a prominent Ecliptic adorned with diagrams of the 12 zodiacal constellations.[21]

On the other hand, I am aware of only two world maps made in the sixteenth century that depict the complete Zodiac in a geometrically consistent way: Guillaume le Testu's map in two hemispheres of 1566 and Jean Cossin's sinusoidal world map of 1570. [22] Both are manuscript charts made in Normandy, both display the Zodiac and its signs in a prominent way (with allegoric figures on Le Testu's map and color gradients on Cossin's), and in both cases the Zodiac adopts a curved shape that matches quite accurately the corresponding geographic projection. Cossin's chart actually depicts a second representation of the Ecliptic, in addition to the main Zodiac and shifted 180 degrees with respect to it, along which the months of the year are indicated.

In the seventeenth and eighteenth centuries it would become commonplace for mapmakers to draw the Ecliptic on world maps, in particular those composed of two circular hemispheres; but that was not yet the case before 1600.

Hajji Ahmed and astrological cartography

The Ecliptic does not appear on the cordiform world map signed by the Tunisian Hajji Ahmed in Venice in 1559, and whose real authorship remains ob-

21 Lionel Dorffner, "Der digitale Behaim-Globus: Visualisierung und Vermessung des historisch wertvollen Originals,".*Cartographica Helvetica* 14/96 (1996): 20–24. http://www.ipf.tuwien.ac.at/publications/ld_ch96/ld_ch96.html#MB

22 "Ceste Carte Fut pourtraicte en toute perfection Tant de Latitude que / Longitude Par moy Guillaume Le Testu Pillotte Royal Natif de / La ville Françoise de grace… et fut achevé le 23e jour de May 1566," BNF , GE AA-625 RES; 79 x 118 cm. High-resolution facsimile in Gallica: http://gallica.bnf.fr/ark:/12148/btv1b59062 67c/f1.zoom; and "Carte cosmografique ou universelle description du monde avec le vrai traict des vents – Faict en Dieppe par Jehan Cossin marinnier en l'an 1570," BNF, GE D 7896 RES; 25 x 43 cm. High-resolution facsimile in Gallica: http://gallica.bnf.fr/ark:/12148/btv1b59010 87w/f1.zoom.

scure.[23] However, the companion text does establish a correspondence between 12 geographic regions and the 12 Zodiac signs. For example, the Maghrib is linked to Cancer, "the land of the Blacks" to Scorpio, Temistitan (Mexico) to Virgo and so on.

The belief that each part of the Earth is governed or 'influenced' by a sign or a planet is called "astrological cartography" and dates back at least to Claudius Ptolemy's astrological treatise *Tetrabiblos*, which was translated into Arabic in the ninth century and into Latin in the twelfth century.[24] Ptolemy defined 'triplicities' of Zodiac signs with supposedly intrinsic 'characteristics,' linked each of them to a quadrant of the inhabited Earth, and from there explained the behavior of the inhabitants of each region. For example, Western Europeans would be "impatient of restraint, lovers of freedom, warlike, industrious, imperious, cleanly, and high-minded" just because their countries were governed by Aries, Leo, and Sagittarius.[25]

Many medieval astrologers, both Arab and Latin and possibly from other cultural spheres too, invented their own original sets of relationships between regions and signs and/or planets; all different from each other and from those put forward by Ptolemy. Hajji Ahmed's text is not an exception, as the alleged correspondences are different from any previous or later work. I have not identified either any logical principle or geometric pattern that could justify the attribution by Hajji Ahmed of a sign to a particular region. In general astrological cartographers did not base their discipline on any objective fact and, to my surprise, none of them seems to have used the geometric projection of the Ecliptic on a world map as a simple and logical method of relating Zodiac signs with geographical regions.

Allegoric Zodiacs in maps and atlases

Diego Ribero's world map of 1529 includes a circular diagram with the months of the year, theoretically in order to calculate solar declination. Around the circle of months are also shown the signs of the Zodiac. The diagram is located so that the outer circle of the Zodiac wheel is tangent to the two Tropics (see Figure 7). Aside from the potential mathematical application of this representation, I find

23 For a recent review of the literature on the Hajji Ahmed map, see Pascale Barthe, "An Uncommon Map for a Common World: Hajji Ahmed's Cordiform Map of 1559," *L'Esprit Créateur* 48/1 (2008): 32-44.

24 Frank E. Robbins, introduction to *Tetrabiblos*, by Claudius Ptolemy, trans. Frank E. Robbins (Cambridge: Harvard University Press, 1940), xiii.

25 English text taken from J.M. Ashmand, trans., *Ptolemy's Tetrabiblos* (London: Davis and Dickson, 1822), 44; freely available at http://www.sacred-texts.com/astro/ptb/index.htm.

that Ribero managed to harmoniously integrate into a single diagram three key cosmological entities: time, represented by the months wheel, the Heavens via the Zodiac wheel, and the Earth via the Tropics of the world map. There is a clear parallel with Cossin's representation of two Ecliptics, one with the Zodiac signs and the other one with the months of the year.

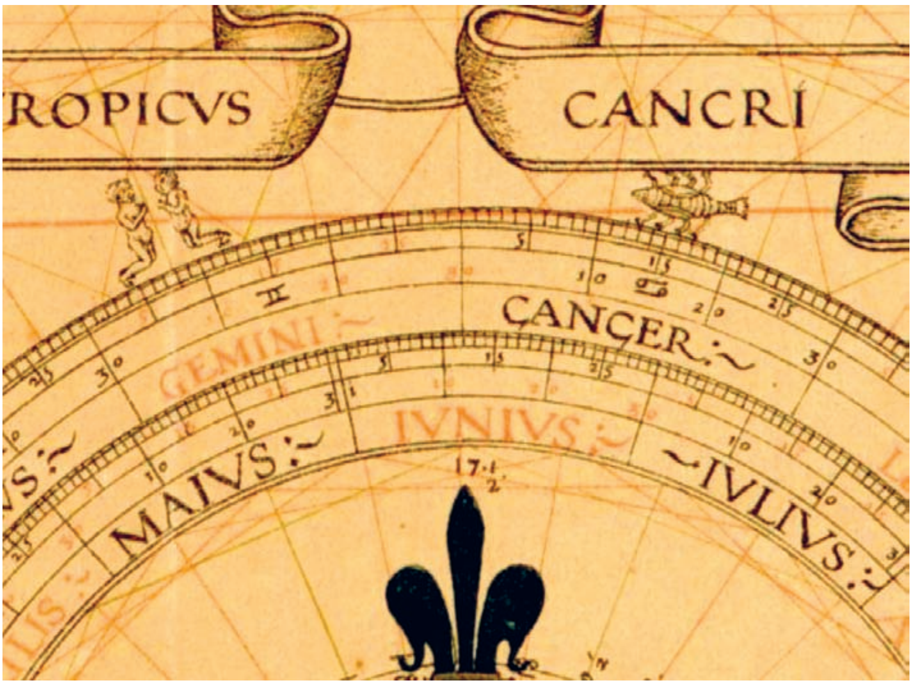

Figure 7: Detail of Diego Ribero's world map of 1529.[26] The concentric wheels of months and Zodiac signs are tangent to the Tropic of Cancer (on the image) and to the Tropic of Capricorn. Image courtesy of the Library of Congress.

Cosmographical diagrams

Whereas a map may be expected to serve to find one's way from a location to another, the purpose of a cosmographical diagram is to provide an overview of

26 "Carta universal en que se contiene todo lo que del mundo se ha descubierto fasta agora / hizola Diego Ribero cosmographo de su magestad, año de 1529, e[n] Sevilla," reproduced from the original in the Museum of the 'Propaganda' in Rome by W. Griggs (London, ca. 1887) ; Library of Congress Geography and Map Division, G3200 1529 .R5 1887 MLC. High-resolution image available in http://memory.loc.gov/cgi-bin/query/h?ammem/gmd:@field%28NUMBER+@band%28g3200+ct002450%29%29

the Universe, in whole or in part, in an easy-to-understand manner. The border between maps and cosmographical diagrams is fuzzy and many ancient world maps could actually be interpreted as philosophical representations of the cosmos rather than as practical navigation or orientation tools.[27]

Numerous pre-1600 cosmographical diagrams include the Zodiac as a circle around the Earth. There are only a few, however, that represent it – or at least the bare Ecliptic – as a line superimposed on a usually circular Earth. The oldest known such diagrams date from the Late Antiquity and were still being copied in the sixteenth century (see Figure 8).

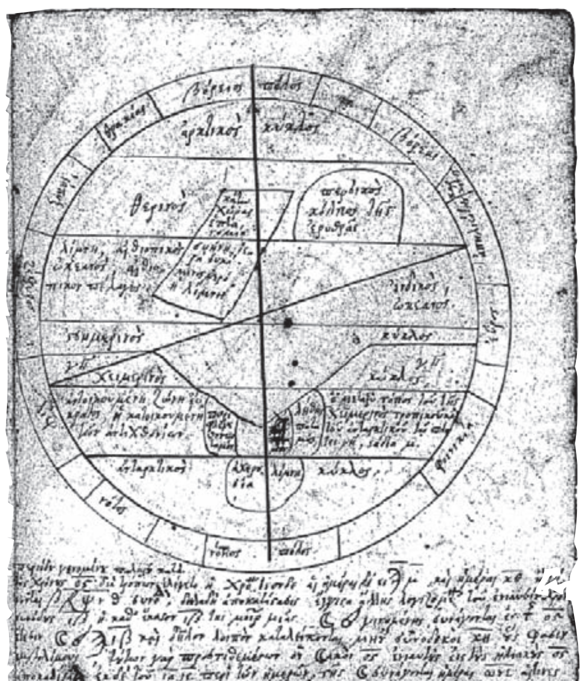

Figure 8: Greek cosmographical diagram with the Ecliptic drawn as a diagonal straight line (Oxford, Bodleian Library, Dept. of Oriental Collections, MS Marsh 42, fol. 4r / 156b). Undated copy, late sixteenth century. Reproduced from Edson and Savage-Smith, "An astrologer's map," 8, with permission from the Bodleian Library.

27 Evelyn Edson and Emilie Savage-Smith, "An astrologer's map: A relic of late antiquity," *Imago Mundi* 52/1 (2000): 7-29.

It would be too lengthy to detail the different cosmographical diagrams produced in the course of the Middle Ages and Early Renaissance showing the Ecliptic in various manners. There is one however that is particularly relevant for this study: a diagram found in the *Kitab al-Bad' wa-l-Ta'rikh* (Figure 9). It is a circular *mappa mundi* in Arabic language where the seven climes are shown separated by straight parallels. On each clime the scribe has written the name of a planet. The Ecliptic is shown as a set of four straight segments forming a rhomb, with the zodiacal signs written along it, three on each segment. The northern vertex of the rhomb is on the limit between the sixth and seventh climes, i.e. around 47.5° latitude North whereas the southern vertex is on the South Pole. The author of the diagram clearly wanted to represent the complete Zodiac and did not hesitate to position the Ecliptic in extremely unusual coordinates so that all signs could be visible. The resulting rhomb-shape of the Ecliptic is unlike any other I have seen in medieval diagrams and bears some resemblance to the two-segment representation of the Ottoman atlases world maps. Another coincidence is that this particular manuscript copy of the medieval text is dated 1569/70 and is therefore contemporary with the Ali Macar Re'is atlas.

Figure 9: Cosmographical diagram from the *Kitab al-Bad' wa-l-Ta'rikh* (Bodleian Library, Oxford. Ms. Laud. Or. 317, fol. 7a). Copy dated 1569/70. Diameter of the original: 10.2 cm; reproduced with permission from the Bodleian Library.

Finally, I would also like to mention the cosmographical diagrams included by Battista Agnese in his series of manuscript atlases, which were mentioned above as they contain the earliest known maps based on the AOP. The Ecliptic is not depicted on Agnese's world maps but the Zodiac appears prominently in two diagrams that occupy the two first sheets of each atlas (see Figure 10). The representations of the Zodiac drawn by Agnese were by no means a novelty but are relevant for this article because Agnese's atlases may have been a source of inspiration for the authors of later Ottoman atlases.[28] Neither the Ali Macar Re'is nor the Walters Sea atlas contain such cosmographical diagrams. I wonder if it is because the Ottoman authors considered that representing the Zodiac directly on the world map was a better and simpler way of providing the same information.

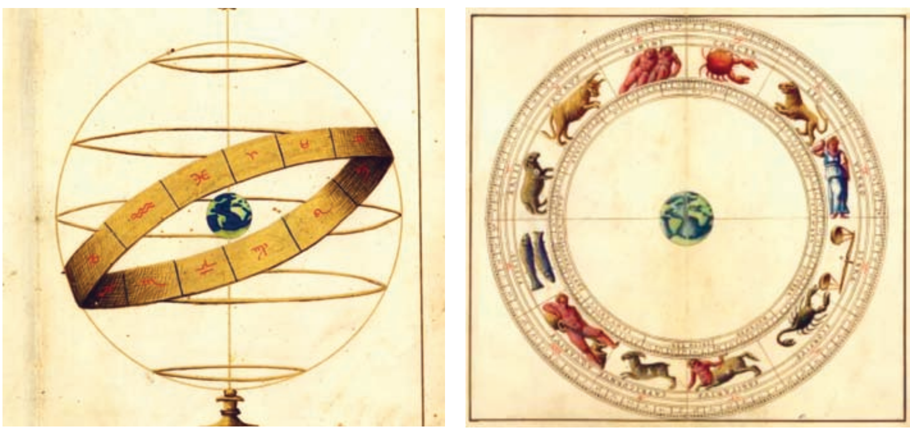

Figure 10: Two representations of the Zodiac around the Earth contained in a manuscript atlas by Battista Agnese from ca. 1544.[29] Images courtesy of the Library of Congress.

28 Svat Soucek, "Islamic charting in the Mediterranean," in *The History of Cartography*, vol. 2 book 1, 279.

29 Battista Agnese. "[Portolan atlas of 9 charts and a world map, etc. Dedicated to Hieronymus Ruffault, Abbot of St. Vaast]," ca 1544: Library of Congress Geography and Map Division, G1001. A4 1544 Vellum 5. High-resolution facsimile available in: http://memory.loc.gov/cgi-bin/query/h?ammem/gmd:@field%28NUMBER+@band%28g3200m+gct00001%29%29

Conclusions

The oval-shaped world maps contained in the Ali Macar Re'is atlas and the Walters Sea atlas were built using a cartographic projection that was quite popular in the 16th century and that seems to have been first used by Battista Agnese, hence the proposed name Agnese Oval Projection.

These two maps are atypical because they show the Ecliptic as two straight segments, a configuration that is not found on any other world map that I am aware of. In the AOP the Ecliptic adopts a curved shape with a complicated mathematical expression. It is understandable that a mapmaker had to simplify its shape in order to plot it but reducing it to just two straight segments is an extreme simplification. The presence of the same inaccurate shape of the Ecliptic on two different maps suggests that the authors of both maps may have had in mind a common prototype image. A copying mistake from a now-lost prototype could also be the reason for the erroneous position of the Ecliptic on the Walters map. An *a posteriori* addition by an uninformed painter might be an alternative explanation.

Drawing the Zodiac accurately on celestial or terrestrial planispheres was possible with the available mathematical and astronomical knowledge in sixteenth-century Western Europe. While this does not imply necessarily that the same knowledge was available to the authors of the Walters and Ali Macar Re'is world maps, it does hint that the straight shape of the Ecliptic was not taken from a Western European source. If a model is to be looked for, a more likely candidate could be an Arabic cosmographical diagram that depicts the Zodiac as a set of four straight segments.

The precise reason why the Zodiac was represented on these two Ottoman maps is unknown but this line seems to have been important in the mind of their authors, as evidenced by the prominent graphical treatment it received in both charts. In the sixteenth century numerous other cartographic works depicted the Zodiac and/or the Ecliptic in quite diverse manners. Given that drawing such features on a world map is generally of little practical application, the aim of the authors had probably more to do with simultaneously representing the Earth and the Heavens. This likens world maps to cosmographical diagrams, on which the Zodiac is often represented albeit rarely in the shape of a line.

Agnese's atlases, which probably influenced Ottoman atlas makers, combine portolan charts, an AOP world map and diagrams of the Zodiac. While Ottoman authors chose not to include specific cosmographical diagrams in their atlases, they may well have felt the need to represent the Zodiac in some other way and thus decided to draw it directly on the world map.

Appendix 1: Mathematical equations

Explicit equations of the Agnese Oval Projection

The Earth is assumed to be a perfect sphere and described by the two usual angular coordinates: latitude (LAT) and longitude (LON), both measured in radians. The flat map is described by two Cartesian axes: horizontal X and vertical Y, both measured in radians, too. Based on conditions a-d listed in the first section of this article, the equations that transform (LAT, LON) into (X, Y) can be easily derived.

The vertical coordinate is described by the extremely simple equation

$Y = LAT$

The horizontal coordinate is described by two different equations, one for longitudes less than 90 degrees away from the central meridian, and another one for longitudes beyond 90°:

$$\forall\, LON \in \left(-\frac{\pi}{2},\ +\frac{\pi}{2}\right) \qquad X = \pm\left|\frac{LON}{2} + \frac{\pi^2}{8LON}\right| \pm \sqrt{\left(\frac{LON}{2} + \frac{\pi^2}{8LON}\right)^2 - LAT^2}$$

$$\forall\, LON \in \left[-\pi,\ -\frac{\pi}{2}\right] \cup \left[+\frac{\pi}{2},\ +\pi\right] \quad X = \pm\left|LON - \frac{\pi}{2}\right| \pm \sqrt{\frac{\pi^2}{4} - LAT^2}$$

Equation of the Ecliptic in Agnese Oval Projection

Assuming a spherical Earth, the Ecliptic is described by the following equation:

$\tan LAT = \tan E \cos(LON - LON_0)$ where E is the “obliquity of the Ecliptic”, an astronomical parameter that is approximately equal to 23.4 degrees (it changes slightly with time).

In the Agnese Oval Projection, for longitudes less than 90 degrees away from the central meridian:

$$X = \pm\left(\frac{\alpha}{2} - \frac{\pi^2}{8\alpha}\right) \pm \sqrt{\left(\frac{\alpha}{2} + \frac{\pi^2}{8\alpha}\right)^2 - Y^2} \quad \text{where} \quad \alpha = \arccos\frac{\tan Y}{\tan E}$$

for longitudes more than 90 degrees away from the center:

$$X = \pm\sqrt{\left(\frac{\pi}{2}\right)^2 - Y^2} \mp \arcsin\frac{\tan Y}{\tan E}$$

Appendix 2: Maps in Agnese Oval Projection up to 1600[30]

Date	***Author***	***Map title / contained in***
1536 -65	Battista Agnese	World maps in atlases
1540	Sebastian Münster	*Typus Orbis Universalis* in *Geographia* (Shirley #77)
1555 or 1556	Guillaume le Testu	*Cosmographie Universelle* (atlas at BNF)
ca. 1560?	anonymous	World map in Walters Sea atlas (at Walters Art Museum)
ca. 1561	Giacomo Gastaldi	*Cosmographia Universalis* (at BL, Shirley #107)
1567?	Ali Macar Re'is	World map in atlas (at Topkapi Palace Library)
1567	Camoccio	*Cosmographia Universalis et Exactissima...* (Shirley #117)
ca. 1570?	anonymous	World map in Imperial atlas (at Istanbul Archaeological Museum)
1570	Abraham Ortelius	*Typus Orbis Terrarum* in *Theatrum orbis terrarum* (Shirley #122)
1572	Tomasso Porcacchi	In *L'Isole piu Famose Del Mondo…* (Shirley #127)
1572-75	G.A. Vanosino et al.	Celestial planisphere in ceiling of *Sala Bologna*, Vatican
1573-75	O. Trigini and G.A. Vanosino	Celestial planisphere in ceiling of Sala della Cosmographia, Palazzo Farnese, Caprarola
ca. 1575	Jean de Gourmont	Small world map in foolscap (Shirley #134)
1575	Belle-Forest	Copy of Ortelius 1570 in French translation of Münster's *Cosmographia* (Shirley #135)
1578	George Best	In *A True Discourse... of the Late Voyages of Martin Frobisher* (Shirley #138)
1583-84	anonymous	World map in Bezeyit ms. of *Tarih-i Hind-i Garbi*
1587	Christofle de Sarigny	(no title, Shirley #159)

30 The references to Shirley refer to the source cited in footnote 10 above.

1588	Sebastian Petri	In later editions of Münster>s *Cosmographia* (Shirley #163)
1589	Giovanni Maffei	In *Historiarum Indicarum* (Shirley #166)
1589	anonymous	In Haklyut's *Principall Navigations* and in English edition of Linschoten's *Itinerario* (Shirley #167)
1590?	anonymous	(no title, Shirley #169)
1590	Abraham Ortelius	Map of the world known in Antiquity in *Paregon* (Shirley #176)
1594?	Arnold van Langren	Based on Ortelius 1570 (Shirley #186)
1596	Girolamo Porro	In Magini's *Geographia* (Shirley #195)
1597	Giuseppe Rosaccio	10-sheet world map (Shirley #205)
1596 or 1598	Jodocus Hondius	Miniature world map in Langenes and Claesz's *Caerte Thresoor* (Shirley #211)
ca. 1580-1600?	anonymous	(no title, Shirley #224)

Zodiac on Earth: The Ecliptic on two sixteenth-century Ottoman World Maps

Abstract ■ Two Ottoman world maps contained in the Ali Macar Re'is atlas and the Walters Sea atlas share the unique characteristic of showing the Ecliptic line (the Zodiac) as two straight segments. Both maps were drawn in the sixteenth century in a so-called "oval" cartographic projection that was quite popular at the time. The Zodiac must have been important to the authors of the atlases because it was given a prominent graphical treatment in both maps and was one of the last elements to be drawn. However, a geometric survey has found that the shape of the Ecliptic on both maps is inaccurate, particularly in the Walters Sea atlas, whereas several coetaneous terrestrial and celestial planispheres from Western Europe displayed the same astronomical line in a geometrically correct way. This difference suggests that the Ottoman authors' intentions had to do more with symbolism or aesthetics than with geometric accuracy. Given that drawing the Zodiac on a world map is of little practical application, the authors may just have wanted to simultaneously represent the Heavens and the Earth. This likens the two Ottoman world maps to cosmographical diagrams, on which the Zodiac often appears. In addition, the coincidence of the same erroneous shape of the Ecliptic on two different maps hints that their authors shared a common source of inspiration. The existence of an Arabic cosmographical diagram that depicts the Zodiac as a set of four straight segments reinforces the possibility of a common prototype diagram.

Keywords: Walters Sea atlas, Ali Macar Re'is atlas, Ecliptic, Zodiac, oval projections, cosmographical diagrams, Battista Agnese.