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Original article

A Middle Age Qibla Finder and the secret code of Portolan maps

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ABSTRACT

A hidden cache of medieval weaponry was discovered in Verona in 1915. A strange device found among the weapons has since been regarded as a Middle-Age hanging lantern. Here we suggest a different use as mathematical tool to find the Qibla. The new interpretation has opened up unsuspected and original perspectives in the history of science: the tool embodies the application of al-Biruni's (973–1048) method of "azimuthal equidistant projection", a geodetic theory for map representation that preserves angles and distances. We demonstrate that the tool embeds the rules of spherical trigonometry that provide the orthodromic and lossodromic distances and the azimuth of two points of given latitude and longitude, to within 1% of the difference between the Spherical Earth model of al-Biruni (radius = 6339.6 km) and the WGS84 Ellipsoid. The geometric relationships that allow conversion of geographic coordinates to planar coordinates are equivalent to the practice of fixing an origin for a wind rose and drawing a distance along the azimuth. It represents the missing piece of the puzzle that enables us to interpret middle age Portolan maps as based on the azimuthal equidistant projection scheme of al-Biruni.

1. Introduction and remit of the study

On 14th November 1915, Verona became the target of one of the first air strikes in history. In the vicinity of Piazza delle Erbe, the main square, a medieval building was badly hit: the collapse of one of its wings revealed a secret passageway where weapons were found, together with the artefact examined in this study (Fig. 1).

According to the last owner, weaponry and armors were soon sold to Stefano Bardini (1836–1922), the antique dealer and founder of the "Museo Bardini" in Florence [1]. In the 1940s, the tool was sold by an antique dealer in Verona, reaching its last owner as an inheritance. In 2009, Cesari [2] examined the artefact and described it as a "Hanging lantern of Veronese provenance", that could perhaps be ascribed to a craftsman active between the thirteenth and fourteenth century. Doubts still remain, however, "since we have never come across anything of this kind", he claims. Furthermore "the difficulties in establishing the period of manufacture and the exact geographical origin of the artefact are due to the lack of definite terms of comparison, as well as accurate documentary evidence".

Finally, the orientalist G. Curatola ascribed it to the Islamic Golden Age, presuming multiple uses despite reassurances that "an item like this is a unique specimen, never seen before" (personal communication, 2014). The cultural pages of the newspaper *l'Arena di Verona* devoted some space to the topic, and even suggested a possible use for the enigmatic artefact [3].

The survey of mathematical instruments available in fourteenth century in Egypt and Syria reported by Charette [4] does not mention any similar device.

In this work, we will show the artefact attitude for determination of the Qibla, the direction that is to be faced by Muslims during their prayer. In addition, we ascertain its function for determining the distance between two points of known terrestrial coordinates. In the last section, we'll show how these characteristics make it a calculating instrument embedding the procedure adopted to draw Portolan maps, which made their appearance for the first time in the mid 13th century in Italy (Carte Pisane, Bibliothèque Nationale de France) [5].

2. Instruments and knowledge: The Islamic Golden Age

The shape of the artefact brings to mind constructions of spherical trigonometry, a topic in which Islamic scholars excelled in medieval times.

During the Middle Age, astronomical instruments were called mathematical instruments: although designed for the solution or description of astronomical problems, the principle of their functioning was in fact rigorously based on mathematical laws [6–11].

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Fig. 1. The Qibla Finder. Red lines are projections of Equator (0°), Tropic (23.5°), Polar Cirque (66.5°) and Pole (90°). The distance on the tool of Pole from Equator is 200 mm and corresponds to the radius of a local sphere. The two branches of the larger ogive are the planar projection of the −30° and +30° meridians. In the inset the detail of a fine scale spanning 15°. Base hooks are at a distance of 15°. All measurements reported in the figures where the Qibla Finder is used may be easily checked by the reader scaling a digitalized image in which the reference points are the extremes of the with line and their distance is 200 mm.

Medieval Islamic scientists perfected and adopted new and original constructions. Specific works devoted to astronomical instruments have been passed down from the eighth to the fifteenth centuries. Some authors described their own "constructions", while others presented a general survey of instruments of one kind or another. These surveys were disseminated as manuals for the study and accurate production of astronomical instruments: especially astrolabes, sextants and armillary spheres. Perfecting the techniques and mathematical/geometrical construction designs gave astronomers the chance to increase their observational precision.

Following Ptolemy's work presented in the *Almagest*, important Arab astronomers like al-Khwarizmi, al-Battani, Kushyar ibn Labban, al-Kashi improved Ptolemy's solar tables. They added the value of obliquity and the tables with the equation of time (taʿdīl al-ayyām bi lay*ālayhā* [9,11,12]). They were fully aware, therefore, of the problems concerning the definition of the difference in longitude between two places, the chief source of error in determining the position of a point on the Earth's surface. In his book on geodesy, al-Biruni [13,14] describes the methods employed at the time to determine the difference in longitude between two places:

- through the observation of lunar eclipses;
- through the known latitudes and the position of the Moon with respect to the coordinates of fixed stars, carried out by Avicenna and described by al-Biruni in his *The Mas'ūdi Canon* [12 quoted in 16] as theoretically perfect but difficult in practice;
- through the measurement of distances between places with known latitudes [12].

Fig. 2. Detail of the engravings marking the subdivisions of the bars. The nails on the ogives are set at 20° intervals (see Fig. 1), small circular decorations correspond to smaller intervals of 2°. Small dots on the vertical bar correspond to 1° (see upper right corner).

3. The Instrument

The instrument, which we will call the Qibla Finder (hereafter QF) is made of iron and is decorated with bronze plating and copper plates with embossed beads. XRF analyses performed in the Department of Earth Science at the university of Pisa (analyst P. Armienti) provide the following composition: Fe = 98.7%, Si = 0.2%; S = 0.4%; *P* = 0.2%, total 99.5% practically pure iron.

The QF is composed of a central bar with two terminal hooks, and another bar perpendicular to it. From one end of this base to the other, ogive shaped arms jut out and link up on the central bar at 200 mm from the base bar (Fig. 1 and insets). The ogives are studded and finely chiseled with a border decoration of semicircles (Fig. 2).

In both the inner and outer ogives, the semicircles decrease in number as the distance from the horizontal bar increases. The external ogives fit the orthogonal projection of two meridian circles, at −30° and 30°, of a local sphere with a 200 mm radius (Fig. 3).

In Fig. 3, the red lines superimposed to the ogives are the plot of the orthogonal projections of the −30° and 30° meridians on a XY plane tangent to the sphere, perpendicular to the Prime Meridian plane and with origin in the tangent point. The relations between longitude (λ), latitude (ϕ) and Cartesian coordinates on the projection plane are provided by the equations:

$$X = R \quad \cos(\phi)\sin(\lambda), \quad Y = R \quad \sin(\phi)$$

with ϕ and λ in radians. Accordingly, red points marked from 0° to 90° on the meridians, represent the intersections with the corresponding parallels and show decreasing vertical and horizontal distances inherited by the projection rules. The blue line in Fig. 3 is the projection of the −90 and 90 meridians (outlines of the local sphere), and the yellow lines represent the two symmetric meridians −14.73° and 14.73°, in correspondence of half the difference in longitude of the two projected localities (Mecca and Pisa- see next section *Operational Principles*).

As the lateral ogives span a 60° interval in longitude, the five hooks below the base positioned at regular intervals, correspond to the chords of arcs each measuring 15°. At the back, the horizontal bar is covered, without any welding, by an iron strip which terminates, at both ends, with identical rings shaped as three joined bands. They appear to function as holders for candles or small oil lamps, or even a scroll (Fig. 1).

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