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The stars in sixteenth-century nautical literature: a comparative study

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Summary
The beginning of the sixteenth century was a period of intensive knowledge circulation between Atlantic and Indian Ocean navigational practices. Mariners began to incorporate new information from the disciplines of geography and astronomy into their sailing methods. Portuguese nautical instructions written in the decades after Vasco da Gama rounded the Cape of Good Hope in 1497 provide clear testimonies to this shift. This article is an attempt to characterize part of the information that circulated in this transitional period through a comparative examination of Portuguese nautical instructions and Arabic navigational treatises, focusing specifically on the stars used for latitude measurements.

Keywords: navigation, Arabic, Portuguese, Indian Ocean, astronomy

Introduction

The interaction between Atlantic and Indian Ocean navigational practices experienced a major change by the end of the fifteenth century. These two evolving traditions had always been connected to a certain degree in the Mediterranean, but with the Portuguese rounding the Cape of Good Hope, links between them deepened significantly. By then, Atlantic sailors faced a new sea, with new and different winds, currents, and landscapes and even a different view of the night sky. Atlantic sailors needed help and thus often sought advice from Indian Ocean pilots. As a consequence, two distinctive sets of navigational practices began interacting, creating a multicultural environment characterized by the circulation of cosmological, geographical, and practical information. The focus of the present paper is to try to identify some of that information and, more specifically, to compare the stars used for navigational purposes in Atlantic and Indian Ocean nautical texts. Relying on the works of scholars such as Gerald Randall Tibbetts (1981), Paul Kunitzsch (1977), José Malhão Pereira (2019), and Eric Staples (Staples 2013; al-Salimi & Staples 2019), this paper aims not only to bring new material into the discussion, but also to track arguments developed by various scholars at different periods. Finally, it proposes a small reflection on the circulation of knowledge between Atlantic and Indian Ocean navigational practices.

The sources

For descriptions of stars and star-based latitude measurements originating in Atlantic navigational practice, this paper draws upon the Portuguese nautical instructions known as *Regimentos*. By discussing works written just before and just after the Portuguese arrival in the Indian Ocean, the paper will attempt to provide a clearer picture of the new elements that were introduced in selected nautical instructions. It will begin with a few passages from the *Regimentos de Munique e Évora* (Seafaring rules of Munich and Evora) (Albuquerque 1965a), which are two related copies of the same set of nautical instructions. Although the earliest version of this text dates to around 1509, the copies under consideration are reflective of navigational practices in the second half of the fifteenth century. Next, the paper will review the *Livro de marinharia de João de Lisboa* (The seafaring manual of João de Lisboa) (Lisboa 1903), particularly relevant here not only because it was written at the very beginning of the sixteenth century but also because it was continuously copied thereafter.

For descriptions of Indian Ocean stars and star-based measurements, this paper relies on two authors: the fifteenth-century pilot Aḥmad Ibn Mājid and the later (and much-understudied) Sulaymān al-Mahrī. Taken together, these authors wrote all the extant pre-sixteenth-century descriptions of Indian Ocean navigation techniques. Given their prolific activity, the

paper does not discuss all their works, but focuses mainly on Ibn Mājid's *Kitāb al-Fawāʾid fī uṣūl ʿilm al-baḥr wa-al-qawāʿid* (Addenda on the principles and foundations of maritime science) and Sulaymān al-Mahrī's *Al-ʿUmdat al-mahrīyah fī ḍabṭ al-ʿulūm al-baḥrīyah* (The reliable Mahrī treatise on the exactitude of maritime sciences).

Polar Star measurements

Polaris is a star that has been used for latitude measurements since antiquity. Given its proximity to the Pole, it was known that the altitude of Polaris above the horizon was very close to the value of the observer's latitude. However, the calculation of latitude from altitude was not entirely straightforward. Adjustments were needed because Polaris was not located exactly over the Pole but revolved in a small circle around it.

Atlantic navigational practice

In Atlantic navigation, the position of Polaris was most commonly determined through the movement of the Guardians (Kochab and Pherkad, βγ Ursae Minoris). This is already clear in the rule to estimate the altitude of the North Pole printed in *Regimentos de Munique e Évora* (Albuquerque 1965a: 192–193). There, a human figure was depicted in the heavens with Polaris close to its centre, the head to the north, the feet to the south, and the arms stretched to both east and west (and thereby on the same level as the Pole). While the two Guardians would be seen moving around the extremities of the imagined human figure, Polaris would move about its centre (Fig. 1).

With this scheme in mind, according to the same structure all the main positions of the guardians would

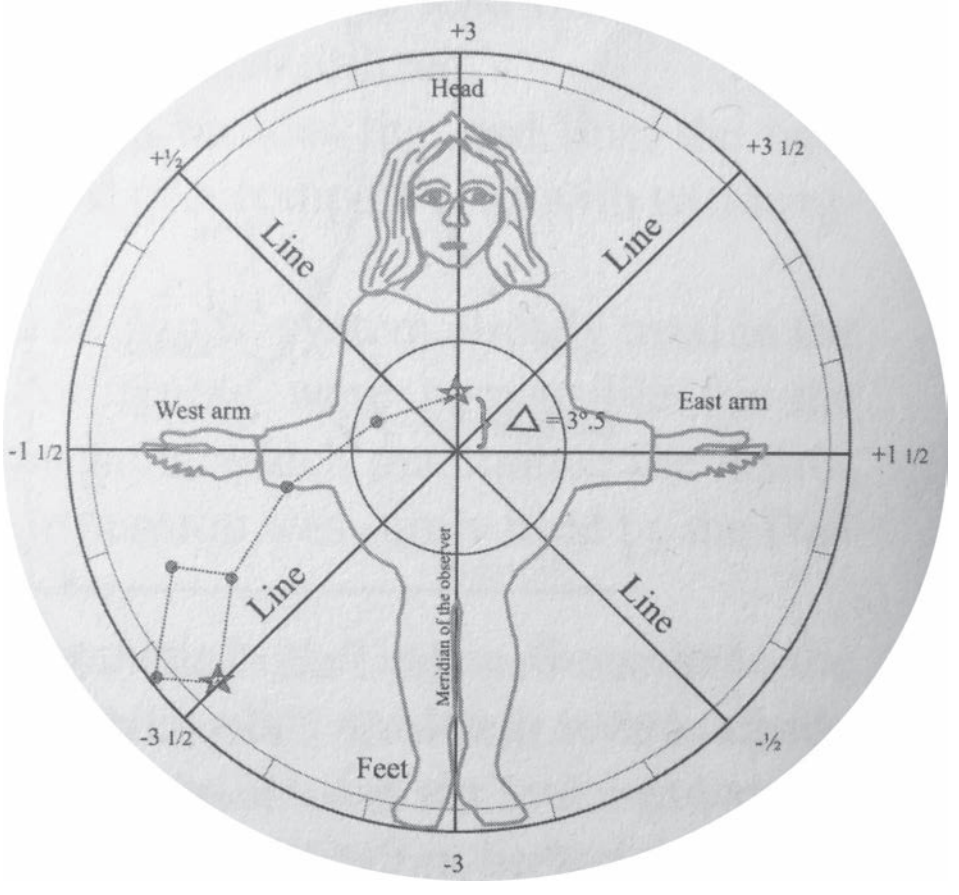

Figure 1. *The movement of Polaris and The Guardians around the True North Pole (Malhão Pereira 2002: 8).*

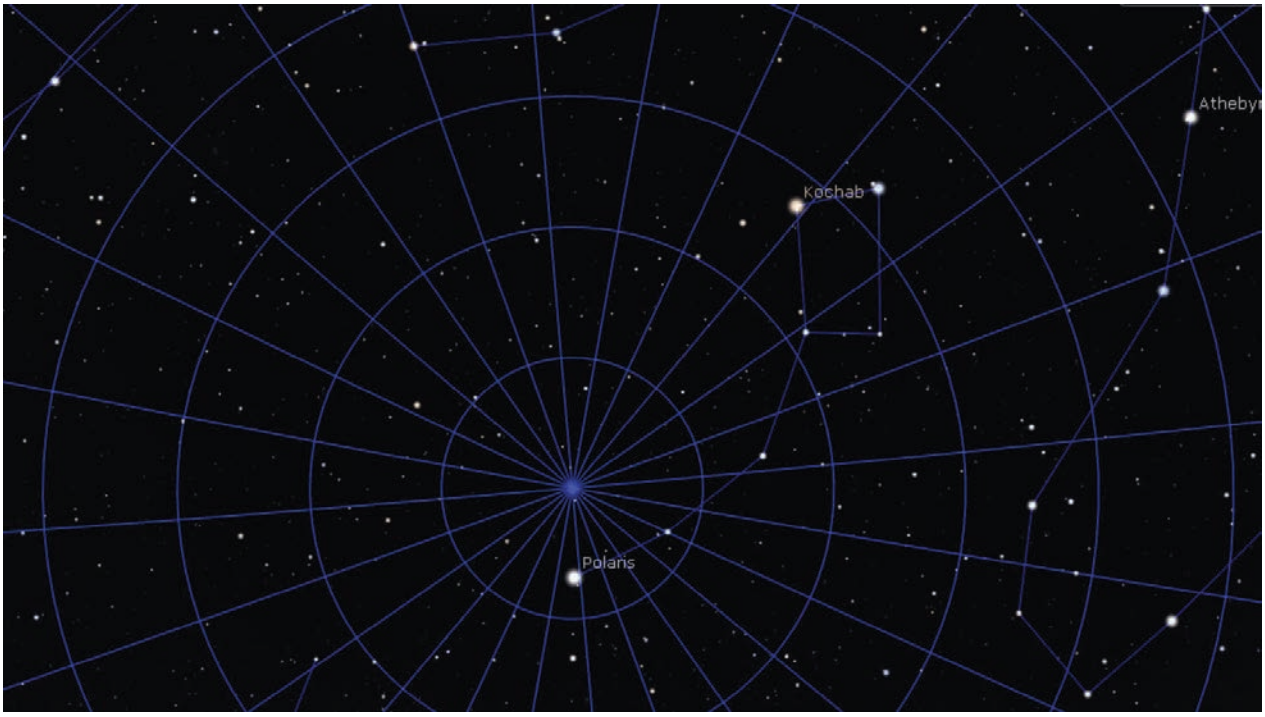

Figure 2. *The position of Polaris when the Guardians were horizontal to the east (picture taken using Stellarium).*

then be associated with those of Polaris. A typical paragraph of a sixteenth-century seafaring manual — such as João de Lisboa's — runs as follows:

> 'You shall know that when the Guardians are in the line above the Eastern arm, one of the Guardians is to the other [in a direction of] East-West, and the North Star is under the axis by 3½ degrees. Whenever you take the altitude of the North Star and the Guardians are in this line, you shall add 3½ degrees to the altitude you take. All added, that is how far you shall be from the line of the equator to the North side.' (Lisboa 1903: 35)

Indian Ocean navigational practice

When compared to Atlantic nautical literature, one of the features that immediately stands out in Indian Ocean texts is the diversity of star combinations used to determine the altitude of the Pole Star. Arabic literature often describes combinations of particular stars that, when observed in a particular way, would indicate Polaris's position on its path around the Pole — a calibration known as *bāshī*. As this paper aims to compare features of both Atlantic and Indian Ocean nautical literatures, I shall not go over all possible combinations with all recorded stars. What is important at this stage is to stress that Arabic navigational practice used a different concept of latitude, which was referred to in terms of fingers (*isbaʿ*). The width of a finger seen at the distance of an outstretched arm was considered to be the most basic unit in ancient times, when altitudes were taken directly by measurements of the hand. By the fifteenth century, the value of this width became more or less standardized, although there was still no single explanation for exactly how much it should be. Ibn Mājid and Sulaymān al-Mahrī provide different definitions which, though frequently conflicting, are sometimes in agreement. For instance, Capela is described in all nautical works as being four fingers apart from the star β Aurigae. If we bear in mind that these stars were separated by 7.6° in 1500, then this definition would imply that a finger was equal to 1.54° (see Shihāb 2013: 25–26). Apart from this measuring system, the latitude values obtained in Indian Ocean practice were

Al-Mahrī	Munich and Évora nautical instructions
Second position Kochab is directly above Polaris Its *bāshī* is a little less than half a finger. There are seven fingers and a half between Kochab and the Pole.	The Guardians are in the head Kochab is north of Polaris Polaris is under the axis by 3 degrees.
Third position Polaris's *bāshī* is one finger and three quarters. Pherkad is directly above the Kochab. The Guardians are above the Pole by 5 fingers and a quarter.	When the Guardians are in the line under the head; Polaris is under the axis by half a degree; The Guardians are in a direction of north–south to one another.
Fourth position The Guardians are horizontal to one another to the west. The *bāshī* of Polaris is four fingers [its maximum position]. The Guardians are under the Pole by the same amount that they were over it when they were horizontal due east [i.e. 5 fingers].	When the Guardians are under the line of the western arm. The Guardians are to one another in a direction of east-west Polaris is over the Pole by 3½ degrees [its maximum position]
Fifth position Kochab is under Polaris The *bāshī* of Polaris is three fingers and a half Kochab is under the pole by that which it was over it when it was directly above Polaris.	The Guardians are on the foot; Kochab is directly south of Polaris; Polaris is over the axis by 3 degrees.
Sixth position Kochab is directly above Pherkad The *bāshī* of Polaris is two fingers and a quarter Kochab is under the Pole by that which it was over it when it was directly above Pherkad.	The Guardians are over the line of the foot; The Guardians face each another in a direction of north–south; Polaris is over the axis by half a degree.

Figure 3. *The movement of Polaris and the Guardians around the True North Pole as described by al-Mahrī and Seafaring rules of Munich and Evora.*

also distinct because they were not equivalent to the altitude of the North Pole — as in the Atlantic practice — but rather equal to Polaris's minimal position around it.[1]

The *bāshī* — that is, the calibration of Polaris's altitude — was thus used to refer not to the true North Pole but to the minimal position of Polaris, two fingers below it. In other words, a *bāshī* was zero whenever Polaris was located at the very lowest point of its path. When level with the Pole, it would measure two fingers; and when located at its highest point, it would measure four.

The Two Guardians, the *Farqadān*, were indicators used by both Arabic authors mentioned in this paper, but it is Sulaymān al-Mahrī who provides the most complete set of instructions on how to apply their position to latitude calculation. In *al-ʿUmda al-Maḥriyah*,

[1] 'A point to be mentioned is that De Saussure states that a *bāshī* of 2 *iṣbaʿ* meant that the Arab sailor had to make no correction for the height of the Pole Star. This again is following Mediterranean practice, where the height of the Pole itself was essential because altitude readings were also taken on the sun whose height was measured from the equator. The Arab sailors never seem to have calculated at all from the projection of the earth's co-ordinates on the heavenly sphere. All their measurements were based on the Pole Star's lower culmination and it was to this position that all their calculations were reduced.' (Tibbetts 1981: 336; see also Staples 2013: 54–55.

he includes a section 'on the knowledge of the circular movement of the Guardians around the Pole', in which six positions are described according to the following structure (Fig. 2):

> 'First position: when [the Guardians] are both horizontal to the east, they are both over the pole by five fingers. By this time, *al-Ṣarfah* (β Leo) is culminating, and there is no *bāshī* to Polaris. If Polaris is five by then, they are a little less than 12 fingers.' (al-Mahrī 1970: 25)

In a more schematic way, the remaining positions, as mentioned by al-Mahrī and the Portuguese seafaring instructions, can be compared as follows (al-Mahrī 1970: 25–27; Albuquerque 1965a: 192–193) (Fig. 3):

Additional Northern stars

As mentioned above, Indian Ocean nautical literature is particularly varied in its treatments of star-based latitude measurement. Taken together, Ibn Mājid and al-Mahrī mention a total of *c.*150 stars, asterisms, and celestial objects used for this purpose (Ibn Mājid 1971; al-Mahrī 1970; 1972). Such a diversity of approaches is not apparent in Atlantic navigational texts. Yet it is notable that, by the beginning of the sixteenth century new stars began to appear in these nautical works. For the Polar Star calibration, João de Lisboa adds a third star called Meca, which has been identified as γ Cephei (Albuquerque 1965b: 15). His description begins as follows:

> '[...] In the same way, when the Guardians are on the southwest line, the North is over the Pole by 3½ degrees in a straight line. [...] In order to better know where the North is, one needs to know a star called Mequa. This one moves close to the North, and they both move in one line. This Mequa and the North are 9 hours apart from the Guardians. As soon as the North and Mequa are in line, so are the Guardians [in one line]; and you will see Mequa according to this way. There, in that line, you will see the North, and there is no question in this.' (Lisboa 1903: 34–35)

Figure 4. *The position of Polaris, when the Guardians were horizontal to the west and γ Cephei was over the Pole (picture taken using Stellarium).*

In other words, when γ Cephei was right above Polaris, the Guardians would be horizontal to each other in the south-east line and Polaris would be over the Pole by 3½ degrees (see Fig. 3).

In Arabic practice, γ Cephei was called *al-Mīkh* and it was mentioned by both Ibn Mājid and Sulaymān al-Mahrī. In Ibn Mājid's *Kitāb al-Fawāʾid*, it first appears in the section on the Lunar Station *al-Fargh al-Muqaddam* (αβ Peg). When this Station was culminating, *al-Mīkh* was seen directly above Polaris (Fig. 4):

> '[...] It is true that their *bāshī* is four fingers according to us. The Two Guardians are horizontal to the west during the culmination of the *Furūgh*, and *Mīkh* is directly above Polaris.' (Ibn Mājid 1971: 109)

As mentioned earlier, the bāshī was the value of Polaris's altitude on its path around the Pole. Its minimal value would be zero whenever Polaris was located right below the Pole, and its maximal value would be four fingers (when Polaris was located directly over the Pole). If this is taken into consideration, then the two passages can be seen as equivalent. There is no mention of the Lunar Stations in the Portuguese sources, but both passages combine the same specific positions of al-Mīkh, Polaris, and the Guardians, to state that — at the time of those positions — Polaris would be seen at its maximum altitude.

Sulaymān al-Mahrī also mentions these stars in a work called *Tuḥfat al-fuḥūl fī tamhīd al-uṣūl* (The worthy men's classic on the introduction to the principles) (1972). In it, however, his concern is with the distance between the Pole, Polaris, and *Mīkh* regardless of their positions (1972: 20).

The South Celestial Pole

As Atlantic sailors ventured southward, new star-based latitude measurements had to be developed. The first sailing instructions for taking the altitude of the South Pole is described in the *Livro de Marinharia* of João de Lisboa (1903), which clearly favours measurements taken with the Southern Cross. Before describing the technique, however, João de Lisboa gives some advice:

> 'Whenever you travel in the southern part [of the globe], it is necessary that you be acquainted with both stars, that is, with Soel and Solibar — the ones that are closest to the Pole. To spare you the work of observing these stars — for, since you are going without me, you will be uncertain in recognizing them — I have decided [instead] to make a description of the Cross — because this is what everyone knows.' (Lisboa 1903: 22)

Thus, it was seen as exceedingly useful to know the stars *Suhayl* and *Sillibār* if one wished to take latitude measurements in the southern hemisphere. Yet, as most people seemed to be more familiar with the Southern Cross, it was that constellation that João de Lisboa used in his work.

There are two points concerning *Sillibār* in João de Lisboa's introduction that should be highlighted. *Sillibār* (i.e. Alpha Eridani, Achernar) is a peculiar star in the history of astronomy because it was the only first-magnitude star unknown to both Ptolemy and al-Ṣūfī, the authors of the two most influential star catalogues throughout the Middle Ages. According to Kunitzsch (1977), neither Ptolemy nor al-Ṣūfī could have known this star, for it was located too far south. As a consequence, Alpha Eridani was ignored in most Arabic and Latin theoretical astronomy, and it appeared in European treatises only in 1603, in Johann Bayer's *Uranometria*. On the other hand, Alpha Eridani is mentioned not infrequently in connection with the more practical forms of astronomy associated with both Bedouin Arabs and Indian Ocean seafarers. Among Bedouin Arabs, Alpha Eridani went by the name *al-Muḥannith* (The Oathbreaker). *Sillibār*, in contrast, seems to appear exclusively in Indian Ocean nautical literature, and it was by this name — *Solibar* — that João de Lisboa referred to Alpha Eridani, eighty-nine years before Bayer.

Before moving on, we should note that the *Livro de marinharia* conflates *Sillibār* with *Suhayl* (i.e. α Carinae, Canopus). Given that these two stars were only mentioned briefly, it is impossible to tell how João de Lisboa would go about using them for latitude measurements. In Arabic sources, on the other hand, they appear grouped more than once. In al-Mahrī's list of the seven most popular star-based measurements among pilots, the last in the list (al-Mahrī 1970: 110) was one taken when *Suhayl* and *Sillibār* were level with one another during the culmination of the second Lunar

Figure 5. *Canopus (*Suhayl*) and Achernar (*Sillibār*) horizontal to each other (picture taken using Stellarium).*

Mansion, *al-Buṭayn* (εδρ Ari) (Fig. 5). Ibn Mājid, too, mentioned that it was one of the best measurements taken by experienced pilots.

In Atlantic nautical literature, the Southern Cross was more commonly used for taking latitude measurements. Sixteenth-century seafaring manuals, such as João de Lisboa's, would include instructions for measuring the Southern Pole as follows:

> 'Whenever you need to take this Cross, you shall wait for it to be made, so that the star of the head [i.e. Gacrux] is with the star of the feet [i.e. Acrux] on a line perpendicular [to the horizon]. Thus, the star of the feet and that of the head are in one straight line with the Pole of the world — that is, [in a direction of] north–south. Then, you shall take the height, while it [i.e. the Cross] is in this way. The star of the feet is separate from the Pole of the world by 30 degrees. [...] You may take the other [stars] if you know their circular movement, that is, the star of the head is separated by 35 degrees; and those of the sides, the eastern one has 34 degrees and the western one has 33 degrees — and this is to be understood from the Southern Pole.' (Lisboa 1903: 37)

The altitude of the Southern Pole was thus to be taken whenever Gacrux was seen directly above Acrux — 'You shall wait for it to be made'. Whenever this happened, pilots knew that the Southern Pole was located 30 degrees below Acrux, which then allowed them to determine their latitude.

Measurements using the Southern Cross were also acknowledged by the two Arabic authors cited in this paper. In *al-ʿUmda al-maḥriyyah*, Sulaymān al-Mahrī considered it to be the second best-known measurement among pilots (1970: 107). Yet, as with *Suhayl* and *Sillibār*, the position of the Southern Cross is immediately linked to that of Polaris, and there is no mention of gaps or distances between the Cross and the Southern Pole. In contrast, Ibn Mājid dwells on this particular measurement to specify that it should be taken when Gacrux is directly above Acrux. According to him, ancient authors used the two middle stars, but such a measurement was weak as it did not take place right above the Pole (Fig. 6).

> 'Whereas our measurement of the lower *murabbaʿah* [i.e. Acrux] is directly above the Pole. Besides, our

Figure 6. *The Southern Cross (picture taken using Stellarium).*

> stars are brighter than the two middle stars and — when the middle ones appear horizontal to each other — our measurement descends from its place, a quarter of a finger. Thus, understand this, for it is beneficial to you in cloudy weather during landfalls. Be knowledgeable in all its gaps, add them and subtract them.' (Ibn Mājid 1971: 82)

Conclusion

Atlantic and Indian Ocean navigational practices both used star-based latitude measurements. The purpose of this paper was not to provide an extensive list of all techniques described by either practice, but rather to discuss particular features that they may have in common.

The cross-pollination of navigational techniques suggested by the cases in this paper reflects important circulations of technical knowledge. Such a comparative exercise required, of course, that Atlantic and Indian Ocean practices be treated as separate entities. And yet, by accepting that these practices were somehow in communication and open to receiving and transmitting information, it is understood here that such a division is, in part, artificial. Strict borders between these two sets of navigational practices could not, and were not, maintained during the period under study. Still, by juxtaposing these traditions, we may more readily track the flow of knowledge between navigational cultures. This cross-cultural communication is evident in both measurement techniques, as well as in star nomenclature, used in fifteenth- and sixteenth-century Arabic and Portuguese literature.

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