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EAST AND WEST ENCOUNTER AT SEA

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East and west encounter at sea

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First of all, I must say, that I am really very honoured to be here today, facing such an illustrious audience. Thank you dear Dr. Mathew for giving me this opportunity to contact again Indian scholars, and also of European nations, with which my country has so much in common.

It is the fourth time that I am in India on account of history (this time with *Fundação Oriente* sponsorship, which I highly appreciated), and in fact, although I am involved now in historical research related to the Portuguese navigations, what I am really is an humble sailor who tries to interpret history with some of the experience I have got aboard sailing and motor ships of my country's Navy, and of my family's navy, if I can say that, because we are happy owners of a sailing boat.

I am not speaking in my personal name only, but also, being member of *Academia de Marinha* in Lisbon, I brought from its President, Admiral Rogério de Oliveira, who couldn't come to India this time, the mission to address His Grace Most Reverend Dr. George Valiamattan, his regards and best wishes for a great success of this Seminar. Admiral Oliveira told also to me that he is entirely available for any cooperation considered useful, with your Institutions.

The purpose of my paper is to comment the encounter of western techniques of navigation with their counterparts in the Indian Ocean. In its early stage, the pilots of Vasco da Gama and the mouslim pilot embarked in Malindi in April 1498 have performed this encounter.

I am going to compare, in a very abridged way, the techniques used by Indian and Atlantic Ocean's navigators, and mainly to discuss and suggest some areas of research.

It is also my purpose to give a wider view of the problem of ocean navigation, speaking of the many times forgotten role of Pacific Ocean navigators, who so early in history have colonized the Pacific islands.

HIGH SEAS NAVIGATION IN THE DIFFERENT OCEANS

Before the first Europeans sailed outside of sight of land in the Atlantic Ocean, the Indian Ocean was already sailed by Arab, Indian, Persian, Chinese and other nations sailors. They began with coastal navigation, but by the beginning of the Christian Era, they were continuously sailing more and more in the high seas, till by the first century AD, according to some historians, their ships sailed directly from the Gulf of Aden to India.

But their navigations were mainly made with a very important help, which was the regularity of the monsoon winds that affected all the northern Indian Ocean from Sofala in the African coast, to the South East Asia and China Seas. According to their specific needs, the appropriate techniques, which included astronomical means, were introduced, and were adequate for the purpose of their navigations. And they were used till and after the arrival of the Portuguese in their areas of operations.

Before that, a great part of the Pacific Ocean was colonized by people departing from southeast Asia, as it is now generally recognized, being the thesis of Thor Heyerdal, of an east to west migration from south America, not completely accepted by the majority of the scholars.

The navigations of these colonizers, although not corresponding to long distances, were among islands, sometimes very small and low. In spite of that, new voyages were made to the previously discovered places, and its techniques involved orientation by the stars, swells, wind and birds.

On the other hand, in the Atlantic during the exploration of the West African coast in the first half of the fifteenth century, and its progress towards the south, the Portuguese sailors had to return to Portugal through a route that brought them very faraway from the coast, because the prevailing north-easterly wind didn't allowed them to make a direct route.

This return trip was a tiresome voyage of almost 3000 miles or much more, depending of how far south they departed. Besides that, the Azores was populated since 1431/2, and the voyage was an ocean trip of more than 800 miles. So, they performed not only coastal voyages, in which case the dead reckoning navigation would be sufficient. It was necessary to know with a certain amount of accuracy the position of the ship on the high seas.

In figure 1 we can have a visual view of the problem. The return from Mina, performed later, is even a longer voyage of around 4500 miles out of sight of land.

For that purpose, the Portuguese introduced the application of some already known principles of astronomy to the navigation in the open sea, namely the calculation of the latitude by observation of the appropriate

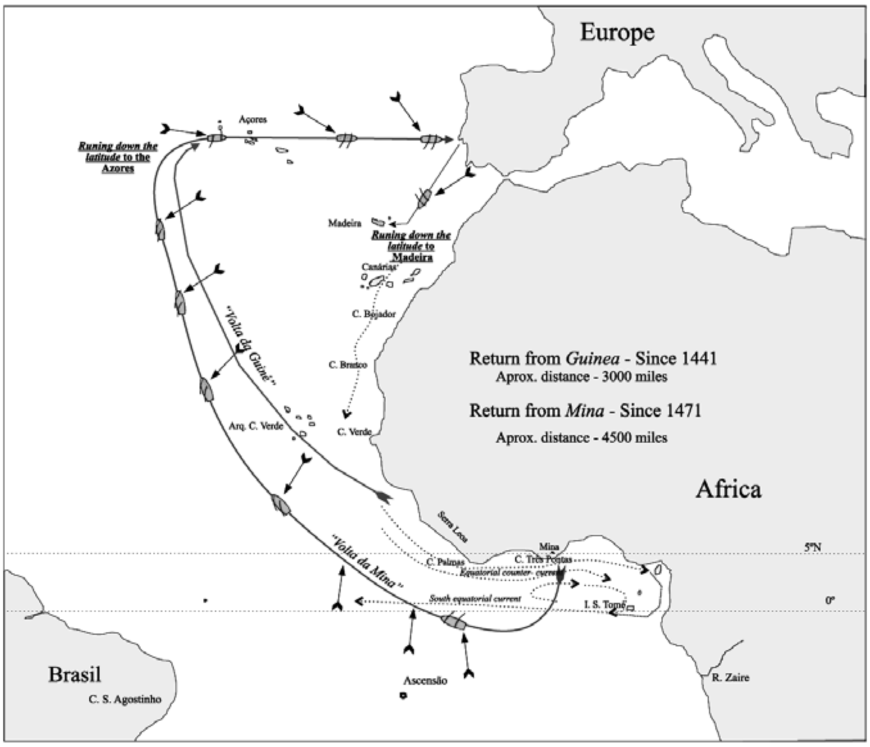

Fig. 1. The prelude of astronomical navigation in the Atlantic.

stars or the sun. Those principles were known in the Iberian Peninsula, mainly on account of the great Castilian king, *Afonso X*. He directed the translation and adaptation to the Castilian language of many important ancient works of geography and astronomy, mainly of Arabic and Jewish origin, which were included in the famous *Livros del Saber de Astronomia.* The other coordinate, the longitude has only been found at sea with practical accuracy, by the end of the 18th century[1].

[1] The inauguration of ocean navigation, and in general the history of navigation, is very well covered by the excellent work of E. G. R. Taylor, *The Haven Finding Art. A History of Navigation from Odysseus to Captain Cook* (London, Hollis & Carter, 1956). About the Portuguese pioneers and their techniques, the works of Fontoura da Costa (*Marinharia dos Descobrimentos*, 4.ª ed., Lisboa, Edições Culturais da Marinha, 1983), Gago Coutinho (*A Náutica dos Descobrimentos*, 2 vols, Lisboa, Agência Geral do Ultramar, 1969), Teixeira da Mota (*Mar Além Mar*, Lisboa, Junta de Investigações do Ultramar, 1972), Luís de Albuquerque (*Historia de la Navigación Portuguesa*, Madrid, Mapfre, 1991), are among the best.

The astronomical navigation introduced an important development in cartography, which was the inclusion of a latitude scale on the charts used for navigation.

WESTERN AND EASTERN TECHNIQUES COMPARED

Let us make now a very rapid review of the techniques of each other's areas of sailing, which later will be justified more deeply, specially the ones used in the Indian and Pacific Oceans.

The Portuguese used in coastal navigation the lead line and in the East this very rudimentary instrument was also utilized.

The compass was at the beginning, besides the lead line, the only instrument of navigation. It was formed of a compass rose with two magnetic needles sealed underneath.

The compass was graduated in 32 winds, system already used in the Mediterranean. Nevertheless the Portuguese were responsible for the adaptation to the compass of a suspension, which maintained the instrument permanently horizontal. This suspension was surely used by the Portuguese since 1537.

The main direction-finding instrument in the Indian Ocean was the *stellar* or *sidereal compass* based on the fact that the areas sailed outside the sight of land were very near the Equator. By day the sun was used to orientate the compass. The direction of the relatively constant wind and waves were also utilized for the same purpose. As previously said, I will develop this subject after.

During the beginning of their ocean navigation, the Portuguese used for finding the latitude, the altitude of the Pole Star above the horizon, as it was known already that the altitude of the north celestial Pole above the horizon corresponds to the latitude of the place.

As the Pole Star was not in the north celestial pole but separated from it by 3°.5, corrections were made to its altitude, using simple methods that could be understood by the not greatly educated pilots. So, a set o rules, the *Regiment of the North,* were introduced and the other stars of the Little Bear, revolving around the North Celestial Pole, gave, in eight different positions the corrections to reduce the altitude above the horizon of the Pole Star. Let us try to explain those rules, with the help of the figures that follows.

Fig. 2a shows the Little Bear, with its stars, from which the Kochab (one of the guards of the this constellation), and the Pole Star are well marked. In the centre is represented the North Celestial Pole, and the movement of the celestial sphere, which is counter clockwise, for an observer facing north is also shown. We can recognize that Kochab goes ahead of the other stars in the diurnal movement, and on account of that and also of its relative brightness, was used, in connection with the Pole Star, as a dial of a watch.

Fig. 2b, shows the *dial* 12 hours later.

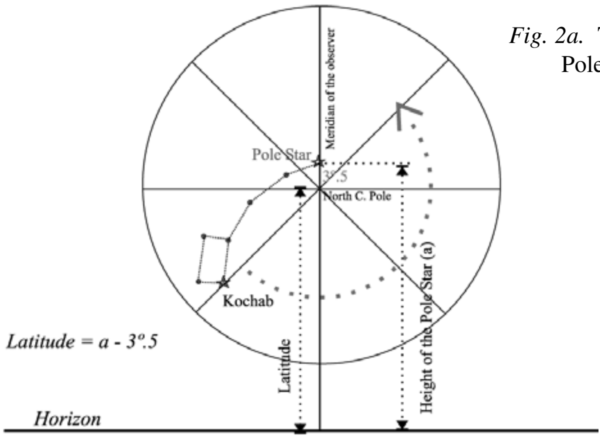

Fig. 2a. The alignment Pole Star-Kochab, used as a dial.

We see that the Pole Star, which was passing the meridian of the observer over the North Celestial Pole in fig. 2a (we say that it passed the *upper branch of the local meridian*), 12 hours later[2] passes bellow it (we say that it passed in the *lower branch of the local meridian*). The angular separation from the Pole is 3°.5 as previously stated.

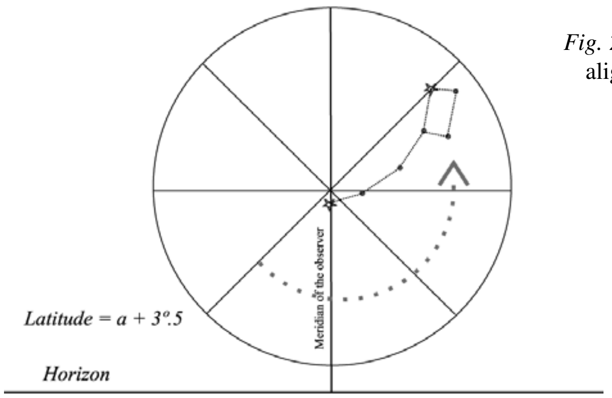

Fig. 2b. The same alignmen twelve hours later.

[2] In fact, it will be more precisely eleven hours and fifty-eight minutes, because sidereal time is faster than meantime. The stars rise everyday four minutes earlier than the sun, on account of the translation of the earth around the sun.

For finding the latitude in these two positions of the star, the only operation necessary was to subtract 3°.5 to the altitude of it above the horizon in the first case, and to add that amount in the second situation.

We can now imagine other positions equally separated from those ones, to which the correction was calculated. For memorizing the rules and the correction to apply, a human figure was imagined to stand in the North Celestial Pole, facing the observer with his arms stretched.

Using the alignment Kochab-Pole Star as a dial, the later star can be in the head, west arm, feet, etc. in relation to the human figure. The correspondent corrections, which were indicated, were then easily applied.

In fig. 3 is represented an adaptation of the illustration of the *Regimento do Norte*. We can see the figure facing the observer, the lines and also, in its periphery, the corrections in degrees and decimal degrees, affected by the minus and plus signal. In the same figure I included the schematic view of the Little Bear, with the front guard, Kochab, in the line under the west arm. We can see that this position corresponds to the situation in figure 2.a, where, for finding the latitude, it is necessary to subtract the polar distance of Polaris (3°.5), to the altitude of the star.

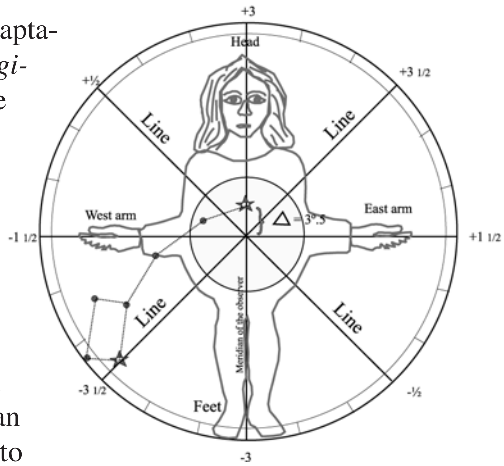

Fig. 3. The human figure that helped the interpretation of the *Regimento do Norte.*

If the position of Kochab was for example in the arm of the west, it will be also subtractive and of 1°1/2. But if it was in the head, it will be additive and in the amount of 3°.

It is generally accepted that the first *Regimento do Norte* is the one that is published in the *Manual de Munique*, studied by Fontoura da Costa and Luís de Albuquerque, among other historians[3].

[3] See *Marinharia dos Descobrimentos*, (*Op. cit.*, pp. 54, 55), and from Luís de Albuquerque, his critical study of the referred manuals (Luís Mendonça de Albuquerque, *Os Guias Náuticos de Munique e Évora*, Lisboa, Junta de Investigações do Ultramar, Agrupamento de Estudos de Cartografia Antiga, 1965, pp. 21-51. This study is even deeper then the one of Fontoura da Costa. See also E. G. R. Taylor in *The Haven Finding Art,* (*op. cit.*), pp. 162-165, among other historians.

The following translation is made from the text of the *Manual de Munique*, as per the transcription of Luis de Albuquerque[4]:

> This is the Regiment of the North
>
> And when the guards are in the arm of the west, is the North Star above the pole one degree and a half.
>
> Item. When the guards are on the line below the arm of the west, the North Star is above the pole three degrees and a half.
>
> Item. When the guards are at the foot, the star is three degrees over the pole.
>
> Item. When the guards are in a line below the arm of the east, the star is over the pole half a degree.
>
> And when you take the altitude of the star, and the guards are in some of theses four places in which the star is above the pole, from the altitude you take of the star, it is convenient to know, you will take those degrees that the star is above; and the remaining degrees, are those that you are separated of the equinoctial line.
>
> In these four places the North Star is below the pole.
>
> Item. When the guards are in the arm of the east, the star is below the pole one degree and a half.
>
> Item. When the guards are in the line above the arm of the east, the star is three and a half degrees below the pole.
>
> Item. When the guards are at the head, the star is below the pole three degrees.
>
> Item. When the guards are in the line above the arm of the west, the star is below the pole half a degree.
>
> When you take the altitude of the star, and the guards are in any of these four places in which the star is below the pole, it is convenient to know, you will add those degrees that the star is below the pole, with the altitude you take from the star; and the degrees you find, those are the ones you are separated from the equinoctial line.

Probably two decades before Vasco da Gama´s voyage, as the south Atlantic was navigated, loosing the sailors the Pole Star, it was used for finding the latitude the altitude of the Sun in its meridian passage. The principles also came in the *Libros del Saber de Astronomia*, of Afonso X, but we can imagine how difficult it was for the astronomers in land, to find easy rules to the rude pilots. Declination tables were calculated and a practical *Regimento do Sol* was introduced with easy rules for the pilots[5].

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[4] *Os Guias Náuticos de Munique e Évora*, pp. 135, 136. Fontoura da Costa dates the *Regimento* as early as 1483, 1484 (*See Marinharia dos Descobrimentos*, p. 54).

[5] Fontoura da Costa considers that the first *Regimento* was made in 1483 or 1484. See *Marinharia dos Descobrimentos*, p. 69.

As I intend also to translate the *Regimento*, it will be useful to give a simple idea of the method of determination of latitude by the meridian passage of the sun, which will permit to understand the rules.

Let us represent a diagram of the celestial sphere in the plane of the meridian of the observer. In fig. 4 Q Q' represents the equator, P_n P_s the line of the poles, H_s H_n the horizon, with its zenith at Z and the nadir at N. The latitude φ is by definition the arc QZ, or the angular distance, in the meridian of the observer, from the equator Q to the place Z. This angle is equal to the angle $P_n\hat{O}H_n$, because both have perpendicular sides. So, this angle or altitude of the elevated pole (in our case the north pole), is the latitude of the observer at Z.

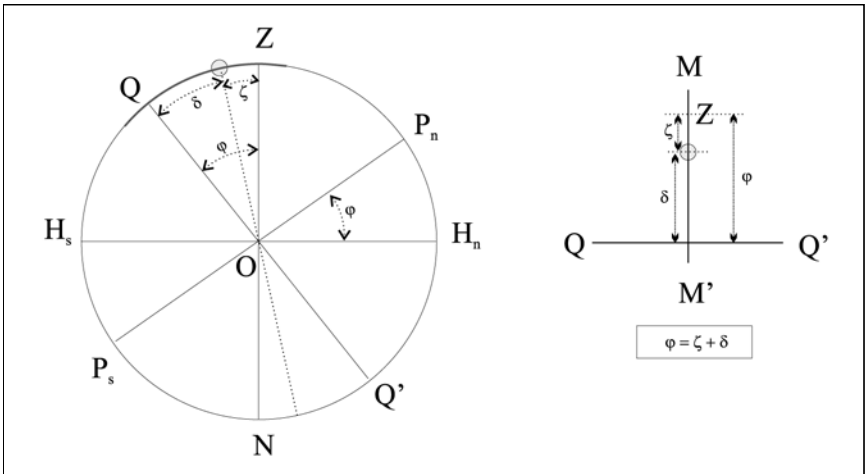

Fig. 4. The determination of the latitude by the observation of the zenith distance of the sun.

If we consider the sun in the meridian of the observer (when it attains its greatest altitude above the horizon), its angular distance to the equator is its declination, and the complement of its altitude above the horizon, the zenith distance. These angles are represented by δ and ζ respectively.

For the simplification of the problem, and to help the interpretation of the rules, let us imagine that of fig. 4, we only take the portion that represents the zenith, the equator and the meridian of the place (in red). This is represented in the right side of the same figure.

If the observer can measure the altitude of the sun (h) aboard his ship, and consequently its complement ($\zeta = 90° - h$), it will be very easy to find the latitude, using a simple computation. For knowing the declination the pilots have to consult a convenient table.

The rules of the different *regimentos* were modified to be more useful to the rude pilots, and the ones that I am going to indicate are those explained by Fontoura da Costa in modern language, and extracted from the works of Pedro Nunes, the famous Portuguese mathematician of the 16th century[6].

Regiment of the altitude of the sun at midday

1) The sun at the equinoctial [declination zero]: the latitude will be equal to the zenith distance.
2) The sun at the zenith: the latitude is equal and of the same name as the declination.
3) The sun and the shade of the same name: the sum of the declination with the zenith distance will be the latitude of the same name of the shade.
4) The sun and the shade of different names: if the declination and the zenith distance are equal, you will be at the equator; if they will be different, subtract the smallest from the biggest and the remain will be the latitude of the same name of the biggest.

It is necessary to understand that the shade gives the bearing of the sun at meridian passage, which for example, for an observer in Cochim is north if the sun has north declination and bigger than 10 degrees, which is the latitude of this town.

These apparently confusing rules can be understood by the following figures, based in the second image of figure 4.

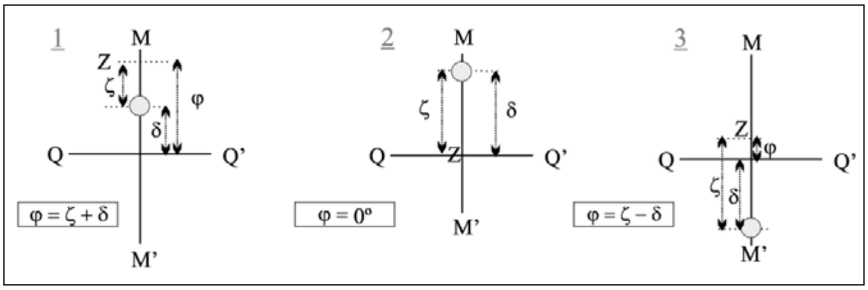

Fig. 5. Explanation of the *Regimento da altura do polo ao meio dia*.

We have to assume that the sun can be either to the north or to south of the observer during the meridian passage. It can also be south or north of the equator.

The first and second rules are self-explanatory.

[6] *Marinharia dos Descobrimentos*, p. 72.

The third one corresponds to the situation when the sun is between the observer and the equator, being either to the south or to the north of it. Fig 5, position 1, shows the situation when the sun and observer are north of the equator, being the shade of the sun north, or of the same name as the latitude of the observer. It is clear that the latitude is the sum of the zenith distance and the declination.

If both were in the same conditions but to the south of the equator, the shade will be to the south, or of the same name as the latitude of the place. The latitude will be again the sum of the declination and the zenith distance.

The fourth rule corresponds to the situation of the sun and place in different hemispheres. Its first part is clearly explained by position 2 of fig. 5. One of the conditions of the second part is explained by position 3 of the same figure.

The Portuguese also developed the latitude determination by the observation of the Southern Cross, for which a set of simple rules was proposed. It is interesting to note that the rules to the Southern Cross were "invented" in Cochim, by a pilot called Pedro Anes, with the cooperation of João de Lisboa. This last famous Portuguese pilot collected a great amount of information that was spread among the pilots, and made a manuscript that became known as *Livro de Marinharia de João de Lisboa*[7].

It will be appropriate to explain the principle of those rules and for that let us consider a schematic view of the southern sky, with the Southern Cross passing on the meridian of an observer near the equator (fig. 6). I am going to utilize the same kind of presentation as the one used for the meridian passage of the sun or of the Pole Star.

In the diagram are represented the horizon, the local meridian and the Southern Cross at the moment of meridian passage. It is necessary to note the fact that for an observer facing south, the movement of the celestial sphere is clockwise, as opposed to its counter clockwise movement for an observer facing north. Note also that the polar distance (the complement of its declination), of the star Gacrux, the one that is near the south celestial pole, is 30°, which was the value accepted for the 16th century[8].

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[7] This manuscript was only published in 1903, and contains precious information about the Portuguese techniques of navigation, prior to the two first decades of the 16th century. See *Livro de Marinharia de João de Lisboa. Tratado da Agulha de Marear de João de Lisboa*, ed. Jacinto Ignacio de Britto Rebello, Lisboa, Imprensa Libanio da Silva, 1903.

[8] In fact the declination of this star to the year 1510 was 60º 22', which gave a polar distance of 29º 38'. In 1600 it was 60º 52' or a polar distance of 29º 08'. The Southern Cross and its use by the Portuguese pilots, is also extremely well studied by Fontoura da Costa in his Marinharia dos Descobrimentos. See op cit., pp. 118-146.

The rule that was spread among the pilots was the following or a variation of it, but with the same principles in mind[9]:

> It. you have to know that when you take this Southern Cross [*cruzeiro do sul*] you have to take it when it is upright [*empinado*] having this aspect and you will take the star of the foot [Acrux] and you take care for them [Gacrux and Acrux] to be north-south one with the other and east-west the arms [Betacruxis and Deltacruxis] and you look well how many degrees you take and if you take 30 degrees [h = 30º] you are on the line [the equator] and if you take less than 30 degrees [h <30º] the amount less than 30 you will be separated to its northern part. And if you take more than 30 degrees [h > 30º], all that amount you will be to the southern part, being them a small or a great amount, all of it will be to the southern part. [There is after a repetition of the last concept in three more lines of text]

I think that the observation of figure 6 will clarify the situation.

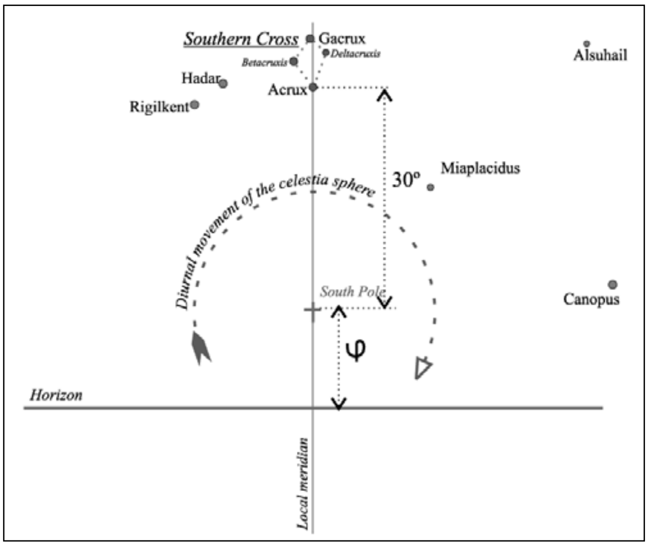

Fig. 6. The Southern cross and other conspicuous stars around the south celestial pole.

In fact, the situation exemplified by the figure corresponds to an altitude of Acrux bigger than 30º. If that altitude was for example 40º, the latitude of the place will be 10ºN. For any other situation, it is a question of a correct positioning of the elements in question.

[9] This one is taken from the *Livro de Marinharia de João de Lisboa*, as per the transcription by Fontoura da Costa in his *Marinharia dos Descobrimentos*. See *op. cit.*, p. 141.

Other stars had been selected for the determination of latitude during its meridian passage.

Those rules, as well as other Portuguese *Regimentos*, were published by practically all the European nations that followed the Portuguese in its maritime expansion.

In the Indian Ocean, with its almost permanently clear skies, the altitude of the Pole star was used for determining latitude in places north of the equator. South of the Equator, other stars near the North Pole were used for the same purpose. In reality it is generally considered that the Indian Ocean navigators did not use the altitude of the Pole to find latitude but to search the parallel of the place of destination, which is almost the same. Let us say that, not having hydrographical maps similar to the ones utilized later in the west, the altitude of the Pole was treated in another way[10].

For calculating their position daily the Portuguese used the latitude determination, the course steered by magnetic compass and the distance

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[10] There is really a general idea that Indian Ocean techniques did not included the sun for finding latitude. Besides that, G. R. Tibbets clarifies his interpretation of the techniques used in the Indian Ocean, saying in the introduction of his extensive and deep work: "… I am not a practising navigator and have not therefore attempted to reproduce navigational terminology exactly as it is used on the high seas today." After saying that the navigational historian should have that in mind, notes: "He [the navigational historian] should note that I have used the term «latitude» for a position on the earth's surface and «latitude measurement» for the measurement of such a position, although the measurements themselves and the position given by them were known to the Arabs only in terms of stellar altitude.". See, G. R. Tibbetts, *Arab Navigation in the Indian Ocean Before the Coming of the Portuguese*, London, The Royal Asiatic Society of Great Britain and Ireland, 1971, p. xvii. So, in reality, the interpretation we shall give to the method used in the Indian Ocean can be the interpretation given by for example Laguardia Trias to the methods used by the Portuguese in the Atlantic, to which he calls "preastronomic navigation" (See Rolando Laguardia Trias, "Interpretacion de los Vestigios del Uso de un Metodo de Navegacion Preastronomica en el Atlantico", in *Revista da da Universidade Coimbra*, vol. XXIX, Coimbra, 1970, pp. 569-593), which are considered by Luís de Albuquerque the first phase of the astronomical navigation in the Atlantic (see from this historian, *Historia de la Navegación Portuguesa*, Lisboa, Mapfre, 1991, pp. 50, 51). This method consisted in using the height of the Pole Star as a reference for the progression in a north-south direction, not yet related with the definition of latitude. Teixeira da Mota has a similar opinion saying that: "Cette méthode de navigation n'a aucune corrélation directe avec les notions d'équateur et de degrés de latitude. Il s'agit d'un système purement empirique, aux objectifs éminemment pratiques et détaché du concept de coordonnés géographiques.». See, A. Teixeira da Mota, «Méthodes de Navigation et Cartographie Nautique dans l'Océan Indien avant le XVIe Siècle», in *Studia*, n.º 11, Lisboa, Centro de Estudos Históricos Ultramarinos, 1963, p. 56.

of a day's run appreciated by eye. A table of the distance in leagues travelled in a fixed course in order to raise the latitude by one degree was calculated, and the *Regiment of the leagues* introduced. Its comparison with the distance evaluated by eye, made possible a fix, which was the product of the correction (in Portuguese, *emendas*) of all these elements.

Let us give a simple idea of that *Regimento*, whose principle was the resolution of a plane right triangle (see fig. 7). Its origin goes back to the Mediterranean Sea navigation, being its ancestor the *Toleta de Mateloio*, which was based in the same principle[11].

As the finding of latitude become more common and accurate, and being the navigation, in a great percentage, made along the meridian, with a great variation of latitude everyday, the pilots made his fix, having in mind the diurnal variation of that coordinate.

So, a means of knowing the consequence of variation of latitude per day (or for more than one day, sailing at the same course), in the east-westing and distance travelled had to be found. If we have a table where we can find the distance travelled along a given course ("Relevar") and the distance travelled along the parallel ("Afastar"), per each degree of variation of latitude, by a simple proportion we can have the actual value for a certain number of degrees of latitude.

In fig. 7, a plane triangle is represented, with its vertical side being the number of leagues that in the epoch were considered to represent a degree of latitude.

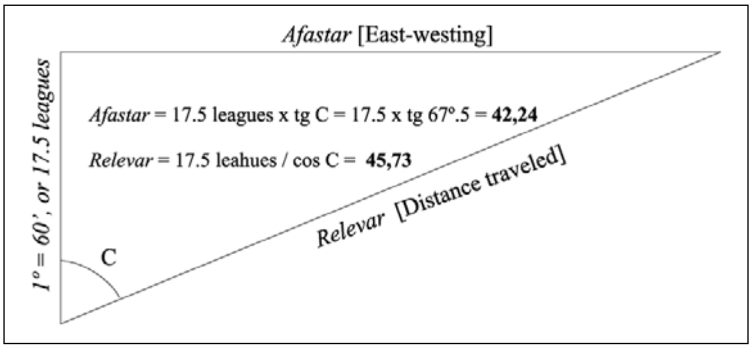

Fig. 7. Principle of the determination of the *Regimento das Léguas*, as published in the *Manual de Munique.*

[11] Fontoura da Costa gives a deep overview of this subject. See *Marinharia dos Descobrimentos*, pp. 355-372.

Sailing in a given course C, the ship will travel the distance represented by the hypotenuse of the triangle, which was designated by the Portuguese word *Relevar*. The distance travelled along the parallel is the *Afastar* of the figure. By simple trigonometry the *afasta*r and *relevar* have the result as shown, for the course of 67º.5 or 6 points (*quartas* in Portuguese).

The following text is the translation of part of the *Regimento* of the *Manual de Munique*:

> Item you will know that the north south degree is of seventeen leagues and a half, and so you have to know that sixty minutes make one degree.
> Item by one point *releva* by each degree seventeen leagues and five sixths of a league. And you *afastas* from the straight-line three leagues and a half.
> Item by two points *releva* by degree nineteen leagues and one sixth of a league.
> And you *afastas* from the straight-line seven leagues and a half.
> ....
> Item by seven points *releva* by each degree eighty-seven leagues and one sixth of the league.
> And you *afastas* from the straight-line eighty five leagues[12].

Resolving the triangle for the course angles of one point (11º.5), two points (22º.5) and seven points (78º.75) we have respectively and for the *relevar* and *afastar*: 3.48 and 17.84 leagues; 7.25 and 18.94 leagues; 87.98 and 89.70 leagues. We see that these values differ little from the ones of the *Regimento*, although it is generally admitted that they were obtained graphically or geometrically[13].

We have to recognize however, that the main technique for finding an island or any other harbour in a continent was to *run down the latitude*. The ship was directed to the parallel of destination, to a position clearly safe to the east or west of it, according with the present conditions, and after that sailed along the parallel. And this was the procedure of the Indian Ocean pilots prior to the Portuguese development of high seas navigation in the Atlantic.

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[12] The text is the one that Fontoura da Costa transcribed from the *Manual de Munique*. I maintain the expressions relevar and *afastar*, which have no translation in English. See *Marinharia dos Descobrimentos*, p. 364. The text contains all the courses of the quadrant, which were traditionally measured in points from one to seven.

[13] This subject, among many others, is also deeply studied by Luís de Albuquerque in his critical study, *Os Guias Náuticos de Munique e Évora.* See *op. cit.*, pp. 96, 97, 116-119, 138, 193-194.

In the Indian Ocean a similar system was used, a table also being calculated with the distance travelled by the ship on a fixed bearing in order to raise the latitude by one *isba*, which was the angular unit of the area and corresponds, according to Gabriel Ferrand, to 1º 37'[14]. This is the interpretation given by G. R. Tibbetts and Gabriel Ferrand to the concept of *tirfa*, in the Arab texts[15].

For taking the altitude of the sun and stars the Portuguese used mainly the astrolabe and the quadrant, which had as reference the vertical of the place.

The astrolabe corresponds to the adaptation by the Portuguese navigators of the planispheric astrolabe for its use at sea. This astrolabe was known in Europe even before Christ, and was used to solve many astronomical problems, required mainly by the popular astrologers.

The instrument is well known and was used till the middle of the seventeenth century to take altitudes of sun and stars, when it was superseded by the cross staff for shooting the sun backwards. To observe a star, which couldn't produce a convenient beam of light, the astrolobe was suspended at the level of the eyes of the observer, where the alidade should be aligned with the heavenly body.

The quadrant was used before the astrolabe for taking the altitude of the Pole Star. It was made of wood, being simply a circular sector of 90º (or quadrant), conveniently graduated from zero to 90º and having suspended from its centre a small string with a lead or brass weight of 100 to 200 grams in its extremity. Mounted on its side where ends the 90º degrees graduation, are two sights with two holes, similar to the ones produced on the alidade of the astrolabe. It was also used for the sun, with the help of the two holes, in a similar way.

It was easier to observe a star with the quadrant, because the instrument was lighter than the astrolabe. To observe the sun the astrolabe was more accurate, because its weight materialised better the vertical of the place.

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[14] See Gabriel Ferrand, *Instructions Nautiques et Routiers Arabes et Portugais des XV[e] et XVI[e] Siècles*, ed. Gabriel Ferrand, tome III, «Introduction a L'Astronomie Nautique Arabe», Paris, Librairie Orientaliste Paul Geuthner, 1928, p. 171. It follows an extract of part of the text, where Ferrand also explains his interpretation of *tirfa*: «Un *tirfa* serais donc le changement en latitude d'un isba, mais comme le texte spécifie que chaque cap a son *tirfa*, il est préférable de considérer le tirfa comme un coefficient indiquant la longueur de route à parcourir à un cap donné pour provoquer un changement d'un isba dans la hauteur du pôle.».

[15] See *supra* the interpretation of Gabriel Ferrand. Tibbets says (See *op. cit.*, p. 299): "The tirfa was the distance travelled by a ship on a fixed bearing, in order to raise its latitude by one isba.". Tibbetts says also that "... *tirfa* measurement were used in the Indian Ocean considerably earlier that the Portuguese «raised the Pole».".

The photographs on Annex A1 and Annex A2, shows the two instruments and exemplifies its use at sea, according with experiences that I made aboard the sailing ship *Sagres*, of the Portuguese Navy[16].

The navigators of the Indian Ocean used an instrument to measure the altitude above the horizon of the Pole Star and other circumpolar stars. That instrument was called the *Kamal*, and had as reference to measure the altitude, the visible horizon.

It was based on the same principle of the cross-staff, and was found in common use by the Arab pilots in the Indian Ocean by Vasco da Gama.

It consisted of a rectangular piece of wood with a hole in the middle where a line with many knots was attached. The knots corresponded to the appropriate graduation in *isba*. It was mainly used to navigate in an east-west direction between the harbours of eastern Africa (and Arabia), and India. Fig. 8 shows its use for measuring the altitude of a star.

The first Portuguese nautical charts were the adaptation to the Atlantic of the technique used by the Mediterranean navigators in their "portulans".

They had, diverging from strategically located points on the chart, groups of 32 lines, which corresponded to the 32 winds of the compass

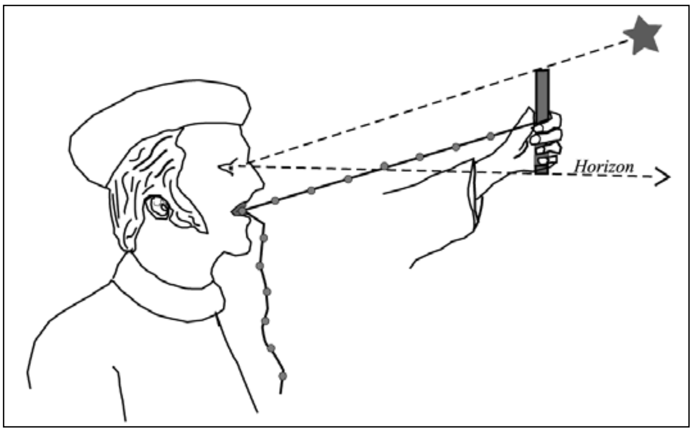

Fig. 8. The *kamal* and its use at sea.

[16] These experiences were carried out during the years of 1989 till 1993, and its results were published in "Experiências com Instrumentos de Navegação Antigos" in *Anais do Clube Militar Naval*, Lisboa, vol. CXXI 1991, pp. 833-866", Lisboa, 1991. This publication is a magazine of the Portuguese Navy Officers Club. An improved description of the experiences and its results was also published. See José Manuel Malhão Pereira, "Experiências com Instrumentos de Navegação da Época dos Descobrimentos", in *Mare Liberum* n.º 7, Comissão Nacional para as Comemorações dos Descobrimentos Portugueses, Lisboa, 1994, pp. 165-192.

rose. These lines were used to mark the courses from the departure to the destination harbour, using a parallel ruler or dividers. And they were in many areas of the chart to allow that there was always one line near the area of the chart that was in use.

The astronomical navigation introduced an important evolution in cartography, which was the inclusion of a latitude scale on the charts used for navigation. On the chart of Pedro Reinel of 1504, it is clearly visible a latitude scale, which was the result of decades of experience with the new methods. Annex B shows a copy of part of this chart.

Indian Ocean navigators would have had nautical charts or something with a similar objective, and that information is included on the Portuguese chronicles. Marco Polo also spoke about them. But unfortunately they were not found.

Portuguese pilots have also written navigation instructions, or *Roteiros*, for the Atlantic, Indian and western Pacific Oceans, which on the first decades of the sixteenth century covered an enormous area of this waters.

Indian Ocean navigators had also their pilot books, of which the *Kutchi Rehmanis,* which will be referred later, are an example.

Environmental conditions of the Indo-Pacific regions of navigation and its consequence to navigation techniques

As a result of what has been said above, it seems that the techniques used by the Portuguese when they arrived in the Indian Ocean were similar in certain aspects to the ones used by Indian Ocean navigators.

Nevertheless, some techniques differed from each other and I am going to try to demonstrate the influence of the environmental conditions of the navigational areas that originated the differences in the procedures.

Besides that, a study of the techniques of Pacific navigators showed to many historians that exists a great interchange between this ocean and the Indian Ocean[17].

[17] It is for example the opinion of Tibbetts, expressed in a paper in 1979 (See G. R. Tibbets, *A Comparison of Medieval Arab Methods of Navigation With Those of the Pacific Islands*, Lisboa, sep. CXXI, Centro de Estudos de Cartografia Antiga, Junta de Investigações do Ultramar, 1979), performed some years after the publication of his very important work, *Arab Navigation in the Indian Ocean …* already cited above. He says that: "My own opinion is that in both areas [Indian and Pacific oceans], there must have been a general mutual awareness of the way that navigational problems were solved. In the days when the Malaysian peoples travelled to Madagascar, the Pacific peoples may have been in contact with southeast Asia and similar navigational systems may have operated on both Malayan archipelago.". See *op. cit.*, p. 13.

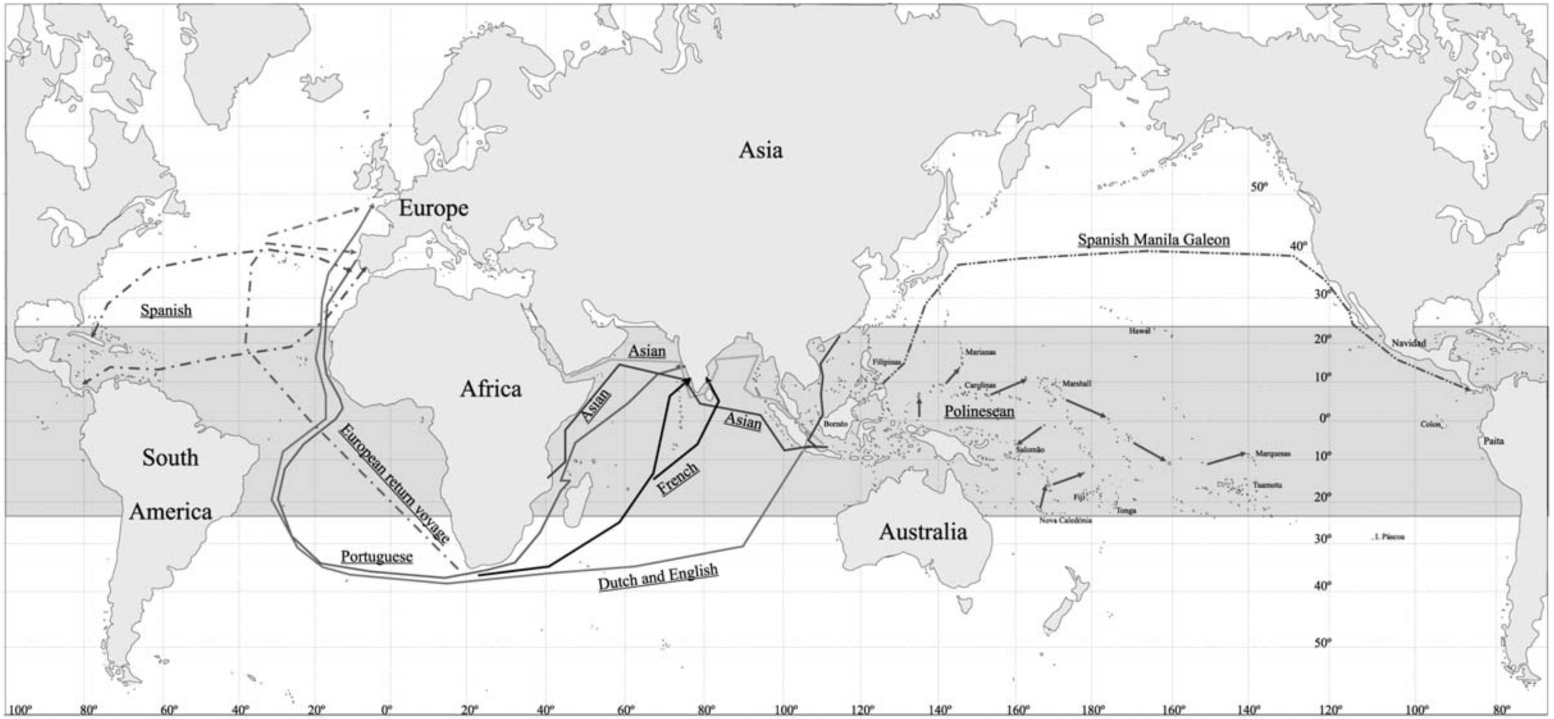

Fig. 9. Intertropical areas at sea. European and Asian routes of navigation
(only for showing areas of operation and consequently not with historical or sailing accurancy).

The first important fact is that the Arab, Persian, Indian, and Polynesian navigation is performed mainly in inter-tropical areas.

Let us take a look of fig. 9, where the inter-tropical areas of the seas of the world are shaded and the routes of navigation schematically represented. It is immediately apparent that Asian routes are mainly inter-tropical, with the only exception of routes of northern parts of China. The Portuguese, Spanish, Dutch, French and English routes have big proportions out of the tropics.

It is also evident from the map, that:

- European routes are long distance ones with many months at sea and out of sight of land.
- Arabian, Persian and Indian routes have some medium distance ocean routes, but more coastal navigation.
- Malayan and Chinese routes are mainly coastal or short distance high seas navigation, with the exception of the probable but not very frequent direct routes to Africa.
- Western Pacific routes are mainly short inter-island routes, which never exceed the 350 miles distance, with the exception of the voyages to Hawaii and New Zealand.

It is my deep conviction that all sailors find the necessary techniques and instrumentation for their areas of operation. And sailors are very practical and only use or develop what is needed for the purpose of the navigation.

Taking in consideration what has been said above, let us imagine what does a sailor needs to know to return to a previously discovered island or harbour in a continent, far away from his home place and out of sight of land which means that ocean navigation methods are needed, instead of coastal navigation methods.

The first thing is to find a means of recognizing the direction he has to take to return there, admitting that the same system has been used to return to his point of departure. But for finding a direction it is necessary any reference to measure that direction.

Fig. 10 shows two islands A and B sketched on the sand of a beach. The arrow is the path that any ship has to sail on, to go from A to B or vice-versa. For attaining this objective, it is necessary to materialize any means of finding the direction, for example from A to B.

One of the means is having a reference related to the direction of the swell, if it is constant during the period of navigation.

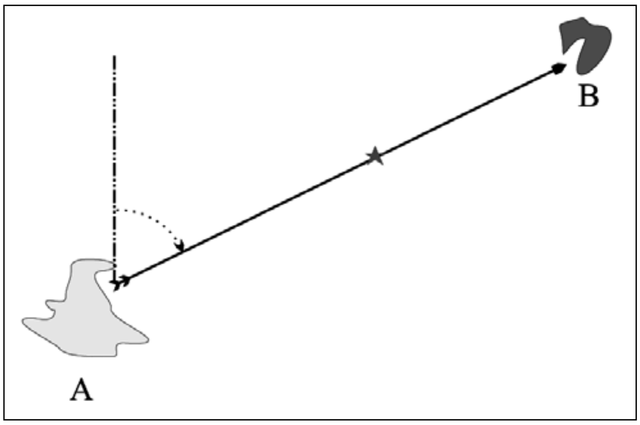

Fig. 9. The need for *direction*.

Another can be the direction of the wind, again if it is constant in direction.

Another can be the flight of birds, if they go always to the same place B.

We see that those means have too many *ifs*, and people soon recognized that the heavens, with its stars and planets during the night, and sun and moon during the day, could be a good reference. From those, the best are the stars, because they maintain their relative positions for very long periods. Besides that they rise and set in well-defined positions in the horizon.

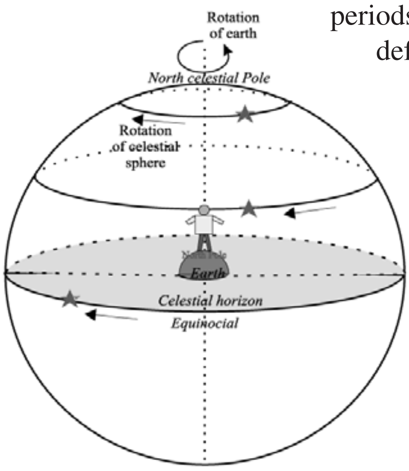

Fig. 11. Observer at the Pole. Parallel sphere. Stars never rise and never set. Only half of the celestial sphere visible throughout the year.

However, the effectiveness of stars to be direction references depends mainly on latitude as we are going to see.

Let us imagine that we are standing on the North Pole (fig. 11). On account of the rotation of the earth around its axis the celestial sphere moves apparently in the opposite direction. As we have the axis of the earth in our head, during 24 hours the celestial hemisphere, with all its visible celestial bodies, revolve around us and never rise and never set. The astronomers and navigators call it parallel sphere, because the heavenly bodies have their movements along celestial parallels.

As there is no rising and setting, and they are always moving horizontally, celestial bodies are not good references for direction.

Let us now consider the observer at the Equator (fig. 12).

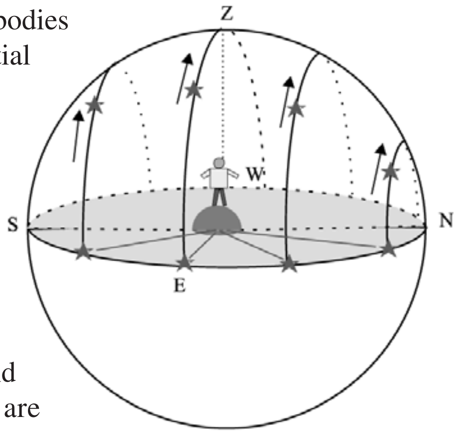

Fig. 12. Observer at the Equator. right sphere. Stars trace circles perpendicular to the horizon. Equatorial stars defining, during rising an setting, long periods of accurate bearings.

Heavenly bodies trace perpendicular circles around the observer, and their rising and setting bearings are maintained during long periods, specially the equatorial ones. See for example that a star at the equator (or the sun during the equinox), rises in the east, maintains its east bearing till meridian passage and maintains its west bearing till it sets.

If the observer is at high latitude (see fig. 13, observer at 45ºN), heavenly bodies trace oblique circles relative to the horizon, and their rising and setting bearings vary rapidly.

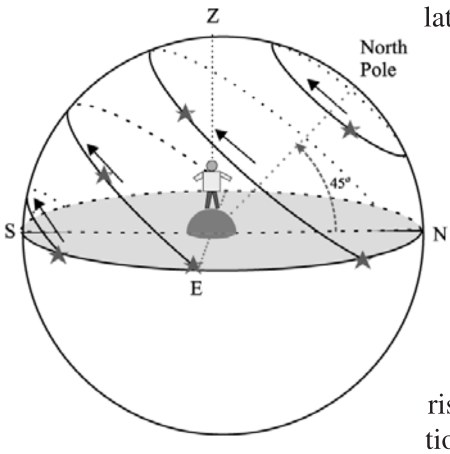

Fig. 13. Observer at 45° of latitude. Oblique sphere. Stars trace circles oblique to horizon, defining, during rising an setting, very short periods of accurate bearings.

Nevertheless, any observer at the same latitude has throughout the year always the same bearing of a given star during rising or setting. But if he changes latitude, the bearing will change appreciably if he is in high latitudes, but change a small amount in places near the equator.

For clarifying the situation, let us see the table shown after fig. 13, where the bearings (Z) of the rising of four stars of northern declination (δ) and the settings of four stars of southern declination, are shown for the latitudes 0º to 60º north, in intervals of five degrees of latitude.

The 8 stars selected are part of the

16 that Tibbets identified in the Arab stellar compass, and cover almost the entire horizon[18].

I am going to admit that we are looking to the present day sky, that is January 2002, which is sufficient for the purpose of my study. The declinations and bearings are to the accuracy of the degree and the bearings are from 0° to 360°, clockwise, which is the normal way used by navigators.

OBSERVER IN THE NORTHERN HEMISPHERE																
Stars with northern declination. Bearings of rising.									**Stars with southern declination. Bearings of setting.**							
Latit.	Kochab		Schedar		Capella		Altair		Sirius		Antares		Canopus		Achernar	
	δ	Z	δ	Z	δ	Z	δ	Z	δ	Z	δ	Z	δ	Z	δ	Z
0º	74ºN	016º	56ºN	034º	46ºN	044º	9ºN	081º	17ºS	253º	26ºS	243º	53ºS	217º	57ºS	213º
5ºN	"	015º	"	033º	"	044º	"	081º	"	253º	"	243º	"	217º	"	212º
10ºN	"	012º	"	032º	"	043º	"	081º	"	253º	"	243º	"	216º	"	211º
15ºN	"	004º	"	030º	"	042º	"	081º	"	253º	"	242º	"	215º	"	210º
20ºN	"	---	"	027º	"	040º	"	081º	"	252º	"	242º	"	213º	"	207º
25ºN	"	---	"	023º	"	037º	"	080º	"	252º	"	241º	"	209	"	203º
30ºN	"	---	"	015º	"	034º	"	079º	"	251º	"	239º	"	203º	"	194º
35ºN	"	---	"	---	"	028º	"	079º	"	250º	"	237º	"	194º	"	---
40ºN	"	---	"	---	"	019º	"	078º	"	248º	"	234º	"	---	"	---
45ºN	"	---	"	---	"	---	"	077º	"	246º	"	231º	"	---	"	---
50ºN	"	---	"	---	"	---	"	076º	"	244º	"	226º	"	---	"	---
55ºN	"	---	"	---	"	---	"	074º	"	240º	"	220º	"	---	"	---
60ºN	"	---	"	---	"	---	"	072º	"	235º	"	209º	"	---	"	---

We can see that the bearings of the stars on rising (the setting is symmetrical), have a small variation with latitude, around latitudes 0 to 20 or 25 degrees. I enhanced the variation in bearing of not more than two degrees in light grey and of not more than 4 degrees in dark grey.

Latit.	Kochab		Schedar		Capella		Altair		Sirius		Antares		Canopus		Achernar	
	δ	Z	δ	Z	δ	Z	δ	Z	δ	Z	δ	Z	δ	Z	δ	Z
0º	74ºN	016º	56ºN	034º	46ºN	044º	9ºN	081º	17ºS	253º	26ºS	243º	53ºS	217º	57ºS	213º
5ºS	"	015º	"	033º	"	044º	"	081º	"	253º	"	243º	"	217º	"	212º
10ºS	"	012º	"	032º	"	043º	"	081º	"	253º	"	243º	"	216º	"	211º
15ºS	"	004º	"	030º	"	042º	"	081º	"	253º	"	242º	"	215º	"	210º
20ºS	"	---	"	027º	"	040º	"	081º	"	252º	"	242º	"	213º	"	207º
25ºS	"	---	"	023º	"	037º	"	080º	"	252º	"	241º	"	209	"	203º
30ºS	"	---	"	016º	"	034º	"	079º	"	251º	"	239º	"	203º	"	194º

[18] See *Arab Navigation in the Indian Ocean...*, *op. cit.*, pp. 294-299. Tibbetts follows Léopold Saussure, in the work of Gabriel Ferrand, *Instruction Nautiques et Routiers Arabes et Portuguais …, op. cit*., pp. 92-124.

Now we can also see that for the same stars but to south latitudes of the same amount, which I only extended to 30ºS, the bearings are the same. See table above.

This is a very interesting fact that sometimes is not recognized, even by experienced navigators[19]. It gives an added advantage of using rising and setting stars for direction between the tropics because their bearings are equal if we are at the same latitude, even if we are in different hemispheres. This means that the entire area of the tropics is suitable for this purpose and not only half of it.

It also shows clearly, that for observers between the tropics, the rising and setting of stars are an accurate way for direction, and that out of the tropics, they are not suitable for that purpose.

In consequence of what has been said above, it can be understood that intertropical navigators soon recognized that the rising and setting of stars were almost constant when they made their inter-island voyages, although they did not had the notion of latitude as we have today.

So they began to recognize that the island B (fig. 10), was, as seen from island A, in the direction of the rising of some star. And this after repeated voyages.

As other islands were in other directions, they soon memorized other different stars that were suitable to maintain the direction required.

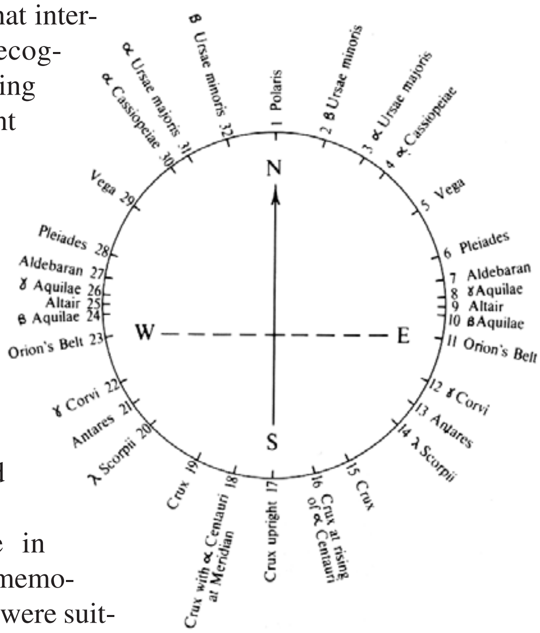

Fig. 14. Carolingian star compass.

19 The formula for finding the bearing Z of any celestial body at rising or setting is: cos Z = sen δ x sec φ. As the latitude is always less than 90º its secant is always positive, so cos Z will always be of the same sign of sen δ. So the bearing Z will allays be of the same name as the declination. This is also very clearly shown on the excellent work of David Lewis (*We the Navigators. The Ancient Art of Landfinding in the Pacific*, second edition, Honolulu, University of Hawii Press, 1994. In its Appendix I is an excellent study about this subject.

As stars are only near the horizon for a short period, other stars were used on the same direction or bearing (this is nowadays the appropriate technical word).

As in the same bearing the amount of stars was not sufficient to cover all the horizon, soon practical navigators recognized that other stars would be associated with the others, if they made an image of them, altogether, on a piece of circular or square wood, where they marked all the stars useful for the purpose of finding different islands.

And we can also understand that this system is useful mainly in areas near the equator, and where navigation is made in all possible directions, among islands (which is the present case of the Western Pacific), and sailing in the open ocean for relatively short distances.

It is also necessary to understand that their voyages were in directions that covered the entire horizon, on account of the physical characteristics of the areas navigated, with a great amount of islands.

As other islands were in other directions, they develop the use of low stars for references. From this stage, it is easy to understand the development of a compass rose that showed to the navigator the different directions which in the future could be the reference for future voyages. In consequence of this the Carolingian compass was introduced. See fig. 14[20].

This kind of navigation technique, since historians know, was only practised during the colonization of the Pacific Islands and after the continued establishment of people on those areas. Neither the Atlantic, nor the Southern Indian Ocean was navigated before the Western Pacific. Many centuries before the Vikings and the ocean navigation in the Northern Indian Ocean, the most part of western Pacific Islands were colonized.

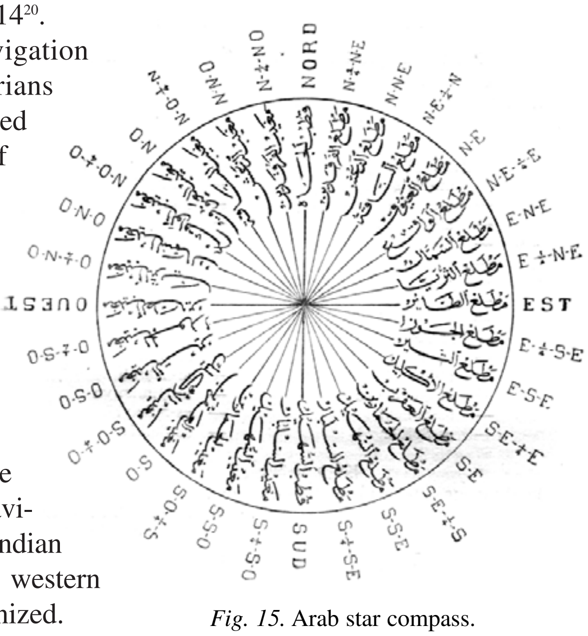

Fig. 15. Arab star compass.

[20] Adapted from David Lewis, *We the Navigators….*, p. 104.

Let us imagine now the navigators of the Northern Indian Ocean (Persians, Indians, Arabs), who sailed in northern latitudes, between the 7th and 23th parallel mainly in an east-west direction, and not among islands and in all directions.

In consequence of this, they soon recognized (like the Portuguese after recognized in the Atlantic), that the Pole Star which was always above their horizon and near the North Celestial Pole, was a good way to find direction and very appropriate to maintain an east-west course.

But as the Pole Star or the other stars of the Little Bear could be covered by clouds, other stars were chosen and drawn in a piece of wood, separated each other by the angles that separated them in the horizon. So, a star compass of the Indian Ocean was idealized, which represented the Pole Star as the main star for direction. See fig. 15[21].

They also do not needed (in the Indian Ocean), to use the sun for latitude, because the latitudes navigated and the clear skies in the periods outside the peak of the southwest monsoon, permitted the use of stars during almost all the night, for the same purpose.

Portuguese navigators, on the other hand, sailing long periods of their voyages in higher latitudes, with cloudy skies and frequent storms, should rely on the meridian altitude of the bright sun for finding latitude.

So, Indian and Pacific Ocean navigators, sailing in a specific and limited area of trade, maintained their adequate techniques for that particular area.

Portuguese navigators, having the ambition to navigate to India rounding the southern tip of Africa, had to develop new techniques.

All of this has been deeply studied by many scholars like Gabriel Ferrand[22], G. R. Tibbetts[23], Laguardia Trias[24], Custódio de Morais[25],

[21] Adapted from Gabriel Ferrand, *Instructions Nautiques et Routiers Arabes et Portugais des XV et XVI Siècles*, Tome III, *Introduction à L'Astronomie Nautique Arabe*, Paris, Librairie Orientaliste Paul Geuthner, 1928, p. 91.

[22] *Op. cit.*

[23] G. R. Tibbetts, *Arab Navigation in the Indian Ocean Before the Coming of the Portuguese*, London, The Royal Asiatic Society of Great Britain and Ireland, 1971. Also, from the same author, *A Comparison of Medieval Arab Methods of Navigation With Those of the Pacific Islands*, Lisboa, Junta de Investigações Científicas do Ultramar, Centro de Estudos de Cartografia Antiga, 979.

[24] Rolando A. Laguardia Trias, *Las Mas Antiguas Determinaciones de Latitude en el Atlantico y el Indico*, Madrid, Instituto Historico de Marina, 1963.

[25] J. Custódio de Morais, *Determinação das coordenadas geográficas no Oceano Índico pelo pilotos portugueses e pilotos árabes no princípio do século XVI*, Coimbra, Universidade de Coimbra, 1960.

Vitorino Magalhães Godinho[26], Moura Braz[27], David Lewis[28], William Kelsalka[29], Teixeira da Mota[30], among many others. Lewis and Kelsalka made interesting sailing experiences, with extremely important results.

Let us comment and compare some more techniques of the different areas. We have seen that in Indian and Pacific Oceans was used the stellar compass instead of the magnetic compass. In fact, the stars are better means of knowing direction in the area navigated[31].

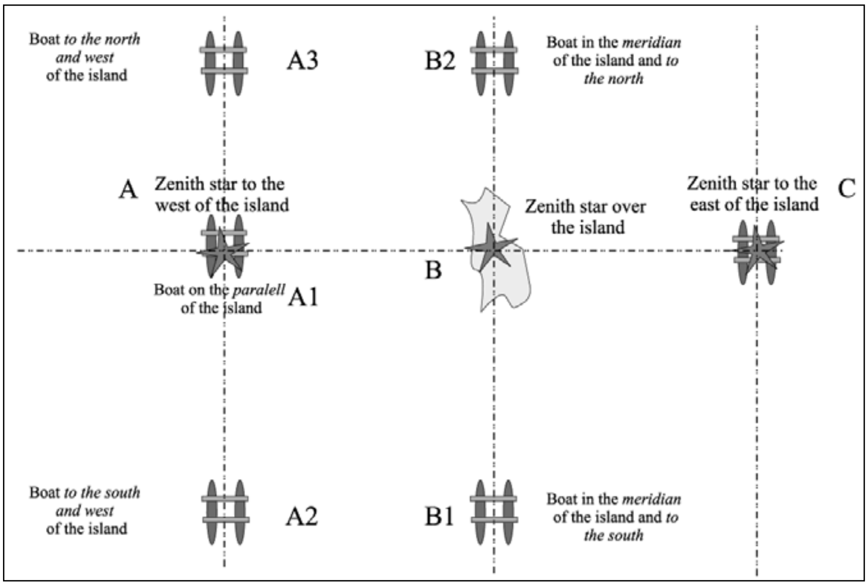

Fig. 16. The zenith star technique. Note that boats in positions B1 and B2 only recognized that the star, on its highest point in the sky, was over the island, if they were sure to be due south or north of it.

[26] Vitorino Magalhães Godinho, "Navegação oceânica e origens da náutica astronómica", in *Ensaios (I, Sobre História Universal)*, Lisboa, Sá da Costa, pp. 177-227.

[27] C. A. Moura Braz, *O Encontro das Marinhas Oriental e Ocidental na Era dos Descobrimentos*, Lisboa, Sociedade de Geografia, 1962.

[28] *Op. cit.*

[29] Will Kelsalka, *An Ocean in Mind*, Honolulu, University of Hawaii Press, 1987.

[30] A. Teixeira da Mota, " Méthodes de Navigation ...", *op. cit.*

[31] Lewis considers that "... steering by horizon stars is every bit as accurate as by magnetic compass and probably easier than trying follow the gyrating compass card of an island schooner or a yacht.". I agree 100% with this assessment, and it can be added that the problem of magnetic variation, that can go to more than 20º to the east or the west of true north, is completely eliminated by the observation of rising or setting of stars, which is a true bearing. See *op. cit.*, p. 121.

On the Western Pacific, another use of stars was performed. Besides the use of the sun, swells and birds for orientation during the day, an interesting technique of *zenith star* was used at night. Its principle is that an island can have a star that passes every night over it. That star should have, of course, a declination that equals the latitude of the place. If a navigator knows in advance the time when that star is overhead the island, the direction to that star is the direction to the island.

But for this it was necessary to know the times of overhead passage, which was not possible in the past. So, the overhead star or zenith star was used as an indicator of, let us say, the *parallel* of the island when it passed overhead the observer, situated to the east or the west of the referred island. It was only necessary to navigate due east or west to the objective. See fig. 16, position A1, where it was necessary to navigate to the east and position C where it was necessary to sail west. The other situations can easily be understood.

The zenith star passing on the *meridian* of the observer, gave also an indication that the island was directly due north or due south, but only if the observer previously new that he was in its meridian, which was not a common situation. Lewis has detected evidence of these techniques in his experiences[32].

Windward landfall, also extensively commented by Lewis, is another technique perfectly adapted to the Pacific and also the Indian Ocean. It consists of approaching the island or coast, to its windward (and up current). This is understandable, because the voyage was made in sailing boats. But what is more interesting is that this technique was complemented with the zenith star technique, which insured to the navigator that he was on the parallel of the destination as it has been explained above[33].

[32] See *op. cit*., pp. 280-286. It is very interesting Dr. Lewis description of local and his own technique of ascertaining that the star was overhead the boat.

[33] See *op. cit*., p. 286. Lewis says here that "latitude sailing" or *running down the latitude* as I said previously, "… was the method used by ancient Indian Ocean seafarers and by Western seamen prior to the late eighteenth century, that is, before a practical method of ascertaining the longitude had been developed.". Comments after that, that "Akerblom correctly points that although, theoretically speaking, it was possible for the Polynesians to have navigated by latitude sailing, there is not an atom of proof that they ever did so.". I do not understand this statement, if we consider that the *zenith star* technique is, in a certain way, a method that approaches the *latitude sailing* method.

CONCLUSIONS

From what I have said above, it can be again emphasised that the navigation techniques are mainly a result of environmental conditions and different sailors find different procedures in different areas of operation.

But in the Portuguese case what was really incredible was how fast they developed their cartography of the new waters navigated, and the correspondent pilot books or *Roteiros*, after the first voyage of Vasco da Gama.

The charts of Francisco Rodrigues, made around 1515, have also a great amount of information, which was only possible to acquire not only through direct knowledge, but also local knowledge[34].

The same happened with the pilot books of João de Lisboa of approximately the same epoch, which had already important information of areas east of India, already navigated by the Portuguese but apparently impossible to obtain without local knowledge.

What I really think is that charts, pilot books and navigation techniques of Arab, Indian, Persian, even Chinese origin are not sufficiently studied, although some scholars like G. R. Tibbetts, Gabriel Ferrand, Ybrahim Koury, Joseph Needham, David Lewis have dedicated to it great part of their lives.

But some of them were not sailors, and also some recent findings have not been studied.

Nevertheless, there has been in India, in 1988, a very interesting and productive initiative of the Tamil University that organized an important Workshop on The History of Traditional Navigation in South India. From its Proceedings[35], I found very interesting new material as for example the *Kuchi Rehamanis*, in a certain way, equivalent to the Portuguese *Roteiros*[36].

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[34] Teixeira da Mota studied deeply this subject in his work *Méthodes de Naviagtion et Cartographie Nautique dans l'Océan Indien*, (see note 10), making comments about the references of João de Barros, the javanese chart of Afonso de Albuquerque, the chart of Piri Reis, the references in *Livro de Marinharia de André Pires* and in the *Mohit* of Sidi Ali, and the eastern influences on the first Portuguese charts of the Indian Ocean. He accepted the idea of Youssouf Kamal, in his *Monumenta Cartographica Africae et Aegypti*, who "… conteste l'idée que les Orientaux auraient possédé de véritables cartes nautiques, et estime que ce sont les Occidentaux qui ont contribué au progrès de la représentation des littoraux.». As explained in the text of my work, I do not agree with this definitive conclusion and I consider that a deeper investigation should be made.

[35] *History of Traditional Navigation*, ed. by G. Victor Rajamanickam and Y. Subbarayalu, Thanjapur, 1988.

[36] Idem, pp. 87-99. (*Kalpana S. Desai, Traditional Techniques of Navigation. A study of Log-books of 17th-18th centuries*).

They included also sketches of the coasts, which can be considered, in a certain way, information similar to the one obtained in the European charts.

Also the deep and very well organized program of the National Institute of Science Technology And Development Studies (NISTADS), New Dehli, on *Boat Building and Fishing Communities. Bengal and the Andamans*, in which worked deeply Lotika Varadarajan, can be immensely fruitful[37]. In fact, at the same time as local knowledge of craft and fishing is obtained, information about techniques of navigation can be acquired.

The *Indo-Portuguese Seminars of Maritime History* have been also very important, although they cover a very wide area of study[38] and the more specialized Ma*ritime Seminars* organized by Professor Mathew, had decisive and important results.

Taking in consideration that in my opinion the areas navigated by the different sailors, with their specific physical characteristics, are the most important factor for the different techniques utilized, having in mind the different studies made by the scholars mentioned, and taking into account my own experience, I can arrive to the following conclusions:

– Practical astro navigation has probably begun during the colonization of the Pacific Islands, and was performed without instruments.
– Practical astro navigation using the Pole Star and an instrument to perform the system later called running down the Latitude has probably began in the Arabian Sea.
– The origin of the Stellar Compass, is probably from the Western Pacific area, and the product of contacts of the Indian Ocean navigators through the Malay-Chinese connection originated the Indian Ocean stellar compass.
– Interchange of Atlantic and Indian Oceans techniques, produced later Mediterranean techniques, with the development of magnetic compass, dead reckoning and the cartography.
– Portuguese sailors, contacting Mediterranean sailors, introduced modern astro navigation and developed cartography in a way that

[37] See for example, Hans Kumar and Lotika Varadarajan, "Ap, The Canoe of Chowra Island", in *Techniques and Culture*, 35-36, 2000, pp. 85-120.

[38] On the *IXth Seminar on Indo-Portuguese History* (NISTADS, New Delhi, 7-11 December, 1998) three excellent papers on the subject of navigation have been presented. They are: Lotika Varadarajan, *Indian Routers-The Indigenous Tradition*; C. K. Raju, *Kamâl or Râpalagai*; François Bellec, *Early Pilots on the Indian Waters*. This three works deal mainly with the subject that I am studying in the text of my work. Unhappily, the Proceedings of this excellent event have not been yet published.

permitted, after the end of the 15th century, to repeat voyages to any part of the world, previously recognized and chartered.

– Portuguese sailors adapted in an incredible fast way to the navigation of Indian Ocean and Southeast Asia seas, chartering these waters with the already known elements available locally and its own future experience.

This is the idea I have after crossing information of many great historians, and some of these last conclusions do not agree with of some of them.

I am Portuguese and very proud the of my country's maritime achievements. But I am also a sailor and I recognize that the achievements of Portuguese navigators, like the achievements of any other nation, are the product of information of a variety of origins.

As per the Portuguese techniques, I can say that:

– We adapted for the use at sea the astrolabe, of Greek and Arab origin.
– We transformed and adapted to the Atlantic, the techniques of the Mediterranean sailors, which, by themselves, acquired northern Europe and Arab techniques.
– With the caravel we recognized and chartered the coasts of Africa and of some parts of other oceans coasts, using the efficiency of the latten sail that was brought by the Arabs to the Mediterranean.
– We adapted to the sea the already known principles of astronomy, left by the Arabs and Jews in the Iberian Peninsula, that were by themselves acquired in their areas of birth.
– We utilized the system of running down the latitude that also was used in the Indian Ocean for the same purpose of navigation.
– Arab, Indian and Persian sailors probably acquired from the Western Pacific sailors the stellar compass through the Malay connection.

All of this was a permanent interchange of ideas, which became effective because there were things to be done by all the intervenients in the process, and because there was an incentive, namely the commerce (like nowadays).

And I think that it is impossible to forget this and the future will bring to us the same kind of procedure among all the peoples in the world. The only difference now is that all these exchange of information will be incredibly fast.

But for preparing the future, it is more urgent than in the past that people speak together, and I think that in the maritime history something more has to be done, because a lot of things need to be studied.

And for example, in which concerns the maritime history of the great Indian nation, a lot has to be researched. I quote for example the following passage of the paper of commander K. N. Bahl in the already referred *Seminar in Indian Traditional Navigation*: "Indian archaeologists have unearthed the world's most ancient dockyard in Lothal, a port city in Gujarate. It was in use four thousand years ago. That evidence is sufficient to challenge the myth that sailing and navigation developed in the sheltered waters of the Mediterranean …".

I quote also, from a recent Lotika Varadarajan's work already referred[39]: "Despite literary references to navigators of the past and to recorded voyages (Varadarajan, 1980, 1983a, 1991), the image was that of caste bound Hindu society in which the elite was prohibited from sailing across the black waters. This was enunciated through the concept of Kalivarjya (Varadrajan, 1983b). This image is now being eroded. The first evidence came to light as a result of a lead provided by the late Dr. U. P. Shah, Gaekwad Oriental Institue, Baroda. This led to the location of a set of sailing manuals in the possession of Sri Dushyanta Pandaya at Jamnagar, Gujarat, in 1978.".[40]

I quote also the suggestion of the late Poruguese Admiral Teixeira da Mota in the already referred paper "Méthodes de Navigation et Cartographie dans l'Océan Indien avant le XVI siècle…" : "Nous estimons opportun de consigner ici un voeu pour qu'il soit procédé à la prochaine traduction, dans une langue européenne, des textes nautiques arabes connus, afin que les historiens de la science nautique, non arabisants, puissent facilement les utilizer; …".[41]

So, dear ladies and gentlemen and dear father Mathew. I agree with the idea that the discipline of Maritime History has to be individualized. So I would like to propose that a *Seminar of World Navigation History* should be held somewhere, because all of us contribute to that. And probably the best place will be your country, India. And why not the Kerala, to where all the navigators converged from all other parts of the world?

Here I leave this humble suggestion.

[39] *Indian Rutters-The Indigenous Tradition* (footnote 30).

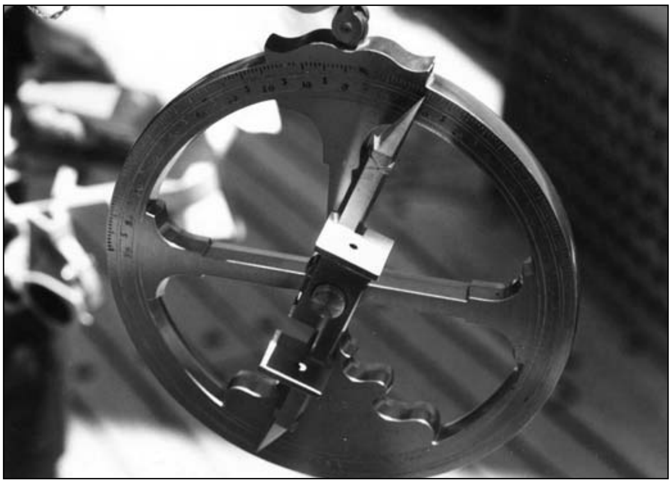
[40] I have already referred these documents, which are the *Kutchi Rehmanis*.

[41] *Op. cit*. p. 58.

ANEXO A1

Observations with astrolobe, aboard the Portuguese sail training ship *Sagres*.

The plane of the instrument should be in the vertical plane of the sun. Note in the first photograph that the shade of the instrument in the deck indicates that it is in the same vertical plane of the sun.



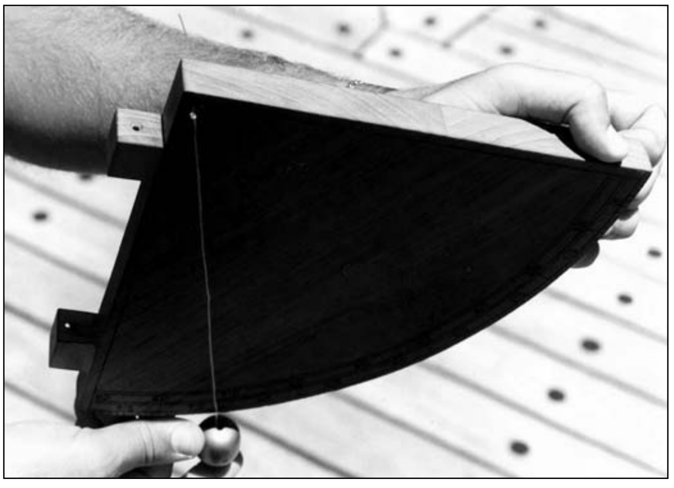
The projection of the sunbeam on the second pinule, after crossing the first one.

ANEXO A2

Observations with the quadrant and astrolabe aboard the Portuguese sail training ship *Sagres*.

Observing the sun with the quadrant.

Observing a star at night, with the astrolab.



As with the astrolob, the sunbeam crosses the first pinule of the quadrant, and hits the second one.

ANEXO B

**Fragment of the chart of Pedro Reinel, of 1504.
Note the latitude scale on the left.**