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THE SEA- OR MARINER'S ASTROLABE

BY

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The sea- or mariners's astrolabe

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«II apparaít avec évidence que c'est au Portugal qu'ont été pratiques, *pour la première jois,* en Occident, les procédés de direction du navire par l'observation des astres, sans lesquels il eut été impossible d'entreprendre des exipéditions aussi aventureuses.»

> Joaquim Bensaude, L'*astronomie nautique au Portugal à l'époque des grandes découvertes,* Berne, 1912, quoted by Professor Luciano Pereira da Silva in: «A Astronomia náutica das descobertas Portuguesas», *Revista da Universidade de Coimbra,* Vol. in (1914) and *Obras Completas* (1943), Vol. I, p. 16.1.

«O astrolábio era considerado o melhor dos instrumentos. A altura do sol toma-se «mejor eon estrolábio...» diz Mestre João, na carta escrita de Vera Cruz a D. Manuel, em 1 de Maio de 1500. O astrolábio é «O melhor instrumento de todos», diz D. João de Castro numa nota de Roteiro de Lisboa a Goa...» [of • 15.38].

L. Pereira da Silva, *Obras Completas* (1943), Vol. n, p. 263.

The choice of subject as a contribution to a work in honour of Professor Luciano Pereira da Silva has been made with ideliberation. Luciano Pereira da Silva was the first scholar to write scientifically about ithe sea — or mariner's astrolabe. Of the forty-five papers comprising his eollected works no less than ten deal directly with the mariner's astrolabe and its associated tables, its characteristics, and use at sea C[1]); a number of his other papers are concerne d with

(*) Pereira da Silva, L., *Obras Completas de Luciano Pereira da Silva,* 3 vols., Lisboa, '1943. *Volume I:* VI. A Astronomia náutica das descobertas portuguesas, pp. 159-186; VIII. A Astronomia dos

planispheric astrolabes, those instruments which the Portuguese modified into the sea-astrolabe for the use of their pilots that they might:

> «A maneira de nuvens se começam
> A descubrir os montes que enxergamos,
> As âncoras pesadas se adereçam
> As velas, ja chegados, amainamos:
> E pera que mais certas se conheçam
> As partes tão remotas onde estamos,
> Pelo novo instrumento do Astrolábio
> Invenção de sutil juízo e sábio,
>
> Desambarcamos logo na espaçosa
> Parte, por onde a gente se espalhou,
> De ver cousas estranhas desejosa

Lusíadas, pp. 199-2514, Esp. pp. 383401; *Volume II:* IX. As tábuas náuticas portuguesas e o «Almanach perpetuum» de Zacuto, pp. 3-20; X. A ciência náutica portuguesa apreciada em Espanha, pp. 31-33; XI. O astrolábio náutico dos Portugueses, pp. *49-62]* XII. Astrolábios existentes em Portugal, pp. 63-72; Esp. pp. 70-72; XXI. A arte de navegar dos portugueses desde o infante a D. João de Castro, 4—'O astrolábio náutico, pp. 223»432, Esp. pp. 257-265; *Volume III:* XXIX. O «Regimiento de Navegacion» de Pedro de Medina, pp. 91--108, Esp. pp. 99403; XXX. O «Roteiro da primeira viagem do Gama», pp. 109426; XXXIX. Um Astrolábio náutico do Século XVI, pp. 327--330. Other papers on instruments of nautical astronomy of the period were: XXVI. Kamal, tábuas da índia e tavoletas náuticas, Vol. III/744; XXXI. O «Roteiro» da primeira viagem do Gama e a suposta conjuração, Vol. IH/427460. *Figures: Vol. I,* p. 384, Astrolábio náutico — gravura inserta no *Compendio dei arte de navegar* de Rodrigo Çamorano, Sevilha, (1591; f. p. 386, Astrolábio náutico do Observatório Astronómico da Universidade de Coimbra. *Vol. II;* p. 52, Do; p. 71, Do; p. 361, Do; f. p. 54, Astrolábio náutico de madeira, construído no Instituto Superior Técnico; p. 258, Pesagem do Sol no astrolábio — gravura inserta no *Regimiento de navegacion,* de Pedro de Medina, Sevilha, 1552; p. 259, Astrolábio náutico — figura da *Carta Universal,* de Diogo Ribeiro, 1529; p. 260, Astrolábio náutico —' gravura inserta no *Compendio dei arte de navegar,* de Rodrigo Çamorano, Sevilha, 1591; p. 262, Astrolábio náutico suspenso de uma cábrea; e p. 309, Astrolábio náutico, guaduado de 0 a 180°. *Vol. III,* p. 100, «Pesagem» do sol com o astrolábio, figura reproduzida do *Regimiento de Navegacion* [Pedro de Medina, 1552]; p. 329 «Roda de um astrolábio náutico do Século XVI». [Dredged from Santa Cruz, 1903].

Da terra que outro povo não pisou:
Poreém eu cos pilotos na arenosa
Praia, por vermes em que parte estou
Me detenho, em tomar do sol a altura
E compass ar a universal pintura» ([2])

Ravenstein, in his great study of Martin Behaim and his globe of 1492, first proved decisively that the source of Portuguese nautical astronomy was Iberian, not German; Bensaúde in his magisterial studies of Portuguese nautical science in the age of the great discoveries showed conclusively that the almanacs, rules and tables used by the Portuguese pioneers of the late fifteenth and early sixteenth centuries were Portuguese products; Luciano Pereira da Silva demonstrated beyond reasonable doubt that the instruments were especially devised for their use by Portuguese scholars and that the sea-astrolabe was for long the best. There is an awareness today of the fundamental role played by nautical astronomy and its associated instruments in the development of civilisation over the last 500 years which certainly did not manifest itself when Luciano Pereira da Silva began his series of brilliant studies. Historians are indebted to him for helping to unravel the tangled skein of the early history of nautical astronomy and for knitting the strands into a coherent and intelligible pattern the validity of which subsequent research has but confirmed. «0 sr. Joaquim Bensaúde...», he wrote in 1914, «vem pondo em plena luz a importante cultura científica que em Portugal acompanhava os arrojados feitos dos descobrimentos. É digna dos maiores encómios esta obra patriótica...» ([3]).

This is, in truth, a fitting tribute to his own works. The field of research which Bensaude opened in 1912 with his *L'Astronomie Nautique au Portugal a Vl'époque des grandes découvertes,* Luciano Pereira da Silva shared brilliantly and harmoniously in cultivating until his tragic death in 1926. His writings illuminated much concerning the way of a ship through the trackless paths of the sea in the first days of oceanic navigation that had lain hidden for centuries in the

([2]) Camoes, *Os Lusíadas,* Canto v, 25 and 26.
([3]) L. Pereira da Silva, *Obras Completas,* (1943), vol. I, p. 166.

darkness of ignora nce or loomed niisileadingly in the twilight of ill-founded speculation.

The purpose of this paper is to honour the memory of Luciano Pereira da Silva by summarising whith outline drawings to a standard scale, the main features of ali known surviving sea-astroiabes (including one destroyed in 1940), in order to make their main features generally available for study. «O astrolábio era considerado», by the Portuguese pioneers, he wrote truly, «o melhor dos instrumentos». Its significance in history lies An the fact that for about one hundred and fifty years it was one of the principie «path-finders» of civilisation over the featureless wastes of the sea.

Earliest known use of an astrolabe by a mariner

Manuel Telles da Silva, Marques de Alegrete, states that Diogo d'Azambuja was the first mariner to use an astrolabe. This was during a voyage down the west coast of Africa in 1481 ([4]).

Use of astrolabe by other mariners in the 15th century

On his voyage of 1487-88 Bartholomew Diaz used astrolabes, as .did Vasco da Gama on his voyage of 1497, and Master John, pilot in Cabral's fleet on his voyage of 1500 ([5]).

On his first voyage of discovery Columbus attempted to use an astrolabe —< «no pudo tomar ;la altura con ©I astrolábio ni cuadrante» (3 Feb. 1493) ([6]). This was on the retum half of the voyage started in 1492. In that year Martin Behaim completed his globe on which is to be found

O Manuel Telles da Silva, Marquês de Alegrete (1689), *De rebus gestis Joanni II*, Lisboa, p. 152.

([5]) Ravenstein, E. G. (1908) *Martin Behaim*, London, p. 15 citing *Alguns Documentos*, p. 122.

([6]) Guillen, J. F., *El Primer Viaje de Cristobal Colon*, Madrid, 1943, p. 145.

La parla marinera en el Diário dei primer viaje de Cristobal Colon, Madrid, 1951, p. 30.

«those who navigate this sea must sail with the help of the astrolabe» ([7]).

Type of astrolabe used by mariners in the fifteenth century

One authority for Vasco da Gama's use of astrolabes is João de Barros (1496-1570) writing his *Da Asia* in 1539. According to his account, on reaching the Bay of St. Helena, da Gama went on shore to take the altitude of the sun with a large wooden astrolabe, «un astrolábio náutico de três palmos de diâmetro» (about 60 cms. or 24 ins. in diarneter), «el estrolábio era de palo». He did so because on board ship he had been unable to take a sight either with that astrolabe, or with -some of the smaller astrolabes of brass with which he had been supplied.

De Barros, having asserted that the Portuguese were the first mariners to use these altitudes for finding latitude, explainad how King John II of Portugal had assembled a *junta* which had determine d upon and made a practicable method for seamen to navigate south of the equator by observing the altitude of the sun. This *junta,* he explained, made tables of deolination, such as are now in use among navigators, and which are now more exact than in the beginning, when the large wooden astrolabes were in use ([8]).

We have an indication of the type of brass astrolabes supplied to da Gama. Gaspar Correa, in his *Lendas da índia* deseribed how Zacuto, the Jewish astronomer c-alled in to assist in the solution of Vasco da Gamas navigational problems, made a form (pasta) of copper of thickness of half a finger, «round, with a ring (argola) with which it was suspended. In the centre was mounted another plate (chapa), also of copper, (the alidade) which slid around the circumference, and on which were placed some holes bored opposite to one another, so that the sun entering through

([7]) Ravenstein, E. G., *op. cit.,* p. 14.

([8]) Ravenstein, E. G., *op. cit.* p. 12. It is of interest to note that when Hadley invente d the refíecting quadrant in 1731 it was a large wooden instrument and was developed in the course of the next fifty or so years into a similar but small metal instrument.

both at the moment of midday, the elevation of the sun could he measured «and he named it astrolabe...» ([9]). This description is epitomised by Camões» «Pelo novo .instrumento do Astrolábio invenção ide sutil juízo e sábio». At the time of Cabrals expedition astronomical observations were still rather the exception. In his letter of 1 May, 1500 to King Manuel he wrote from Brazil that who navigated best, the other pilots «with the ehart» or he «with the chart and astrolabe», would be determined when they reached the Cape of Good Hope. «It seems to me», he continued, that «at sea it is better to be guided by the height of the sun, than by the .stars and it is better to use the astrolabe than the quadrant, or any .other instruments» ([10]).

There is no good, practical reason to suppose that these early metal sea-astrolabes were not simple instruments. They were intended to be used by seamen, who are essentially and of necessity practical men, for one of two purposes: to observe the meridian altitude of the sun ^and to observe the altitude of Polaris or other suitable stars in order to find latitude. Simplified astronomers' tables were supplied for their use to show the sun's daily ideclination at noon north or south of the equator — not its position on the ecliptic. The sailor nceded only one scale—**an** altitude scale — and we can be sure that that was all he got for there were good grounds for avoiding confusing him with the complexities of the planispheric astrolabe and souod economic reasons for avoiding its cost when something cheaper would serve his purpose.

One reason why altitude was measured for finding latitude by observation of the sun, as well as for finding it by observation of the Pole Star, when it would have been simpler mathematically for the sun's zenith .distance to have been measured, can be found in the first use of astronomical

([9]) Gaspar Correa (1869), *The Three Voyages of Vasco da Gama,* Hakluyt Society. First series, vol. 42. A translation from the *Lendas da índia* of Gaspar Correa, pp. 21-25, which I have adapted to make clearer.

([10]) Prestage, E. (11933) *The Portuguese Pioneers,* London, whose translation I prefer.

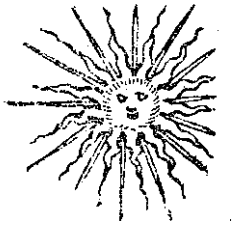
instruments by mariners. At first they were usedtomeasure indirectly linear distance from a datum port, not angular distance from the equator. The mariners were taught to observe the altitude of the Pole Star with its Guards *(Kochab)* in a given position, or the altitude of the sun at noon and, to compare the result with the already tabulated altitude of the star when the guards were in the same relative position, or of then sun at noon at a pre-selected datum port, and to convert the angular difference into leagues north or south of the datum port (") . This was the method used by Diogo Gomes, of Sintra, when on a voyage to Guinea he made the first recorded astronomical observation by a seaman, in 1461 (or 1462): « Y o tenia un cuadrante cuando fui a esos países...», he recounted.

A further reason for observing altitude was that stellar observations preceded solar ones. The altitude of the Pole is equal to the latitude of the place of observíation. The simplest nautical observation was, therefore, one which measured the altitude of the Pole Star und was corrected by adding or subtracting its angular 'distance below or above the pole. When solar observations were begun the altitude scale was thus already in use and the same instrument was used for solar and stellar observations. When the sea-astrolabe was introduced the easiest thing was to make no change to the scale. Again, the 'shadow' irules orRegimentof the Sun were derived from rules already codified in the thirteenth century and based on observations of the sun's altitude. When, as a result of Vasco da Gamas and Cabrals experience, the use of the astrolabe for stellar sights was dropped by the Portuguese navigators and the use of the astrolabe was confined to solar observations the logical mathematical change was soon made—Portuguese astrolabes were engraved for zenith distance — thereby simplifying the calculation (the bugbear of seamen) to find latitude from a solar observation. The quadrant was retained for stellar observations because *it* was much more suitable for taking them.

Stellar Observations. These were taken by holding the

(") *Manual de Munich,* c. 1509.

quadrant up to the eye and sighting the star through the pinnules. It can ben imagine d how difficult this is to do with an astrolabe, and relatively easy with a quadrant with which instrument the altitude is indicated by a plumb tine.



O R I Z O N T E

Fig. 1 — The earliest iliustration of a man using a sea-astrolabe, 11552. This identical iliustration is from second edition of Pedro de Medina's *Regimiento de Navegacion,* Sevilha, 1363 (By courtesy of the Trusfcees of the National Maritime Museum).

Solar Observations. These were made by hanging the astrolabe in one hand at waist or lower levei and moving the alidade with the other until the sunligth, passed through lower vane at the moment of the sun's greatest altitude: the astrolabe was *not* held up to the eye while the observer blinded himself by sighting the sun through the pinnules. Pedro ide Medina gives a very clear iliustration of the correct

mariner in his *Regimiento de Navegacion* (1552 and 1563), which 'Luciano Pereira da Silva reproduced in his «O Regimiento de Navegacion» de Pedro de Medina» in 1922 ([12]). Nevertheless the correct method is still not gcnerally known.

The Cross-staff. Until the sixteenth century western seamen used only quadrants or sea-astrolabes. Vasco, ida Gama brought back a *Kamal* from the Indian Ocean. The first references to a balestilha or cross-staff, an instrument most probably inspired by the *Kamal* and possibly by Regiomontanus's Jacob's staff, can be attributed to João ide Lisboa and André Pires. Both wrote their manuscripts before 1520, João de Lisboa probably about 1514. Duarte Pacheco Pereira does not mention the balhestilha in his *Esmeraldo de Situ Orbis* of 1505-08 but states «the laltitude of the sun should be taken exactily, at noon with the astrolabe or quadrant». The *Livro de Marinharia* of João de Lisboa contains a «Regimento para tomar o sol pela balestilha» whereas the earliest regiments printed, clearly from earlier manuscript sources of the fifteenth century, are for use with astrolabes or quadrants: the oldest, the Manual of Munich (c. 1509, lst ed. 1495?) states especially that it is the «Regimiento *do estrolabio* & do quadrante pera saber ha declinacam & ho lugar do soll em cada huúm dia & asy pera saber ha estrella do norte».

Earliest Iliustration of a mariner s astrolabe

The earliest known iliustration of a mariners astrolabe is in an anonymous world chart of 1525, drawn, in fact, by the Portuguese cartographer Diogo Ribeiro. This is similar (except for the date and text) to drawings on the kindred planispheres of 1527, and of 1529 (of which there are two). The reproduction in *Imago Mundi,* in 1954, by Professor A. Cortesão, of the seanastrolabe of 1525 was thus particularly important and valuable as it put the earliest date of an iliustration of a sea-astrolabe back four years ([13]). Formerly the

([12]) *Obras Completas,* (1946), p. 100.

([13]) Cortesão, A., (19.54), 'Note on the Castiglioni Planisphere', *Imago Mundi,* vol. 11, (1954) pp. 53-55. The date «15,25» is on the sea-astrolabe not sea quadrant.

planispheres of 1529 only were generally known. It is pertinent to observe that the royal *cédula* appointing Diego

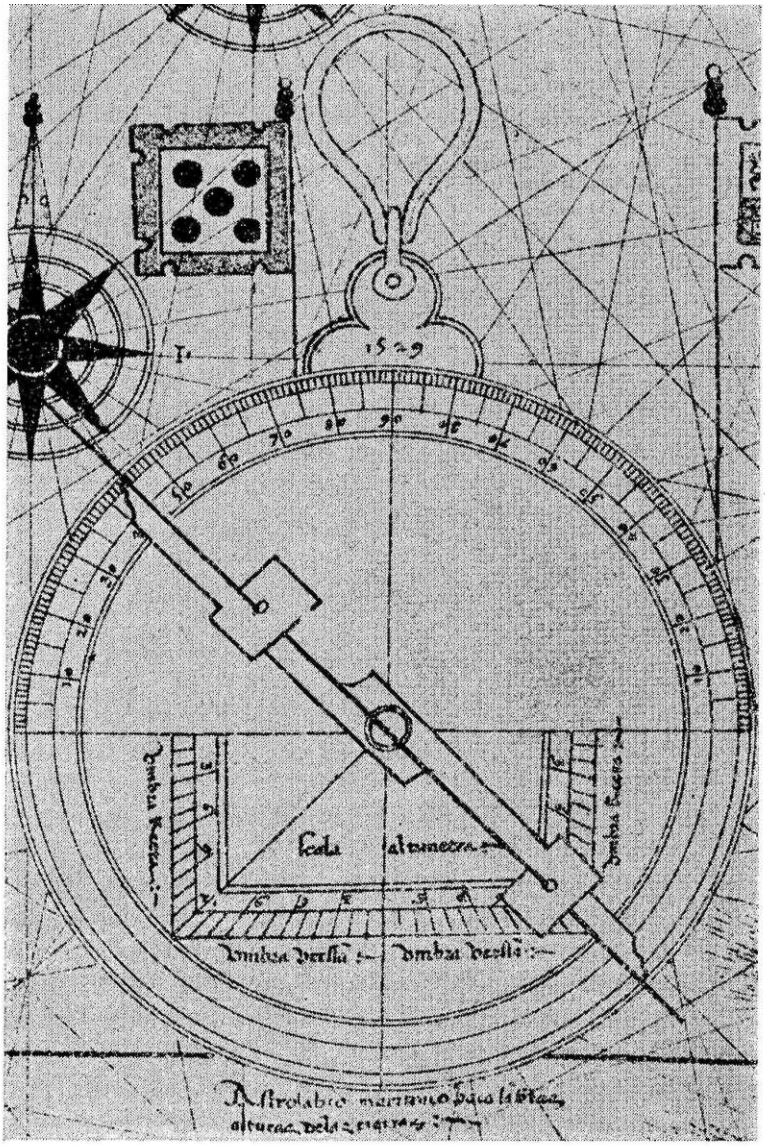


Fig. 2 — «Astrolábio marítimo» by Diego Ribeiro, 1529. The earliest drawing is dated «1525», and is on the Castiglioni Planisphere, *Archivo Marchesi Castiglioni*, Mantua.

Ribeiro the first cosmographcr of the Casa de Contratación, dated Valladolid, 10, July 1523, eommanded that he should be «nuestro cosmógrafo y maestro de hazer *cartas y astrolábios* & otros yngenios», (the planisphere alsodepicts a quadrant) ([14]). The point is made because this would account for the inclusion of the drawing of the astrolabe, which is specially described in the 1529 (Rome) chart as «Astrolábio marítimo para saber las alturas delas tierras» ([15]). Of course it does not follow that this was the only type of sea-astrolabe made at this time but it does suggest that it was the type made by Ribeiro. A point of particular interest is that the pinnules on the alidade are set close together — unlike those of planispheric astrolabes but like those of later types of sea^astroilabe.

The instrument is graduated to read altitudes, is clearly of sheet metal having on the lower half of the face the scale of cotangents *(umbra recta, umbra versa)* generally found in the lower half of the back of western planispheric astrolabes. The prototypc of this instrument was evidently a planispheric astrolabe. In effect, the front of one of these instruments, which typically contained the *tablets* and *rete,* has been reversed so that the back has becomie the front of the sea-jastrolabe. The back of the planispheric astrolabe custoimarily contained the scale of altitudes on the limb, the alidade for measuring altitudes, hour-lines in the upper half, and as already observed, the *umbra recta* and *umbra versa* scales in the lower half. The hour-lines have been omitted by Ribeiro as unnecessary but the cotangent scale has been retained. The planispheric astrolabe was customarily used for observing altitudes of terrestrial as well as celestial objects in connection with survey work so its retention is logical, but the pinnules, as already remarked, have been modified by being placed close together —< a small but important change because it facilitated taking observations from an unsteady platform.

([14]) *ibid.* p. 54, n. |1.

([15]) Cortesão, A. (1935), *Cartografia e Cartógrafos Portugueses dos Séculos XV e XVI,* Lisboa, vol. II, p. 146.

The First Printed Description of a Sea-Astrolabe

Writing in 1545 Martin Cortes gave a very clear account of the manufacture of a mariner's astrolabe of this disc pattern including an iliustration which were published in Sevilla in 1551 in his *Breve Compendio de la Sphera y Arte de Navegar.* One upper quadrant was graduated to measure altitude, the *Umbra Recta* and *Umbra Versa* scales were not included. The same type of astrolabe is shown in the hand of the navigator taking a sun sight in the woodcut already referred to in Pedro de Medinas *Regimiento de Navegacion,* of 1552. Although Medina did not expiam the construction of the astrolabe he described it as «a round instrument no greater than the palm of a man's hand». Cortess iliustration shows a small and a large pin-hole in each pinnule on the alidade and explains that the large pair are for observations of the Pole star. Ribeiros would appear to be the first and only Portuguese iliustration of a sea-astrolabe of the sixteenth century, Cortes's and Medinas the first Spanish ones. It is not until 1581 that a fresh Spanish idescription appears, in Çamoranos *Arte de Navegar;* this includes an iliustration of a new type of seanastrolabe —> the cast wheel type; in 1587 this type, but more decorative in outline, is iliustrated in perspective in Diego Garcia de Palacios *Instructión Náutica* (México, 1587).

The Sea-Astrolabe s Alidade

In planispheric astrolabes the pinnules, with the rarest exception, are widely spaced, being fixed or hinged to the outer ends of the alidade, close to the index pointers ([16]). In Ribeiro's, Cortess and Medina's illustrations the pinnules are shown closer together. It is well known that the earliest users of sea-astrolabes had great diffieulty in using them at sea but that after Vasco da Gamas and Cabral's voyages

([M]) An Islamic Toledian planispheric astrolabe of 1067 survives, the pinnules of which are set close together.

complaints on this score ceased and the regular use of the sea-astrolabe at sea was laid down :and praetised. «The altitude of the sun should be taken exactly at noon with the astrolabe or quadrant», wrote Duarte Pacheco Pereira, between 1505 and 1508. In 1508 Amerigo Vespucci was

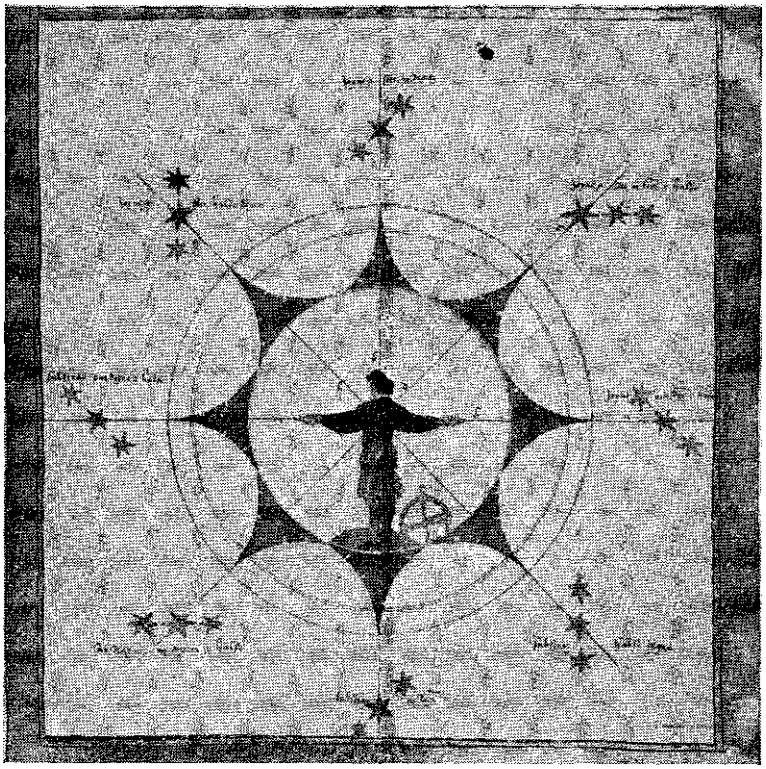


Fig. 3 — The earliest extant iliustration of a cast wheel-type sea astrolabe, in Jean Rotz's *Booke of Idrography,* dated 1542. *British Museum* Royai 20. E. IX.

appointed, by Royai cédula of 6 August, 1508, at Valladolid, «Piloto Mayor» especially to ensure that «los pilotos... sean instruídos y sepanlo que es necesario ide saber ¸n el cuadrante e estrolabio»; João de Lisboa, writing about 1514 explained that, «To navigate by shadows... you must first take the sun's altitude with an astrolabe or quadrant punctually at noon»; Magellans fleet was equipped in 1519 for

the circumnavigation of the globe, with, amongst other navigational equipment, «1 wooden astrolabe» and «6 wooden quadrants» made by Ruy Faleiro, and «six metal astrolabes with rulers». Numerous meridian altitude observations

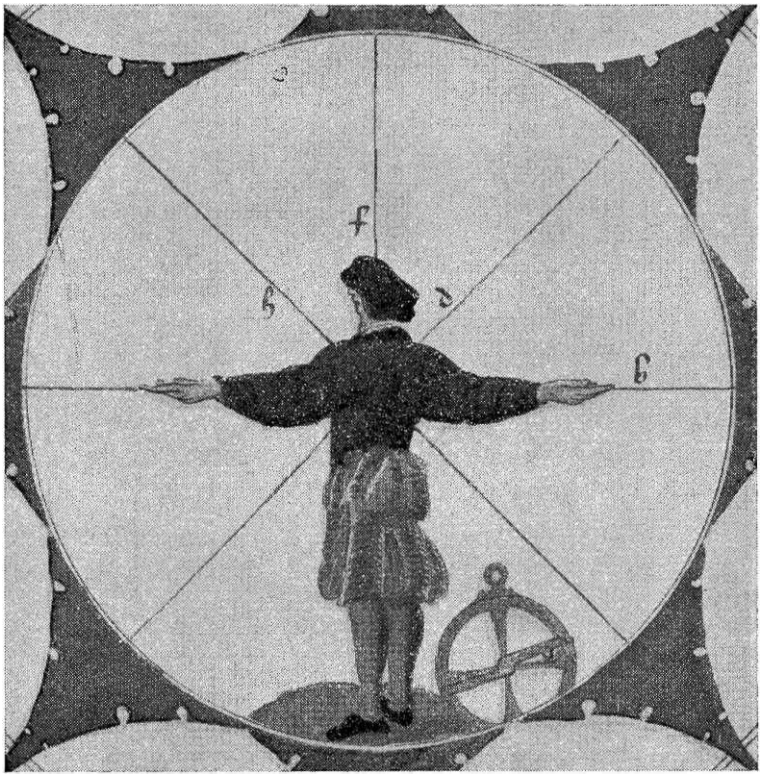


Fig. 4—The earliest extant iliustration of a cast wheel-type sea--astrolabe, 1542. Detail (Figs. 3 and 4 by courtesy of the Trustees of the British Museum).

were made in Magellan's fleet — daily when practicable — with astrolabe and quadrant. In 1523, so necessary had the art of navigation by celestial observation become to Spanish seamen that the Portuguese cosmographer and caritographer Diogo Ribeiro, was lappointed, as already mentioned in a different context, «nuestro cosmógrafo y maestro de hazer cartas y astrolábios y otros yngenios».

In 1527 Sebastian Cabot, by Royai *cédula* dated Valladolid, 2 August, 1527, was espeeially instructed on the examination of pilots. His tasks included ensuring their proficiency with the «astrolábio para el sol y quadrante para el norte». He was then, and had been since 1518, Piloto-mayor de la Casa de Contratación at Seville.

What had happened to bring the sea-astrolabe into favour as *the* instrument for solar observations? A possible explanation is that the wide spaced pinnules characteristic of the planispheric astrolabes had been replaced by close spaced pinnules. As a result of the modification, which certainly had been made by 1525, it was easier to adjust the alidade for taking meridian altitudes of the sun sufficiently accurate for navigational purposes. This modification made it possible to avoid «missed» observations — the result of moving an alidade the adjustment of which, owing to the wide spacing of the pinnules, was too fine for practical ship-board use.

The Earliest Illustrations of a cast wheel-type mariners astrolabe

However, this may not have been the only modification made at this time to the design of the sea-astrolabe. By 1542 a tremendous advance had occurred, the sea-astrolabe was being made in the form of a heavy cast brass wheel. Fifteen forty^two is the date of the earliest iliustration of this type of sea-astrolabe, and it was drawn and coloured by a Freneh pilot in the service of King Henry VIII of England, Jean Rotz ([17]). So far as I am aware this iliustration has never previously been reproduced. Such an instrument had the advantage of stability, low wind resistance, and close-set pinnules. It would appear that the artist has exaggerated the size of the instrument as sixteenth century descriptions and illustrations are of much smaller instruments and surviving instruments of the period are much smaller. In the seven-

([17]) Rotz, Jean (1542) Ms. *Booke of Idrography,* (British Museum Royai 20.E.IX).

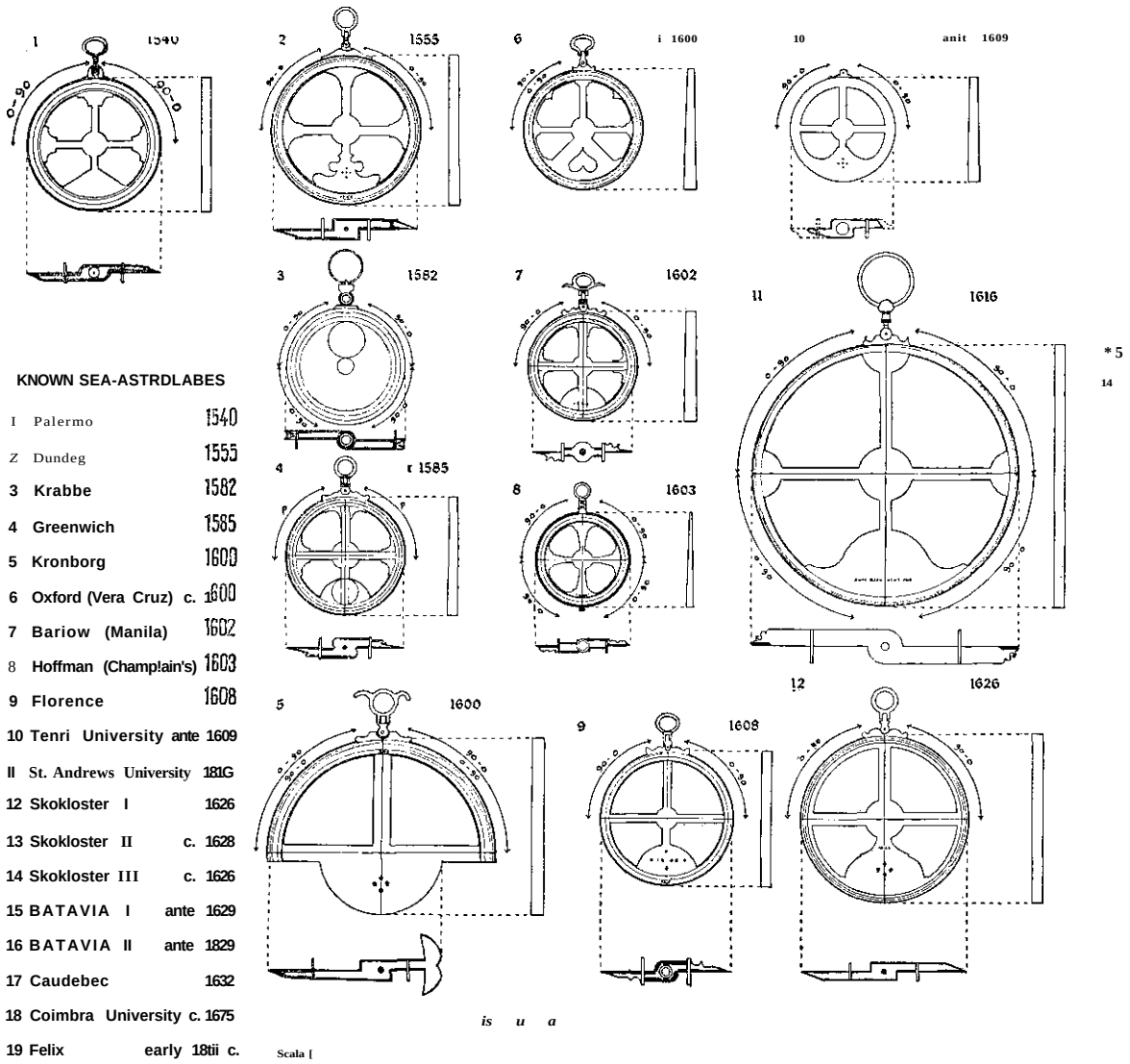
teenth century, however, the St. Andrews sea-astrolabe of 1616 and the Coimbra sea-astrolabe of c. 1675 are as massive as that drawn by Jean Rotz appears to have been; they are respectively 396 mm. (15 5/8 ins.) and 508 mm. (20 ins.) in diameter. The next earliest iliustration of this wheel-type sea-astrolabe appears to be in William Bourne's *An Almanacke and Prognostication for three years... nowe newlye added into my late Rulles of Navigation,* London, [1571], though this was first published in 1567 but no copy survives (18). The woodcut shows an instrument entitled *A sea Astrolabe* graduated in one upper quadrant but with the pinnules set out towards the ends of the alidade close to the inner edge of the limb. The lowest spoke fiares out to provide bottom ballast (19). When, in 1574, William Bourne, published his *Regiment for the Sea,* a somewhat similar instrument was depicted on the title^page but now it was entitled «A Sea astrolob or ring», both upper quadrants were graduated, the two pinnules were much oloser together, and had, like Cortes's, large and -small pin-holes; (20). Seven years later Çamoranos *Compendio de la arte de navegar* (Sevilla, 1581) illustrated the parts, except the suspension ring and sbackle, of a wheel-type sea-astrolabe but his description refers to making it in wood or brass (21). By 1583 the Dutchman, Lucas Janszoon Wagenaer, had illustrated the wheel-type sea-astrolabe on the title page of his *Spieghel*

(18) Waters, D, W., (1958) *The Art of Navigation in England in Elizabethan and early Stuart Times,* London and Hartford, Conn., 1958, p. 127.

(19) Taylor, E. G. R. (ed.), (1963), *A Regiment for the Sea and other writings on navigation by William Bourne,* Cambridge, for the Hakluyt Society, 1963, p. '85. The first English printed iliustration of a sea-astrolabe was in Richard Eden's translation of Martin Cortes's work, *The Arte of Navigation,* London, '1561, when the figure was similar to that of 1551.

(20) Waters, D. W., *op. cit.* PI. XXXIII (a), and Taylor, E. G. R., *op, cit.,* fig. 1.

(21) Pereira da Silva, L, (1943) *Obras Completas,* vol. 1, fig. 28 and pp. 383-386, but this is based on the edition of 159(1. Çamorano was then Piloto-mayor, previously he had been Cosmógrafo de Hacer Cartas y Fabricar Instrumentos para la Navegacion de la Casa de Contratacion de Sevilla.



KNOWN SEA-ASTRDLABES

I	Palermo	1540
Z	Dundeg	1555
3	Krabbe	1582
4	Greenwich	1585
5	Kronborg	1600
6	Oxford (Vera Cruz)	c. 1600
7	Bariow (Manila)	1602
8	Hoffman (Champlain's)	1603
9	Florence	1608
10	Tenri University	ante 1609
Il	St. Andrews University	181G
12	Skokloster I	1626
13	Skokloster II	c. 1628
14	Skokloster III	c. 1626
15	BATAVIA I	ante 1629
16	BATAVIA Il	ante 1829
17	Caudebec	1632
18	Coimbra University	c. 1675
19	Felix	early 18tii c.

Fig. 6 — The surviving sea- or mariner's astrolabes known, 1695. (No 1

der Zeevaerdt, (Leiden, 1583), giving **as** his model one very similar to Çamoranos ([22]). Thenceforward illustrations of wheel-type sea-astrolabes are found in most Dutch and English navigation manuais and «waggoners» published dowii to the late seventeenth century.

Disuse of the Sea-astrolabe

By about 1650 the sea-astrolabe was ceasing to be used and the crosstaff and Davis quadrant or back-staff (invented about 1590 by Captain John Davis the English Arctic explorer and navigator) were the favourite instruments. The latest iliustration in England of a sea-astrolabe with strictly nautical associatioms would appear to be the realistically carved one in the mantlepiece in the then new Admiralty Board Room in Whitehall. This is 1695. In Scotland a wall painting in Burntisland Church, Fife, of a sea-captain in the sea-rig of 1690 shows him holding a wheel-type sea--astrolabe in his right hand (and a cross-staff in his left hand), another painting shows him using his back-staff ([23]).

Spanish, English and Portuguese sea-astrolabes

In his *Exercises* of 1594 Thomas Blundeville wrote at length on the art of navigation and on sea-astrolabes and explained that «broade Astrolabes, though they bee thereby the truer, yet for that they **are** subject to the force of the wind, and thereby ever mooving and unstable, are nothing meete to take the Altitude of anything, and especially upon the sea; which this to avoid the Spaniards doe commonly make their Astrolabes or Rings narrow and weightie, which for the most part are not much above 5 inches broad, and yet doe weigh at least four pound, and to that end the lower part is made a great deale thicker than the upper part

([22]) Waters, D. W., *op. cit.,* PI. in.

([23]) Gunther, R. T. ('1932), *Astrolabes of the World,* 1932, vol. 2, pl. **CXLIII**. «Navigators with cross-staff, Back-staff, and Astrolabe». Paintings in Barntisland Ghurch, Fife. Tbese can be dated c. 1690 on the evidence of the sea-captain's dress and in particular of his hat.

towards the Ring or handle. Notwithstanding most of our Englich Pilots that be skilfal, .doe make their Sea Astrolables or Rings sixe or seven inches broad, and therewith very massive and heavie, not easie to be moved with everie wind».

Çamorano, after his chapter on «The making of the Astrolabe» (I quote from the translation includedby Edward Wright in his second, 1610 — and third, 1657 — edition of his *Certain Errors in Navigation)* included «Another manner of aceounting by the Sun, as they use in Portugall». He wrote, «Some Astrolabes there bee, whoseaccountbeginneth not from the Horizon, but from the Zenith, and endeth with 90 degr. in the Horizon; and the height taken by them is nothing else but the distance of the Sun from our Zenith...» Çamorano was then «Cosmógrafo di Hacer Cartas y Fabricar Instrumentos para la Navegacion de la ContrataçiÕn de Sevilla», and also «Catedrático de arte de la Navegacion y Cosmografia de la Casa de la Contratación de Sevilla». He was therefore particularly well qualified to write about astrolabes and what he wrote seems clear, the Spaniards used astrolabes graduated for altitude, the Portuguese astrolabes graduated for zenith distance (and he gave their Regiment of the Sun for zenith altitude observations). In fact João de Lisboa writing about 1514 had, as previously observed, given a «Regimento da distancia zenital» so the practice was long established in Portugal ([24]).

Manufacture of Mariners Astrolabes

So far as the manufacture of Spanish astrolabes is concerne d the documentary evidence is conclusive that mariners astrolabes, far from being the product of shipyard craf tsmen and brass-founders were the handiwork of especialised navigational instrument makers, whose instruments had to be approved and stamped as satisfactory (or rejected and broken up) before being used at sea. A possible explana-

([24]) Fontoura da Costa, A. (1939), *A Marinharia dos Descobrimentos,* Lisboa, 1939, pp. 71-73.

tion of the «trade marks» found in some surviving examples is that they are the stamp of inspecting officials.

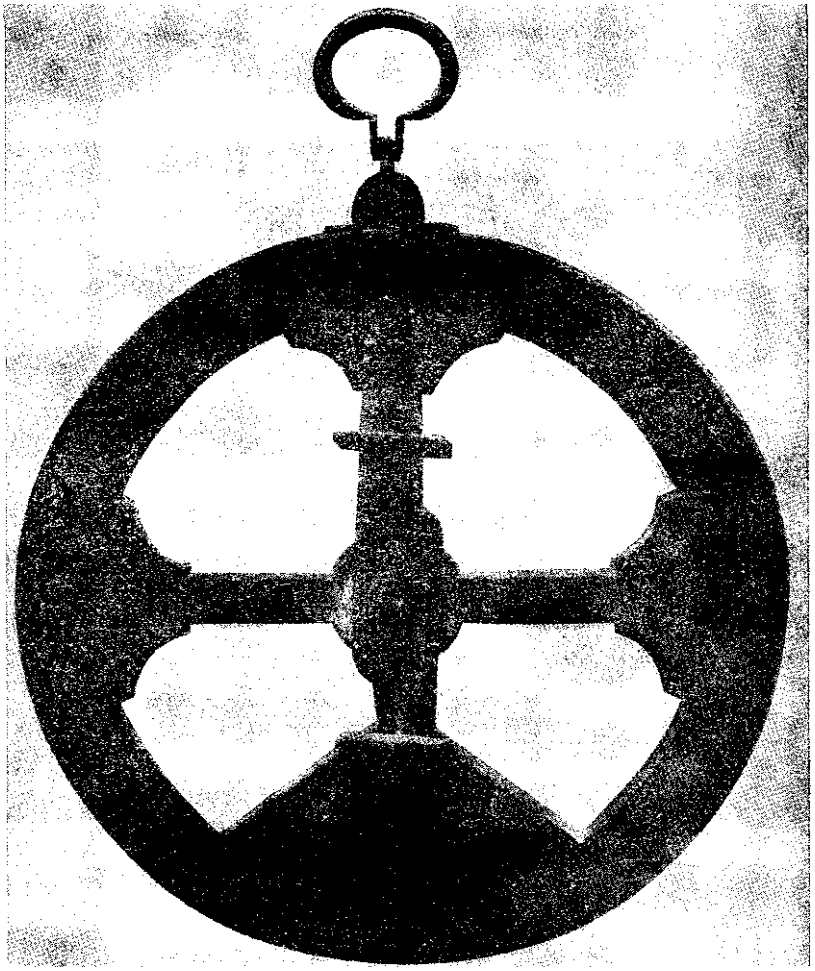


Fig. 5 — The oldest known dated sea-astrolabe, 1540. Most probably spanish (Formely in the Museo Nazionale di Palermo).

In 1674 Miguel Suero was appointed «Cosmografo de Hacer Cartas y Fabricar Instrumentos para la Navegacion de la Casa de la Contrataçión de Sevilla» as a result of a competitive examination on — amongst other things — his

skill in manufacturing instruments of navigation. The report on him ran: «I have examined a brass astrolabe for taking the height of the sun and I find the metal woll idistributed, the lines very well drawn and the graduation on the circumference of one quadrant weil done, the alidade with its pinnules to have ali the qualities necesssary to make correct observations as I have proved by experiment, which I have compared with another Astrolabe tested by observation, and on comparision to give the same height as the old one ([25]).

The Oldest Dated Surviving Sea Astrolabe

In 1935 Lozenzo Caldo wrote an account of some astrolabes: «Astrolabi dei Museo Nazionale di Palermo», *Publicazioni delVOsservatorio Astronómico di Palermo, Memorie, N. 65,* Palermo, 1936, which was reprinted from *Atti delia R. Accademia di Scienze, Lettere e Belle Arti di Palermo,* Vol. xix, fase. in. This included a description of, and a photograph of the face of, a sea astrolabe of the cast wheel type, dated on one of the radii «1540». It has not been seen since the end of the Second World War. It is strikingly like the sea astrolabe illustrated *(see* Fig. 8 p. 25) in Diego Garcia de Palacio's *Instruction Nauthica,* México, 1587. With the Sicilian location of the instrument

([28]) Rubio, J. P. (1950) *El Piloto Mayor de la Casa de la Contratación de Sevilla,* Sevilla, 1950. pp. 343-344.

June, 1674, «el oficio de Cosmógrafo y fabricador de Instrumentos». «En la ziudad de sevilla y casa dela contratación de las índias en dos dias del mes de Marzo de mill y seiscientos y setenta y quatro anos... Un Astrolábio de Bronce para tomar Altura dei sol lo han reconocido y le hallaron con buena distribucion de Metal, mui Bien tirados los arametros y bien hecha la graduacion desa circunferência en una quarta parte delia la Allidada con sus Pinolas oveletas con todas las calidades necesarias para hacer ciertas las observationes como se vio por la expercencia, que es cotejandolo con otro Astrolabio aprouado en observacion se bailo combenir y dar la misma Altura q el Antiguo...».

this suggests, with its «cales for measuring altitudes that, it was of Spanish origin. It was the oldest dated one known.

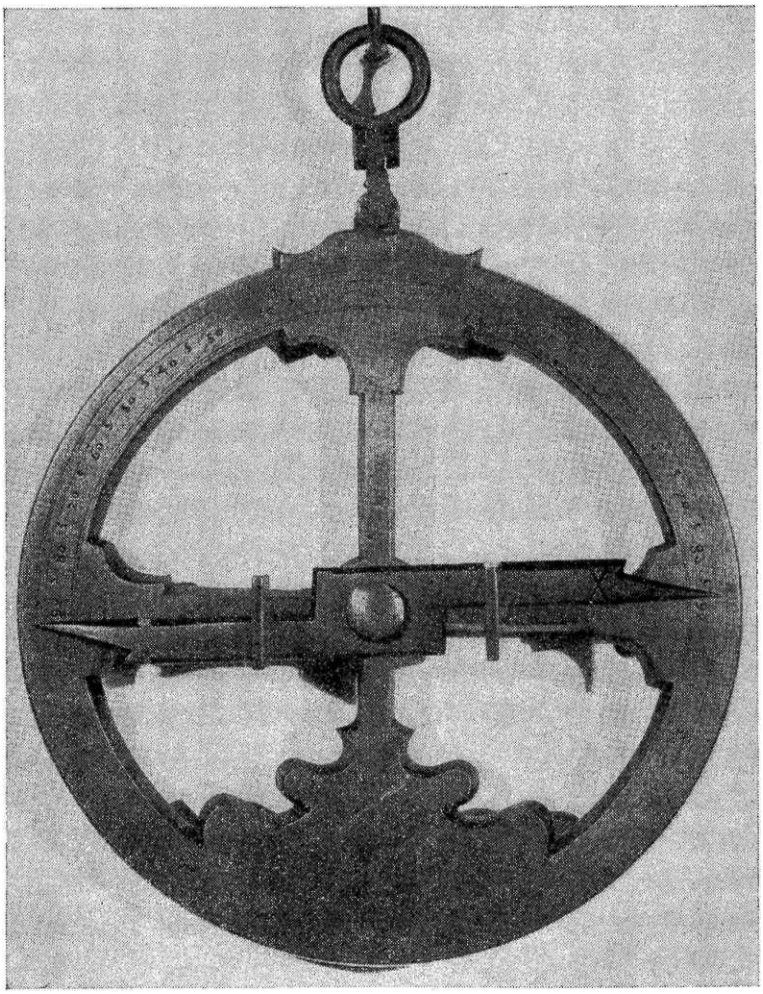


Fig. 7—The second oldest known dated sea-astrolabe, 1555. Most probably of Portuguese manufacture (By courtesy of the Director, *The Dundee Museum and Art Gallery).*

The Second Oldest Dated Surviving Sea Astrolabe

Some years ago a cast brass wheel-type sea-astrolabe dated 1555 was discovered in Dundee, Scotland. Its provenance is unknown, it is perfectly preserved and there is no

reason to suspect the date stamped on the instrument. Its large size, 222 mm. diameter, 16 mm. thickness, and the fact that it is graduated to read zenith distances only, strongly suggest that it is of Portuguese manufacture. It is virtually certain that no English sea-astrolabes had been manufactured at this early date. The various descriptions which have come down to us of Spanish sea-astrolabes ali describe them as being small instruments. It is virtually certain that no Dutch sea-astrolabes had yet been manufactured. On the evidence of Jean Rotz's iliustration of a sea-astrolabe of 1542 it is possible that the French were making sea-astrolabes. I incline to the view that the Dundee sea-astrolabe is of Portuguese manufacture. It is the second oldest dated sea--astrolabe known today.

Surviving Sea Astrolabes

Types

The main facts about the known surviving sea astrolabes are summarised in the acoompanying table and diagram containing their outlines drawn to a standard scale. These astrolabes would seem to fall into four main tyipes with sub-divisioins, as f ollows :

Type I (a) Wheel type with base ballast.
Type I (b) Wheel type with crown ballast.
Type II (a) Semi-sphere with base ballast.
Type II (b) Semi-sphere with crown ballast.
Type III Wheel type without ballast.
Type IV Planispheric for marine use.

Examples of Type I (a) are: Nos. *1, 2, 4,* 6, 7, 8, 9, 10, 11, 12 and 17
Type I (b) Nos. 13, 14 and 15.
Type II (a) No. 5.
Type II (b) No. 16.
Type III Nos. 18 and 19.
Type IV Nos. 3, 20 and 21.

It will be seen from the diagram that of Types I (a) Nos. 6, 7 and 10 obtain additional ballast by being wedge-shaped in their vertical crossection, whereas No. 8 obtains its bottom ballast simply through its pronounced wedge orossection. In fact No. 4 is very slightly wider at the bottom than at the top but not obviously so. A further point of interest is that in Types I (a) and I (b) the pinnules on the alidade are ali relatively close together, though in the case of No. 15 this merely a logical assumption based on its similitude to Nos. 13 and 14.

In Type II (a). In the only surviving example, No 4, the pinnules are unequally spaced in relation to the axis pin. In Type II (b) of which No. 15 is the sole example known the alidade does not survive.

Type III, Nos. 17 and 19. No. 19 has many features which are not characteristic of the wheel type sea-astrolabe. It appears to be made out of brass plate and while this is suggested in the descriptions cited for the making of astrolabes, those which survive ali appear to have been manufactured out of brass castings. The pinnules are rather widely spaced and the method of attachment of the alidade to the body of the astrolabe is unique. Similarly the thumb-ring hinge and crown-piece differ from ali other astrolabes, the crown being attached by screws. It seems remarkable that an astrolabe should have been made in the 18th century for practical use, yet this instrument appears to be a product of the early 18th rather than the late 17th century.

Type IV. Nos. 3 and 21. No. 3, a planispheric astrolabe by Krabbe dated 1582 was specifically described by Krabbe as being designed for use by navigators besides other practical men. It therefore is included in surviving sea astrolabes and while it handles very well and is heavy but beautifully balanced, it can certainly not be classed amongst the type of sea-astrolabe commonly in use iamongst seamen.

The two other planispheric astrolabes (Nos 20 and 21) were designed by Robert Dudley and were undoubtedly intended to be used by seamen though their practical value must be doubted because of their very great size and conse-

quential large wind area which would make them, despite their weight, unsteady in a breeze.

Axis pins

The method of attaching the axis-pin is of interest in the surviving sea-astrolabes. A wedge or horse and slot is used in Type I (a) No. 2, No. 4 and No. 10. Of No. 6 the pin and alidade are missing (modern replacements have been fitted) but a groove in the back of the instrument suggested a wedge was used; and of No. 17 no details are recorded and this instrument having been destroyed by bombing none is now obtainable. In No. 8 a roundheaded nut is serewed on to the threaded end for the exis-pin. In No. 11 the axis-pin serews into the body of the astrolabe. In Nos. 9, 12, 13, 14, 15 and 18, a butterfly nut is serewed on to the threaded end of the axisnpin. It would appear, therefore, that in about 1600 the practice was introduced of substituting a nut and thread on the end of the axis-pin in place of the wedge and slot hitherto used which was the traditional method of securing the axis-pin in planispheric astrolabes from the earliest times (but No. 3 is secured by a 4 sided nut).

Portuguese sea-astrolabes

It will be noticed that Nos. 10 and 18 are formly established as Portuguese. I consider No. 2 to be also. No. 7 migth well be as, although is was recovered from Manila Bay, there were complaints in the latter half of the 16th century that Spanish pilots were obtaining instruments from the Portuguese and this is an instrument graduated for zenith distance only, which is typically Portuguese.

Further Notes on Individual Instruments:

No. 2) *Dundee Astrolabe dated 1555*

The relatively large slze of this instrument and its graduation exclusively for zenith distance suggests that it is of

Portuguese manufacture. It is certainly the second oldest dated surviving sea-astrolabe. On the back has been stamped the name and date of a former owner, Andrew Smyton, and below it the date 1688 ([26]). It was discovered a few years ago in an overcrowded case of miscellaneous material in the

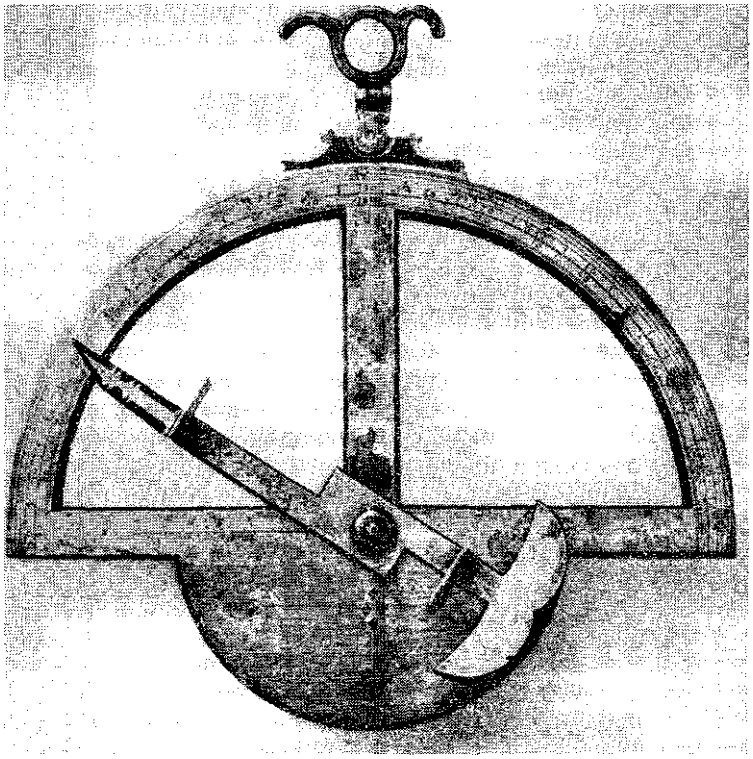


Fig. 8 — The oldest known dated semi-sphere, 1600. (By courtesy of the Director, the *Sofartsmuseet,* Kronborg, Denmark).

([26]) Price, D. J. (1956), «Two Mariner's Astrolabes», *Journal of the Institute of Navigation,* vol. 9, No. 3, July, 1956, pp. 341 and fig. 2 p. 340. Price gives check list munbers to the Dundee, 639; Kronborg, 543; Skokloster I, 577, but these astrolabes and numbers do not appear in his (1955) check list.

now defunct Dudhope Museum, Dundee. Nothing otherwise is known of its provenance.

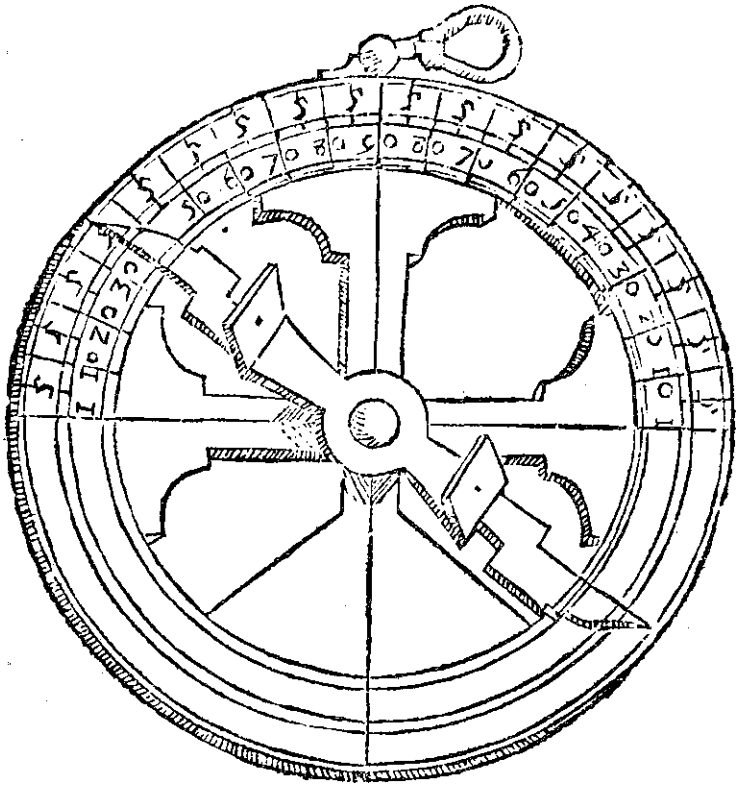


Fig. 9 — Sea-astrolabe in Diego Garcia de Palacio's *Instrucion nauthica para navegar*, Mexico, '1587, very similar to the 'sea-astrolabe dated 1540 formerly at Palermo, Sicily.

No. 3) *Krabbe Astrolabe, 1582*

Signed on the back *Faciebat Johannes Krabbe, 1582;* it has six plates engraved on both sides, with projections for each degree from 44° to 54°. The axis-pin is secured by a nut; the pinnules fold flat. In his *Newes Astrolabium,* Wolfenbuttel, 1608, Rrabbe deseribes this as particularly suited to the needs of seamen.

No. 4) *Greenwich Astrolabe, undated*

It was found under a rock in the Island of Valencia, Ireland, 1845, within view of the place where three vessels of the Spanish Armada were wrecked. It has been supposed to have belonged to one of them. The instrument has not been finished for no numerais are stamped upon it and the circies incised upon the base ballast would appear to have been the outline of a eavity to be made to contam a small compass. It is of interest that the pinnules and alidade are worked out of a single block of brass. Whether this instrument carne from a ship of the Spanish Armada, 1588, or not, its general features suggest a date of manufacture of around 1580 or 1585. Illustrated Gunthcr, R T. (1932) page 528 and pi. CXLIV but note that this astrolabe is now in the National Maritime Museum, Greenwich, and an electrotype copy is in the Science Museum.

No. 5) *Kronborg Semi-sphere dated 1600*

Acquired by the Sofartsmuset Kronborg (Accession No. K. í575) in March 1928 by purchase from an antique dealer in Copenhagen; nothing is known of its earlier provenance (27). Until the recovery of No. 15 (BATAVIA II) this was the only known semi-sphere.

No. 6) *The Oxford Sea-Astrolabe*

This was brought up by one of Pearsons sand-pumps from near a wreck at the bottom of Vera Cruz Harbour in 1903 by Mr. Donald Cowie from whom it was purchased by Dr. R. Gunther. (Gunthcr, R. T.) (1932) see page 528 and pl. CXLIV. Note its similarity to Palacios (1581) ilius-tration.

(27) *Ibid.*, p. 338 and fig. 1, p. 339.

No. 7) *Barlow (Manila) Astrolabe*

Al though found in Manila Harbour this astrolabe, being graduated for zenith distance only, suggests that it may well have been of Portugueses workmanship. Alidad is probably modera.

No. 8) *The Hoffman (Champlain's Astrolabe)*

The alidade has slit and pin-hole sights. When originally found there was a little projecting ring at the bottom which suggests that additional weight could be added to give it greater stability. This ring is now missing.

Gunther, R. T. (1932) page 529, pi. CXLV.

No. 9) *Florence Astrolabe*

This astrolabe is in mint condition and was probably purchased by Robert Dudley at the time of its manufacture and has remained in Florence ever since. It is not catalogued in the «*Catalogo Degli Strumenti,* Firenze», 1954.

No. 10) *Tenri Astrolabe*

This interesting Portuguese sea-astrolabe and the circumstances of its loss and irecovery have been described in Waters, D. W. (1957) «A 10th Mariners Astrolabe», *Journal of the Institute of Navigation,* volume 10, No. 4, October 1957, pages 411-415.

No. 11) *St. Andrew's University Astrolabe*

The only English sea-astrolabe surviving. It was made by the leading instrument maker of the day. This suggests, as do the Spanish records of the Casa de Contrataçión, that sea-astrolabes were the handiwork of skilled craftsmen and not of «shipyard craftsmen and brass founders» as has been suggested ([25]).

([25]) *Ibid.,* p. 343.

Nos. 12, 13 and 14) *Skokloster Astrolabes*

These three splendidly preserved sea-astrolabes form the richest single collection in the world. Field-Marshal Carl Gustav Wrangel, who was also Admirai of the Swedish fleet in the Battle of Femar, 1644, had previously studied navigation and the military arts in Holland in the 1620's. The sea-astrolabes now preserved in Skokloster Castle, which he built in 1650, were almost certainly acquired by him in Holland during his period of studies and have remainod there with other treasures ever since. That they are of Dutch manufacture has been confirmed by the recovery of the sea--astrolabe virtually identical with Skokloster (II) and (III) from the wreck of the Dutch East Indiaman *Batavia*, wrecked off Houtmans Abrolhos in 1629 (see No. 15, Batavia (I) sea--astrolabe). I am indebted to Count R. von Essen, of Skokloster Castle, for the information relating to Field--Marshal Wrangel.

The inscription of No. 13, Skokloster (II) reads:

«My roundness is to praise. I sail with you to indicate the altitude»; modern Dutch would be: «Mijn ronidheid is te prijzen. Ik vaar (met U) mee om de hoogte aan te wijzen».

The name is probably that of the owner, it is not that of a known instrument maker. I am indebted for this information to Mr. G. A. Cox, Director of the Nederlandsch Historisch Scheepvaart Museum, Amsterdam.

No. 15) *Batavia (I) Astrolabe*

Strikingly similar to the Skokloster (II) and (III) sea astrolabes and apparently by the same craftsmen. Of importance because until its recovery mo sea-astrolabes with ballast at the crown could be positively associated with a ship ([29]).

([M]) Halls, C. (íl%4) «The search for the *Batavia*», *The Annual Dogwatch*, No. 21, 19164, an Australian .publication, describes and illustrates the circumstances of the recovery of this sea-astrolabe.

No. 16) *Batavia (II) Astrolabe*

This semi-sphere was recovered from the wreck of the BATAVIA in 1964 and is now in private ownership in Australia. Until its recovery No. 5 was the only semi-sphere known.

No. 17) *Caudebec Astrolabe*

This unfortunately was destroyed in 1940 by general conflagration which followed the bombing of Caudebec-en-Caux.

Illustrated Gunther, R. T. (1932) figure 196, page 531.

No. 18) *Coimbra University Astrolabe*

This astrolabe is preserved in the Observatory of Coimbra University and is remarkable for its size, weight and features. The upper alidade has a large hole in it with a lens inserted in it. The lower alidade has two erossed lines, the sunlight being focuscd upon this cross when an observation is made. John Flamsteed, the first Astronomer Royai, introduced a lens-vane for use with the back-staff about 1675, henoe the tentative date ascribed to this sea-astrolabe, though the devices may weil have been introduced quite independently of one another.

No. 19) *The Felix Astrolabe*

This is at present on loan to the Smithsonian Institution, Washington. It is a very curious instrument as it has many of the features of a sea-astrolabe yet entirely laks its characteristic massive robustness. It is only 5 mm. thick and despite its diameter of 238 mm. weighs only 1530 gms. Its workmanship appears to be of the early 18th century.

Note 1. It may be mentioned here that the instrument signed «J. Renaud Marseille» and illustrated in M. Daumas, Xes *Instruments Scientifiques aux XVII*[e] *e XVIIF Siècles,* Paris, 1953, Fig. 5 as: «Astrolabe de Mer» was

originally a circumferentor for measuring horizontal angles (it measures from 0° to 360°) which has been incorrectly restored.

Note 2. Also, the New York Historical Society's instrument illustrated in R. Gunther, *Astrolabes of the World,* Oxford, 1932, Vol. 2, p. 323, as a Dutch astrolabe is modera. It was made about 1909 for the Hudson-Fulton Celebrations.

No. 20)
No. 21) *Florence Astrolabes (1166) and (1123)*

These two planispheric astrolabes are catalogued in the Florence, *Catalogo Degli Strumenti, Del Museo di Storia delia Scienza,* «1116-1127-1124 Astrolábio náutico di cm. 73 circa» and «1123» and «1124 Astrolábio náutico dei diâmetro di circa cm. 67», and although imvented by Robert Dudley for the use of seamen their great size, eombined with the fact that they were planispheric, would seem to have rendercd them impraecticable for observing altitudes or zenith distances accurately at sea.

Acknowledgements. I am indebted to Mr. A. N. Stimson of the Department of Navigation and Astronomy, National Maritime Museum, for preparing the scale drawings of the surviving known sea-astrolabes; to Dr. Silvio A. Bedini of the Smithsonian Institution, Washington, for supplying details about sfea-astrolabes in the United States of America; to Professor Dr. Maria Bonelli for information about the astrolabes in the Museo di Storia delia Scienza, Florence; to Dr. J. D. Boyd, Director of the Dundee Museums and Art Galleries for photographs of the Dundee searastrolabe; to Monsieur E. Bréchot, Musée Biochet, Caudebec-en-Caux, for information concerning the sea-astrolabe formerly preserved there; to Professor A. Cortesão, of Coimbra University, for supplying details of the Coimbra sea-astrolabe; to Monsieur M. Daumas, Director, Musée ides Artes Decoratifs, Paris, for information about the Caudebec sea-astrolabe; to Baron R. von Essen, of Skokloster Castle, Sweden, for illustrations

of and information about the sea-astrolabes preserved there; to Museumsinspecktor H. Henningsen of the S0fartsmuseet, Kronborg, Denmark, for details eoncerning the isemi-isphere there; to Mr. F. Maddison, Curator of the Museum of the History of Science, Oxford, for much assistance over the past years; to Mr. A. L. Ride, Director of the Western Australian Museum, for referring photographs of and information concerning the sea-astrolabe and semi-sphere recovered from the wreck of the Dutch East Indiaman, *Batavia,* to me, and to Capitaine de Vaisseau Vichot, Director, Les Musées de la Marine, Paris, for valuable photographic assistance. The pioneer work of the late Dr. R. T. Gunther, of the Museum of the History of Science, Oxford, and the researches of Professor Derek ide Solla Price, of Yale University, on astrolabes of the world have, of course, provided the framework for this paper. I am indebted to M.r and M.rs Robert S. Webster of Winnetka, Illinois, for drawing my attention to the paper by Lorenzo Caldo on the Palermo sea-astrolabe and for providing a good photograph of it.

)R MARINERS ASTROLABES

Marks	Pin Secured by	Nationality of Maker	Origin	Place Preserved
1540		[Spanish?]	Unkown	Palermo, Sicily [not located since second world war.]
o 000	W.	[Portuguese]	Unknown	Albert Institut, Dundee.
Faciebat Krabbe 1582	4 sided nut	German	Unknown	National Park Service, Washington, D. C,
NIL	W.	Spanish?	Valencia, Ireland in 1845, (from an Armada wreck?).	National Maritime Museum, Greenwich.
1600		[Dutch]	Unknown	S^fartsmuseet, Kronborg, Denmark.
4 fleurs-de-lys Ã	W.?	Spanish?	Dredged up in Vera Cruz Harbour in 1903.	Mus. of History of Science, Oxford.
Lacking original alidade 1602	W.?	Spanish?	Dredged up in Manila Harbour early 20th C.	On loan to Smithsonian Institution. Washington, **D.** C. (1965).
x 1603 x	Rnd. nut	French	Lost by Champlain in St. Lawrence in 1613; found 1867.	On loan to Smithonian Institution, Washington, **D.** C. (1965).
x x 1608 x x G019	B/F nut	English?	Purchased by Robert Dudley, Duke of Northumberland, in 1608 or later.	Museo di Storia delia Scienza, Florence.
-f o 000 o	W.	Portuguese	Recovered in 1929 from wreck of *Madre de Deos,* sunk m Nagasaki Harbour in 1610.	Tenri Library, Nava-Ken, Japan.
Elias Allen fecit 1616	Screw threaded pin	English	Probably acquired by Prof. James Gregory in 1673 for the University.	St. Andrews University Fife.
1626 4 *Fleur-ãe-lys* (on back '24' and '8')	B/F nut	Dutch	Bought by Field Marshall Wrangelin Holland while a student there.	Skokloster Castle, Sweden.
³ (on back «10-16» and «6»)	B/F nut	Dutch	d".	d«.
(On back «10-18» and «2»)	B/F nut	Dutch	do.	do.
Obliterated if any.	B/F nut	Dutch	Recovered in 1963 from wreck of	Western Australiau Musenm, Perth.

(On back «10-18» and «2»)	B/F nut	Dutch	d°.	d°.
Obliterated if any.	B/F nut	Dutch	Recovered in 1963 from wreck of D. E. I. *Batavia,* stranded in 1629 on Houtman's Abrolhos.	Western Australiau Musenm, Perth.
Obliterated if any.	?	Dutch	d°. Recovered 1964.	Private ownership, Australia.
Nicolas Le Tellier Honnefleur 1632*	?	French	Unknown	Destroyd by bombing in 1940 when in Caudebec-en-Caux.
NIL	B/F nut	Portuguese	Unknown	The Observatory Coimbra University, Portugal.
NIL	Washer and Fiat wing nut.	French ?	Unknown	On loan to Smithsonian Institution, Washington, (1965).
Planispheric		English	Designed by and made for Robert Dudley for nautical use probably between 1616 and 1654.	Museo di Storia delia Scienza, Florence.
Planispheric		English	do.	d.o

k 33, 1955, pp. 243-263, and 363-381.

[5] Examination of detailed photographs of the instrument illustrated in Daumas, M., *Les Instruments Scientifiques aux XVII* et XVIII* Siècles,* Paris, 1953, PI. 2, Fig. 5, leads to the conclusion that this is not an original sea--astrolabe but is adapted from an instrument designed for measuring horizontal angles in surveying work.