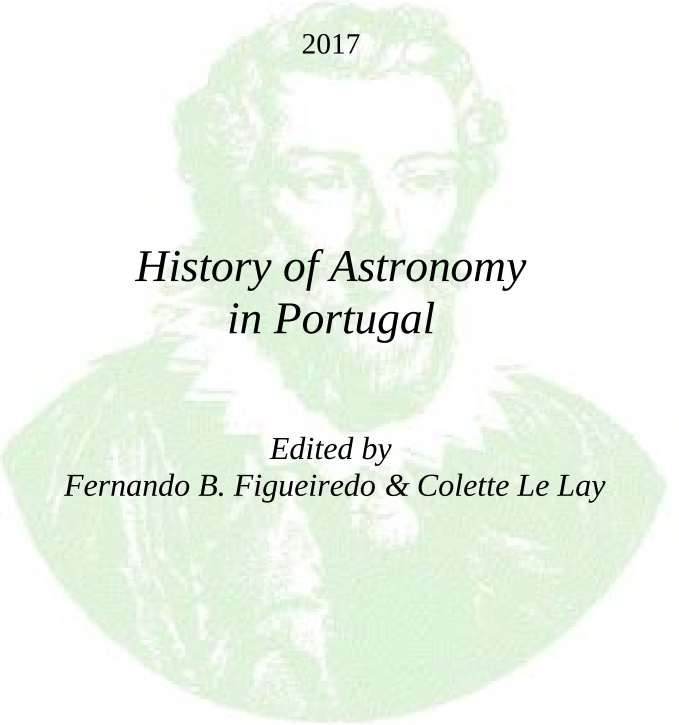
CAHIERS FRANÇOIS VIÈTE

Série III – N° 3

2017



History of Astronomy in Portugal

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Centre François Viète
Épistémologie, histoire des sciences et des techniques
Université de Nantes - Université de Bretagne Occidentale

Imprimerie Centrale de l'Université de Nantes
Décembre 2017

Cahiers François Viète

La revue du *Centre François Viète*
Épistémologie, Histoire des Sciences et des Techniques
EA 1161, Université de Nantes - Université de Bretagne Occidentale
ISSN 1297-9112

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www.cfv.univ-nantes.fr

Depuis 1999, les *Cahiers François Viète* publient des articles originaux, en français ou en anglais, d'épistémologie et d'histoire des sciences et des techniques. Les *Cahiers François Viète* se sont dotés d'un comité de lecture international depuis 2016.

Rédaction

Comité de lecture

ISBN 978-2-86939-245-1

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For the Benefit of Cosmography: Notes on the Contributions of Pedro Nunes to astronomy

Bruno Almeida*

Abstract

This paper addresses the astronomical work of the Portuguese mathematician and cosmographer Pedro Nunes (1502-1578) by focusing on his printed texts. It is mainly argued that this astronomical production was highly motivated by practical needs of his professional activity as a cosmographer. I start with identifying his main interests and contributions in order to show that his astronomical output can be divided into three main categories: translations of earlier texts, commentaries to those texts and original research. This gave way to new vectors of transmission of his work, to fellow scholars and cosmographers in similar professional situations. To exemplify this occurrence, I provide some details of the transmission of his work and its influence in French cosmography.

Keywords: Pedro Nunes, astronomy, cosmography, transmission of knowledge, nautical science, translation, commentary.

Résumé

Ce chapitre traite de l'œuvre astronomique du mathématicien et cosmographe portugais Pedro Nunes (1502-1578) en s'attachant à ses textes imprimés. Nous débutons par l'identification de ses principaux intérêts et contributions afin de montrer que ses travaux astronomiques peuvent être divisés en trois catégories : traductions de textes anciens, commentaires de ces textes et recherches originales. Nous démontrons que cette production astronomique trouve sa motivation essentielle dans l'activité professionnelle de cosmographe de Nunes. Cette production engendra de nouveaux canaux de transmission de son travail à des savants et cosmographes occupant les mêmes fonctions. Pour illustrer cet aspect, nous détaillons la transmission de son œuvre et son influence sur la cosmographie française.

Mots-clés : Pedro Nunes, astronomie, cosmographie, transmission de connaissances, sciences nautiques, traduction, commentaire.

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In 1577, the Vatican issued a missive with a project aiming to reform the Julian calendar: Aloysius Lilius' *Compendium novae rationis restituendi Kalendarium* circulated among scholars all over Europe and reached Portugal via diplomatic channels.[1] The Portuguese Chief Cosmographer Pedro Nunes briefly examined the text while on his death bed but, unfortunately, died in Coimbra, on the 11th of August 1578, without advancing much on the subject.[2] On the 30th of August, Fr. Luís de Souto Maior answered back to Lisbon saying that Nunes thought the text of the project contained some errors and that, under those conditions, nothing could be done to obtain a definitive solution to the problem of the calendar (Carvalho, 1952, p. x-xvi).

Due to this conjunction of facts, History does not list Nunes among those who had a direct impact on the reform of the calendar. It is known that, even retired from active duties, he was the main scientific authority of the country and was recognized as one of the finest European scholars of his generation. But it was only a coincidence that Nunes' last known technical opinion was about the calendar since he was not a full-time astronomer. Astronomy – which Nunes defined as: "the science that concerns with the path of celestial bodies and with the universal composition of the heavens, and not with the vain beliefs and almost rejected that issues judgments upon life and fortune" (Nunes, 1542, p. 141) – was not his main occupation but surely was of primary intellectual interest for him. Professionally, he was a professor of mathematics at the university and was also Chief Cosmographer (that is, the head cosmographer of the state) a practice that combined different scientific disciplines such as mathematics, astronomy and geography with managing duties, advising on nautical questions and teaching.

Most of the astronomical issues that interested Pedro Nunes were motivated by his professional duties as navigational advisor and cosmographer of the kingdom. The historian Henrique Leitão called attention to

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[1] The works about the reform of the calendar are numerous. See, for example (Coyne, Hoskin & Pedersen, 1983).

[2] Pedro Nunes was a Portuguese mathematician, cosmographer and University professor. He was born in Alcácer do Sal, Portugal, in 1502. Not much is known about his family and his early life. He studied at the University of Salamanca, obtaining a bachelor degree in medicine in 1523. He returned to Portugal in 1527 and was appointed cosmographer in 1529. In 1544, he was appointed Professor of Mathematics at Coimbra's University. In 1547, was appointed Royal Cosmographer. He died in Coimbra in 1578.

this mixed mathematical practice, underlining that Nunes was driven by theoretical questions imposed by real problems (Leitão, 2013, p. 25) and that the techniques used to solve them were associated with mathematical astronomy. Also, it must be stressed that he was not an observational astronomer and that "(…) his texts do not give any indications concerning numerical work associated with astronomy (organizing tables, etc.) nor of any interest in astrology or physical-philosophical speculation on the universe's cosmological structure".[3]

Nunes' work on astronomical questions is found in his texts – five printed volumes, a small epitome and one manuscript. The great quality and relevance of these works made them very well known in Europe in the sixteenth and seventeenth century.[4] As an example, one of the scholars that most appreciated his work was the Jesuit Christopher Clavius (1538-1612), one of the main actors of the reform of the Julian calendar.[5] Those texts also provide very good information about his contact with earlier astronomers' works.[6] His books show a remarkable knowledge of the most important and relevant texts within the Ptolemaic-Aristotelic framework, produced by Greek, Latin or Arabic authors. He mastered the introductory texts, such as Sacrobosco's *Tractatus de sphaera* and Peuerbach's *Theoricae*, but also the more demanding like Ptolemy's *Almagest.* To those must be added other relevant texts by Alphonsus, the Wise, Erathostenes, Allacen, Tabit,

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[3] "De notar que os seus textos não dão quaisquer indicações de ter feito trabalho numérico associado à astronomia (preparação de tabelas, etc.), nem de qualquer interesse por astrologia ou por especulações físico-filosóficas sobre a estrutura cosmológica do mundo." (Leitão, 2013, p. 24). Unless otherwise stated, all the translations of the quotations are from the author with slight revisions of the editorial team.

[4] On the general diffusion and impact of Nunes' work in Europe, see (Leitão, 2002); on the diffusion and transmission of Nunes' nautical work in Europe, see (Almeida, 2011).

[5] As an example, Christopher Clavius (1538-1612) referred Nunes as "(...) acerrimo vir ingenio, et nullo hac nostra aetate in Mathematicis inferior" (Clavius, 1611, p. 123).

[6] Nowadays, all of Nunes' books are available with extensive and valuable notes (in Portuguese). Recently, a web page was developed (in English) to serve as an introductory to Nunes' science and historiography. See http://pedronunes.fc.ul.pt. It has, by no means, as much information as the extensive and erudite notes of the modern editions but investigators not fluent in Portuguese can consult some studies, papers and find links to other interesting pages.

to cite a few.[7] Furthermore, he was much influenced by the more recent Germanic astronomical tradition represented by Regiomontanus, Johannes Stöffler, and Johannes Werner, among others.

In my opinion, Nunes' contributions to astronomy can be organized in three main vectors: translation, commentaries, and original research. The following lines will focus chronologically on Pedro Nunes' main texts and draw an overview of his astronomical work. I will also present a few considerations on Nunes' influence on astronomy and cosmography, paying particular attention to French cosmographic literature of the sixteenth and seventeenth centuries.

Tratado da sphera (1537)

Nunes was already thirty-five years old when he published his first book (Nunes, 1537). It consisted of translations of Sacrobosco's *Tractatus de sphaera*, of Ptolemy's book I of *Geography* and of the sun and moon chapters of Peuerbach's *Teoricae novae planetarum* into Portuguese.[8] He also added two original texts addressing navigation problems: the *Tratado sobre certas duuidas de nauegação* [*Treatise on some doubts about navigation*] and the *Tratado em defensam da carta de marear* [*Treatise in defence of the nautical chart*].

With the exception of his *Libro de Algebra* (written in Castilian Spanish and published in 1567), this volume was the only one written in a vernacular language.[9] In the dedicatory of the book to Prince Luís, Pedro Nunes stated that his main purpose was to "reveal" the necessary principles of cosmography in the Portuguese idiom. He specified: "science does not have a language [that is, it can be understood using any vernacular one]"[10] (Nunes, 1537, p. 5).

Nunes' first book presented him as a commentator of texts of science. The original *Tractatus de sphaera* by Sacrobosco was an introductory

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[7] More on some of Nunes' textual sources can be found in the catalogue of an exhibition celebrating the five hundred years of his birthday in 2002 (Leitão & Martins, 2002).

[8] As far as I know, the compilation of these texts in one volume is completely original. Nevertheless, there were editions combining two of those titles. As an example, a book comprising the *Sphera* and the *Theoricae* was edited in Venice, in 1482 (further editions in 1485, 1490, 1499, 1519). See (Nunes, 1537, p. 248-249).

[9] Nonetheless, he would later favour publishing in Latin, which was still the preferred idiom to communicate and share scientific novelties among scholars.

[10] "a sciencia não tem lingoagem: e que per qualquer que seja se pode dar a entender".

textbook to the study of astronomy, well known all over Europe. It brought out a large tradition of scholarly commentaries that motivated important scientific discussions.[11] The same important commentary tradition existed in Peuerbach's *Teoricae novae planetarum* case (although at a lesser scale due to the fact it was a more recent text). Nunes' translation was limited to the sun and moon chapters and included brief commentaries about the illustrations. It must be underlined that it was only the second commentary in vernacular to be published in the sixteenth century, after Oronce Fine's *La théorique des cielz, mouvemens et termes practiques des sept planètes* (1528).

This Portuguese translation of the *Sphere* included twenty-six commentaries. They were generally straightforward but there were some exceptions to be noticed. In particular, the *Annotação sobre as derradeiras palauras do Capitulo dos Climas* [*Commentary on the chapter of climes*]. In this note and for the first time in the history of science, trigonometry and geometry were used to explain the width of the *climate*. This notion was introduced in classical antiquity (as far as it is known by Aristotle) and it was used to divide the Earth in parallels (usually seven). Two consecutive parallels had a difference of thirty minutes in the length of the respective longest day of the year.

The *Commentary* enjoyed a large reputation thanks to Elie Vinet.[12] Starting in 1556, Vinet included a shorter version of Nunes' notes in his multiple editions of his *Sphaera emendata.*[13] This book had at least 32 edi-

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[11] These commentaries were personal notes, sometimes to clarify unproved passages of the original, sometimes to point out errors or to propose improvements. The amount of commentaries to the *Sphere*, that were the basis for an important intellectual tradition, shows that this was an extensively studied text. Commentators included, among others, the names of Michael Scot, Robert Anglicus, Cesco d'Ascoli, Elie Vinet and Christopher Clavius.

[12] Vinet was an admirer of Nunes' work. It is possible that they knew each other from the time when Vinet was teaching at the Colégio das Artes, in Coimbra, between 1547 and 1549. Besides the *Tratado da Sphera*, he knew and possessed other books by the Portuguese cosmographer, such as *De crepusculis*, and he also made a reference to the *De erratis Orontii Finaei* in his own *Definitiones Elementi quincti et sexti* (1575). Vinet had a very important role in the transmission of Nunes' work to some intellectual groups in Bordeaux linked to the Collège de Guyenne. For example, it is possible that the famous Jacques Pelletier became aware of Nunes' work through Vinet, when he was in Bordeaux. The other interesting link of Nunes' *Tratado da sphera* to France is that a copy reached the country through the ambassador Jean Nicot, who planned to translate it (Nunes, 1537, p. 562-563).

[13] Nunes' text was sometimes highlighted in the frontispiece as, for example, in the following edition: Vinet (1559) *Sphaera Ioannis De Sacro Bosco Emendata. Eliae Vineti Santonis Scholia in eandem Sphaeram, ab ipso authore restituta […] et Petri Nonii Salaciencis Demonstrationem eorum, quae in extremo capite de Climatibus Sacroboscius scribit de inaequali*

tions until 1620, which made the *Annotatio* Nunes' most printed text. This fact was meaningful enough to motivate Bernardino Baldi (1553-1617) to include Nunes among the most famous mathematicians and astronomers writing commentaries on Sacrobosco's *Tractatus de Sphaera.*[14]

Considering the two original treatises from 1537, the first one was motivated by two questions related to astronomical routines of navigation, attributed to the nobleman Martim Afonso de Sousa (ca. 1490-c.a. 1571).[15] The answers to Martim Afonso de Sousa's questions introduced solutions to several navigational problems, specifically based on astronomical data and methods. Contrary to the common art of navigation (based in simple rules and processes) his suggestions implied many innovative tools, concepts and procedures resulting from a meticulous use of mathematics, astronomy and geography.

As a cosmographer Nunes was engaged in managing several technical aspects of navigation. Among other things, cosmographers were in charge of organizing the training of seamen. In his *Treatises* he supported the idea that seamen should improve their technical abilities in order to face different challenges in their practice.[16] He suggested general directives to the training of seamen, based on the knowledge of their professional environment using tools from mathematics, geography, astronomy, and even meteorology. Later, these ideas influenced the practice of many cosmog-

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Climatum latitudine, eodem Vineto Interprete. (Lutatiae, Gulielmum Cauellat). In a recent paper, Matteo Valleriani focused on the early modern tradition of commentaries on Sacrobosco's *Tractatus de sphaera*. In particular, he analyzed the diffusion of Nunes' demonstration and how it was published in other places and by different printers (Valleriani, 2017).

[14] (Baldi, 1998, p. 167). Baldi's text circulated in manuscript versions until 1707, when it was published in Urbino. Unfortunately, that edition was truncated and had errors. I use the modern edition of the original manuscript, published in 1998.

[15] It is my opinion that Martim Afonso de Sousa (c. 1490-1571), and even more D. João de Castro (1500-1548), represented Nunes' ideal of the "modern navigator", that is a new professional prepared with enough critical spirit and scientific knowledge to observe natural phenomena, interpret them and act in the best interest for their journey. They should also have the ability to communicate with the cosmographer, bringing relevant information from their voyages and, if possible, doubts like Sousa's.

[16] The author mentioned the *Tractatus de sphaera*, book I of *Geography* and the sun and moon chapters of the *Teoricae novae planetarum* as "the basic knowledge that anyone interested in understanding something about cosmography should have". The translation is mine from the original "(…) sam aquelles principios que deue ter qualquer pessoa que em Cosmographia deseja saber alguma coisa" (Nunes, 1537, p. 5).

raphers around Europe. For example, the Antwerpian cosmographer Michel Coignet, writing in 1581, showed awareness of the differences between a "practically" oriented and a "scientifically" oriented seamanship, making good use of the "(...) pratiques [maritimes] susdites de plusieurs autres reigles fort ingenieuses et instruments prins de l'art de l'Astronomie et Cosmographie (...)"[17] (Coignet, 1581, p. 5).

Among other suggestions, Nunes advised the use of lunar eclipses to solve longitude problems and he systematized the use of 23°30' for the inclination of the ecliptic (a value taken from Regiomontanus), substituting the common value of 23°33'.[18] He also proposed ways to simplify the customary rules to find latitude by using the position of the Sun at noon.[19] As he was also concerned with the determination of latitude by the position of the Sun, he suggested improvements in the use of the tables of declination of the Sun, calling special attention to its correct use.[20]

Nunes introduced improvements to the standard estimation of latitude at noon. He made new suggestions concerning the calculation of latitude at any given time of the day and about the determination of time aboard ships, when the Sun's position was previously known (Nunes, 1537, p. 147). Furthermore, in order to obtain time on board, besides knowing Sun's height, declination and azimuth, he suggested the pilot should also consider the latitude of the observer.[21] This procedure is linked to the problem of the "miraculous" sundial of Acaz, a phenomenon in which, under certain conditions, the Sun's shadow would present a retrograde path. In fact, this is a very difficult phenomenon to observe aboard and, in the opinion of the historian Henrique Leitão, it made Nunes a pioneer in using

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[17] Suggested translation: "(…) the above-mentioned practices and several other ingenious rules and instruments taken from the art of Astronomy and Cosmography".

[18] (Regiomontanus, 1490). The choice of Regiomontanus' value for the inclination of the ecliptic guarantied scientific excellence but provided also a "round" number easier to compute (Nunes, 1537, p. 142).

[19] One of the best studies about this can be found in (Albuquerque, 1988).

[20] That is, the Sun's declination varies slowly during the day, so the navigator should correct the tabulated values in the case he was observing the Sun from a distance of more than six hours away from the place where the tables were computed (Nunes, 1537, p. 142).

[21] This happens because the spherical triangle has two solutions. For a mathematical explanation, see (Smart, 1931, p. 10).

mathematical tools to demonstrate a phenomenon that had possibly never been observed before.[22]

Furthermore, he proposed new instruments to help seamen to determine their position when the Sun was visible. He designed a simple auxiliary instrument called *lâmina de sombras* (shadow instrument) that should be used together with a globe to mark their results. Afterward, he developed a second method using the same apparatus. Finally, he proposed graphic schemes to obtain Sun's declination more precisely.[23]

Nunes also wrote briefly about the use of the pole star to obtain the latitude and made some comments to a crucial parameter used by seamen: the distance between that star and the pole. Relying on Werner's calculations, the Portuguese cosmographer recommended that the value of the distance should be changed to 4°9' (or 10').[24] Seamen and other cosmographers used the value of 3°30' (in fact more accurate) and considered Nunes' suggestion as an error since it did not coincide with the values they observed. This may point out that, at the time, Nunes had made no previous observation of the star and just trusted a highly regarded scholar's authority.

De crepusculis (1542)

The motivation for Nunes' next book *De crepusculis* (Nunes, 1542) was another enquiry, this time by an eminent pupil. In the initial dedicatory lines to King João III, the cosmographer specified that the idea of writing about twilights – defined by him as the "(...) dubious middle light between day and night" (Knobloch, 2003, p. 118) – came from D. Henrique, the King's brother and also a future king.[25] The problem of twilights in differ-

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[22] (Nunes, 1537, p. 156-157). Nunes proved this phenomenon for the region between tropics. The city of Jerusalem is outside this zone, therefore Nunes "avoided" dealing with non-miraculous solutions. Later Clavius extended the mathematical solution to all latitudes. It is not known whether Nunes was also informed of this question by seamen like Aloisio Cadamosto that observed it in Sumatra, as described by Christopher Wren (Elmes, 1852, p. 103).

[23] In theory, these solutions were easy to use, despite needing sine tables and some basic notions of trigonometry. See more in the notes added to volumes I and IV of the *Obras*. Luís de Albuquerque (1988) has made several comments about this.

[24] Werner calculated this value in 1500, based on a rate of precession of 49000 years and on the *Alphonsine Tables*. (Werner, 1514).

[25] For more information about this book, besides the notes in (Nunes, 1542), see also (Vilar, 2006).

ent places of the Earth had been addressed before by astronomers of Latin and Arabic traditions such as Sacrobosco, Ibn Mu^{c}Ādh and Stoffler, among others but Nunes believed that none of his predecessors obtained a definitive solution to the problem.[26]

The distinctive aspect of this work was that the Portuguese cosmographer addressed the problem from a mathematical point of view:

> [twilights'] durations can be easily obtained by arithmetical operations based on geometrical demonstrations on arcs and spherical angles, however, astronomers determine them on astrolabe's limbs (...) because in this way they achieve their objective easily. (Nunes, 1542, p. 147)

He organized his arguments in a "Euclidean" way, in the sense that the demonstrations were ordered in theorems and propositions put in a logical sequence. He also chose to write in Latin, which helped promoting his work to a wider international audience.

The book is divided in two parts. In the first one, the author listed general theorems and propositions. These were used in the second part to deal with aspects concerning the decreasing or increasing of the twilight during the year. The volume had extra bibliographic interest since Nunes also published for the first time the *Liber de causis crepusculorum* by Ibn Mu^{c}Ādh, which again emphasized his attention to early texts.[27] *De crepusculis* is a remarkable work for several other reasons: besides some interesting astronomical results, it dealt with the problems of optics applied to astronomy and suggested instrument improvements, such as the famous "nonius".

Many historians praised this short text and considered it as the greatest example of Nunes' style of dealing with practical problems using mathematical tools. Contemporary men of science (Clavius and Tycho Brahe among others) also acclaimed the book. Christoph Clavius was the first renowned mathematician to cite Nunes' book and one of its principal advocates. His commentaries suggest that he used the text in his classes. However, he considered the book was in some way difficult to read and for that reason he made some adjustments and simplifications. In fact, Nunes' approach to the subject was not straightforward, since at the time, many

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[26] Furthermore, he was not comfortable with some of the technical aspects of these approaches: for example, the hypothesis of the equality of twilights for every day of the year and for all latitudes.

[27] Until recently the earlier Latin text was wrongly attributed to Allacen, because of the reference to Gerardo of Cremona. However, historian A. I. Sabra showed that it should be credited to Ibn Mu^{c}Ādh (Sabra, 1967).

trigonometric functions were not yet available – for example, he used sines and cosines but not tangents. In 1815, Jean-Baptiste Delambre made the first critical comments on *De crepusculis*, which were later included in his *Histoire de l'Astronomie* (Delambre, 1819).[28]

In detail, Nunes considered that the twilights began or ended when the Sun was 18° under the horizon. The time to cover this distance depended on the observer's latitude and on the time of the year (position of the Sun on the Ecliptic). From a technical point of view, Nunes' process was based on the difference between the right ascension of the sun and of another star, whose distance regarding the meridian was previously determined. Among other things, he proved that on any given day, morning and evening twilights had equal durations. Equal length twilights occurred at equal latitudes; at the equator, the maximum twilight occurred at solstices and the minimum at the equinoxes.

Though very theoretical, the book revealed some connections with the author's cosmographical practice. One example is the discussion about what is probably his most popular contribution to science: the "nonius". This ingenious solution was designed to improve the precision when measuring of astronomical angles with circular scale instruments used by seamen, like an astrolabe or a quadrant.[29] The "nonius" was praised by authors as William Barlow, Andrés García de Céspedes, Tycho Brahe and Robert Dudley. Later, the "nonius" underwent several improvements, the best known being proposed by Pierre Vernier (1584-1638), in 1631 and consisting in reducing the system to two linear scales, one fixed and the other movable.

One last detail about this small volume is the presence of a short list of books at the end. It includes works that Nunes intended to publish and, among them, two are directly related to astronomy: *De ortu et occasu signorum* [*The rising and setting of the signs*] and *De astrolabio opus demonstrantiuum* [*Demonstration of the astrolabe*]. In fact, it is not known whether he managed to write these texts or not but the intention shows further about his intellectual interest and preoccupation to work on astronomical matters. Interestingly enough, the book he wrote next was not announced in that list.

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[28] Knobloch underlined that Delambre considered it "(...) long-winded, lengthy, diffuse" (Knobloch, 2003, p. 117).

[29] About instruments of navigation, see (Albuquerque, 1988b).

De erratis Orontii Finaei (1546)

A few years later, in 1546, Nunes published a book entitled *De erratis Orontii Finaei* (Nunes, 1546). Its purpose was to show some erroneous procedures and demonstrations by the renowned Oronce Fine (1494-1555), professor at the Collège de France, in Paris (Ross, 1971). Fine had presented solutions for the famous classical problems of duplication of the cube, trisection of an angle and quadrature of the circle and published it first in *Protomathesis* (1532) and later in a compilation of works (1544). Other subjects also caught Nunes' attention like, for instance, Fine's assumptions on gnomonic and on the problem of determination of longitude.[30]

Nunes' book is much more than an array of criticism to a fellow scholar.[31] He presented a new point of view to sensible topics and an unusual domain of the most powerful mathematical tools of his time. The important historian of science Maxwell Clagett stated:

> The acutest and learned of the critics was the Portuguese mathematician Pedro Nunes. In his *De erratis Orontii Finaei* (Coimbra, 1546), Nunes not only corrected the errors of the French mathematician but revealed himself as the most penetrating student of Archimedes' technique of approximations yet to write in Latin. (Clagett, 1978, p. 1246)[32]

Though the text is mostly focused on mathematics, it is possible to find some passages related to astronomical subjects and applications to cosmography on chapters XV, XVI, XVIII and XIX. In Chapter XV – *How Oronce made a great mistake on the investigation of the longitudes of the places, due to*

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[30] The French scholar expressed thoughts about the determination of longitude in several texts, mainly in his *De inuenienda longitudinis locorum differentia, aliter quam per Lunares eclipses, etiam dato quouis tempore, Liber admodum singularis* (included in those collected works printed in 1544). Fine wrote about sundials in *De solaribus horologiis et quadrantibus*, a text included in his *Protomathesis.*

[31] (Leitão, 2009). Nunes was not the only scholar to point out inaccuracies in Fine's works: among the most "severe" was Jean Borrel (in 1554). Others, like Tartaglia (in 1560) and Adrianus Romanus (in 1597), also made some important remarks.

[32] Nunes was very well informed about the work of Archimedes. Though in previous works he had only made some brief references to works by the Syracusan, he revealed in *De erratis* a greater knowledge of the Archimedean texts, surely motivated by the recent publishing of his works with commentaries by Eutocius of Ascalon. He gave special attention to *De mensura circuli*, included in the edition *Archimedis Syracusani Philosophi ac Geometrae excellentissimi Opera*, from 1544.

the ignorance of basic rudiments of Astronomy,[33] Nunes showed the errors of Fine's proposition to determine the longitude of a place based on the observation of Moon's position. In fact, Fine's solution was a bit different from the one known as "Lunar distances method", previously proposed by Werner in his notes to Ptolemy's *Geography* (Werner, 1514). Fine based his own method on the meridian passage of the Moon rather than on the measurement of distances between the Moon and another celestial body. In detail, Nunes noticed that Fine was incorrect in his considerations about the lag of the Moon and about lunar parallax.

Chapter XVI was dedicated to several errors found in Fine's text *Planisphaerium geographicum, quo longitudinis atque latitudinis differentiae, tum directae locorum deprehenduntur elongationes*, included in *Quadratura circuli*. In this text, Nunes used several techniques of positional astronomy to explain a particular case of determination of the longitude and latitude of a place.

In Chapter XVIII, Nunes made minor comments on some of Fine's ideas about gnomonics and dials in his *De solaribus horologiis et quadrantibus libri IIII*, included in *Protomathesis*. Among other subjects, Nunes commented on the construction of a nocturnal clock. In chapter XIX Nunes kept on correcting the Frenchman about his propositions for the construction of sundials. It is interesting to notice that this last chapter led Clavius to praise Nunes among the "scriptores horologiorum" and Élie Vinet to write:

> Quand a la Theorique et demonstration, mon auis n'a esté d'i toucher: pource que le liure en eust esté beaucoup plus grand est obscur: mais s'il i a quelqu'un, qui doute de la doctrine ici baillée, qu'il aille lire et bien eplucher le liure q'un mien ami Pero Nunez Cosmographe du Roi de Portugal Jehan le Tiers, publia et fit imprimer a Coimbre Vniversité de Portugal, l'an M.D.XLVI: et il trouuera lá, qui le contentera. (Vinet, 1583, Conclusion)

Again, one can notice the direct and indirect connections with Nunes' cosmographic practice. Generally speaking, the study of gnomonics was fundamental to understand and devise a vast array of instruments. In the same way, the determination of longitude was vital to managing all the geographical information of the empire and was also necessary for navigation, tasks which were supervised by the Chief Cosmographer.

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[33] The original title in Latin is: *Orontium uehementer errasse in inuestigatione longitudinis locorum, ob ignorantiam primorum rudimentorum astrogiae.*

Petri Nonii Salaciensis Opera (1566)

The *Petri Nonii Salaciensis Opera* (Nunes, 1566) is a large volume compiling the most important achievements of Nunes' scientific activities. It is divided in two main parts: a short one consisting in the Latin version of his original treatises from 1537 and a larger one, in two books, named *Rules and instruments to find out the appearances of both maritime and celestial things.*[34] The book also included the Latin version of his notes on Peuerbach's theories of the planets.[35]

The publication of the *Opera* triggered a big impulse within the recent scientific field of theoretical navigation which influenced many European cosmographers. One of these people was Michel Coignet, mentioned earlier, who was inspired by the idea that a modern practice of navigation should include not only simple rules but also more sophisticated astronomical procedures. Nunes' influence can be seen in some instruments proposed by Coignet, such as the nautical hemisphere, which included a shadow apparatus in a graduated semi circle. Coignet advised the use of that instrument to determine the latitude at any time of the day, based in a procedure developed by the Portuguese cosmographer.

The association between strictly theoretical principles and practical solutions for everyday navigation problems is evident throughout the book. The knowledge of the position of the sun to determine latitude was very important to navigation and Nunes had addressed it before, in a less formal way, in 1537. Thirty years later, the cosmographer had developed his ideas and presented various comments and thoughts about Sun's theory and its parameters, such as the duration of the tropic year, precession rate and ecliptic obliquity. Related to this topic, in chapter 4, *Of Sun's declination*, he confirmed 23°30' as the optimal angle of the inclination of the ecliptic. Interestingly this value became widely accepted among cosmographers and mathematical practitioners such as Edward Wright (1561-1615) who stated that he used that value "agreeing with that excellent arts-man Germanies Euclide Regiomontanus, whom Petrus Nonius (compared by Ramus to Archimedes) and Clarius [sic] (a great Mathematician though a Iesuite) chose rather to follow, than either of the other [Copérnico and Tycho Brahe] (...)" (Wright, 1599, fl. Aa r).

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[34] From latin: *De regulis et instrumentis, ad uarias rerum tam maritimarum quam et coeletium apparentias deprehendendas, ex Mathematicis disciplinis.*

[35] The modern edition of Nunes (1566) was divided in two volumes. The navigation books (*De arte atque ratione nauigandi*) were published in volume IV (2008) and the notes to Peuerbach's text (*In Theoricas Planetarum Georgii Purbachii Annotationes*) were published in volume V (2011): see the bibliography.

Nunes maintained his commentaries regarding the use of solar tables and the necessity of corrections and adaptations. He also mentioned that the values of the Sun's declination in the tables were approximations that did not consider the trepidation of the eighth sphere.[36] This is a good example of a very specific topic that did not matter to seamen in a direct way, but could be useful to cosmographers and astronomers when calculating tables for nautical use. This also shows how very complex scientific knowledge could reach the relevant practitioners, a process mediated by the cosmographers.

It was also in Chapter 4 (and repeated in Chapter 11) that the author made a brief reference to Copernicus and his *De revolutionibus orbium caelestium* (1543). Nunes was one of the first European scholars to address this pivotal work, showing that he was well informed about contemporary astronomy. Contrary to other readers of Copernicus, Nunes did not worry much about the physical and philosophical implications of the Polish's cosmographical and astronomical theories. In fact, his comment on the determination of the movement of fixed celestial bodies is focused on Copernicus' mathematical inexactness in some passages of his book (Nunes, 1566, p. 329).

In *Opera* there are but few references to astronomical observations. Nevertheless, it is possible to find two of them in Chapter 4. In the first one, the author vaguely mentioned some "regular" observations of the skies. The second one is more specific and revealed the use of the astrolabe on a specific date and place: the 14th of September 1555, in Coimbra, Portugal.[37] In that observation he measured the distance of the Sun to the zenith, which was a simple procedure. In my opinion, these scarce occurrences support the idea that Nunes' astronomical reputation was not based on his observational skills.

Afterwards, in Chapter 5, Nunes proposed three procedures to obtain the inclination of the ecliptic, an essential value for a cosmographer. The first one was actually a graphical process that could be drawn on the back of a plane astrolabe or other plane instruments. The second process was based on Vitruvio's analema. The third one, often known as "quadrante de declinação", was the instrument previously described in the final pages of his *Tratado em defensam da carta de marear* (Nunes, 1537, p. 180-182).

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[36] The trepidation designates a hypothetical variation in the rate of the precession of the equinoxes.

[37] In what concerns ephemeris, the Sun entered Libra on this date.

Chapter 6 is also very important. It addresses subjects related to the measuring of astronomical observable distances such as parallax, atmosphere refraction, light beams, but also the height of atmosphere vapours. More importantly, the author focused on the instruments most commonly used in navigation: the astrolabe, the cross-staff and the quadrant. He reflected upon the limits and problems of those instruments and proposed some alternatives. As an example, he conceived a nautical ring destined to measure Sun's height. This instrument excluded the moving parts of the astrolabe and had the advantage of doubling the precision of the readings.[38] Again, the attention paid to instruments shows his concern with practical applications of theoretical ideas for the benefit of cosmography and navigation. The nautical ring is a perfect example of Nunes' *modus operandi* as Royal Cosmographer: in this case, he applied a simple geometric principle to an instrument to ease a common procedure in navigation. The ring was mentioned by later cosmographers such as the important George Fournier, who paid attention to it in his *Hydrographie*. The fourth chapter of Book X, was dedicated to the *Anneau gradué*, however with no mention to the name of its Portuguese creator. Nevertheless, Fournier praised the instrument, stating: "Cet Anneau est preferable a l'Astrolabe" (Fournier, 1643, p. 372). The famous Claude Deschales also made references to the ring in the Proposition XXIII – *De l'Anneau astronomique* in his *L'art de naviger* (1677):

> Nous appelons Anneau Astronomique une circoference de cercle, faite en forme d'un Anneau. Il doit estre suspendu librement, de méme façon que l'Astrolabe. (…) L'Anneau Astronomique ne peut servir que pour le Soleil, mais il a cette commodité, qu'on n'a besoing que d'une observation; sans estre obligé de baisser, ou de hausser la regle: et de plus, ses degrez sont plus grands que dans l'Astrolabe. (Deschales, 1677, p. 57)[39]

Concerning the quadrant, Nunes suggested practical improvements such as substituting the thread for a metallic rule which would allow a better use under unstable conditions like the ones experienced at high seas (Nunes, 1566, p. 360). Deschales was one of the authors agreeing with that

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[38] Nunes' argument was based on the idea that, because there was a lever effect, the astrolabe was not balanced. Later, it was proven that it had no influence on the instrument.

[39] "We call Astronomical Ring a circumference with the form of a ring. It should be hung freely, in the same manner as the astrolabe. (…) The Astronomical Ring can only be used for the Sun, but it is convenient, for one needs only one observation, without having to lower or to raise the rule; and, moreover, its degrees are larger than the Astrolabe's".

idea: "(...) au lieu d'un filet, mettez une regle qui puisse rouler autour du centre du quart de cercle, la chargeant de trois ou quatre livres de plomb par le bas pour empescher qu'elle ne branle"[40] (Deschales, 1677, p. 73). Another problem addressed in the *Opera* was related to the scales of the instruments so Nunes recalled one of his best-known solutions – the "nonius" – previously published in *De crepusculis*. Finally, he commented on the cross-staff, defending that the instrument should only be used aboard to find distances between celestial bodies separated by distances lesser than a quarter of a circle.[41]

In my opinion, the whole chapter dedicated to instruments is a good example of Nunes' concern about applicability and improvement of procedures aboard ships. Even if his writing style was very theoretical and hard to be understood by common seamen, it has been stressed that this apparent problem of communication could be counterbalanced by the intervention of other cosmographers that could interpret the theoretical information, adapt it and finally transmit it to seamen.

In Chapter 7 – about the distance of the polar star to the pole – Nunes commented again on the value for this distance and its variation according to the latitude of the observer. Here he maintained his compromise with Werner's proposal of 4°9' for the distance of the star to the pole instead of the value of 3° 30' common among seamen.[42] Nevertheless, he proposed the measuring of the distance from the pole star to the North Pole at its highest or lowest passage, in order to avoid seamen's interpolations and mistakes (Nunes, 1566, p. 383-384). He noticed that measuring the pole star out of its meridian passage, did not give constant values at all latitudes (Nunes, 1566, p. 384). This observation – that echoed in the work

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[40] "Instead of a string, put a ruler that can roll around the center of the quarter circle, loading it with three or four pounds of lead from the bottom to prevent it from moving".

[41] Nunes' opinion did not go unnoticed. For instance, Simón de Tovar analyzed his suggestions and prepared a "defense" of the instrument in a book published in 1595 (Tovar, 1595).

[42] In my oppinion, in 1566 he was not so categorical. His writings showed some hesitation on Werner's results, probably because of the pressure that some negative commentaries and the observations of other astronomers put on him. He stated that "if the movement of fixed stars, as obtained by Werner using Alphonsine Tables, is true this distance (...) it is almost of 4° and 9'(...)", completing "(...) However, if we accept Albatenius opinion the distance is a bit less (...)" (Nunes, 1566, p. 375). Unfortunately for Nunes, Werner's calculus was wrong but I call attention to the passage "if it is true" that, in my opinion, does not show an absolute compromise towards the value of his most considered German peer.

of later cosmographers such as Andrés García de Céspedes in his *Regimiento de Navegacion* (1606) – led to the conclusion that the errors were in the order of a minute of a degree which, at the time, was almost indifferent for navigation purposes. Fournier, in Chapter XXIV – *Sçavoir si c'est à tort que Nonius reprend l'usage du Nocturlabe*, commented on Nunes' demonstration of the variation of the distance of the pole star to the pole, defending that these values were small and were not that important in practical terms.

One of Nunes' most relevant suggestions was about the methods to obtain latitude when the Sun was not on the meridian of the observer (that is, when out of mid-day). Again, this procedure was important to obtain latitude at sea at any time and intended to increase the set of techniques available to seamen. In Chapter 10 he analysed a preceding proposition by Peter Apian (1495-1552) and in Chapter 11, analysed another by Jakob Ziegler (c. 1470-1549) (Apian, 1524; Ziegler, 1531). He commented on the use of Ziegler's apparatus (similar to an armillary sphere, meant to solve several astronomical problems) and concluded on the inapplicability of the method, as he had done with Apiano's. Among others, these comments called Deschales' attention, as can be seen in his *L'art de naviger*. In Book VI – *De l'estime corrigé par la latitude*, he made several references to the conditions of application of the regiments of the Sun and pole star and gave some points as to the determination of the latitude at any time of the day. Chapter 11 also contained references to the problem of the sundial of Acaz.

In chapter 18, Nunes went back to subjects related to gnomonics and, assuming the role of cosmographer, he complained about the scarce usage of sundials by seamen. Like he had done in 1537, he recommended the use of an interesting "shadow" instrument to obtain Sun's azimuths. Then, he commented on the conditions under which sun beams were parallel – an important topic in optics and catoptrics – and, among other things, he noticed that the altitude of celestial bodies should be corrected by considering their geometric center (which was in fact important for the Sun and the Moon).

The second part of the *Opera* consisted in thirty-six annotations to Peuerbach's *Theoricae nouae planetarum*. When compared with the notes of 1537, this fresh approach to the text, was much more erudite and selective. It did not intend to comment the complete text but only what he thought needed a better explanation or clarification. The notes cleared and corrected some aspects of Peuerbach's text but also some parts of texts by his commentators such as Schreckenfuchs, Capuano and Reinhold to cite a few. Nunes' commentaries were always printed together with the first part dedicated to navigation (three editions in 1566, 1573, 1592). It is commonly admitted by scholars and historians that these notes are some of the most erudite ever published (for example, Pierre Gassendi included the text among the most important *Theoricae* commentaries) (Gassendi, 1658, vol. v, p. 521) and some extant copies are even bound together with Copernicus' *De revolutionibus*.[43]

Pedro Nunes' followed the original sequence of Peuerbach's text: theories for the Sun, Moon, outer planets, inner planets, "passion" of the planets and the movement of the eighth sphere. Due to its highly technical level, this text was not connected with practical cosmographic duties. Nevertheless, the subjects covered would be of interest to advanced cosmographers that used the original *Theoricae nouae planetarum* as an auxiliary textbook. Outside Portugal, Nunes' text was familiar to Spanish cosmographers such as Cedillo Dias and García de Céspedes and also to astronomers outside the peninsula such as Michael Maestlin (Kepler's professor) and Giovanni Antonio Magini to cite a few. The text entered Jesuit teaching network through Cristopher Clavius; Giovanni Battista Riccioli esteemed it; and it was cited by Claude Deschales in his famous *Cursus seu mundus mathematicus* (1674). Later, Jean-Baptiste Delambre made important and thorough references to it in his *Histoire de l'Astronomie du Moyen Âge* (1819), stating : "(...) il est encore de tous les commentateurs de Purbach, celui qui était le plus géomètre et le plus soigneux; il est aussi le plus instructif" (Delambre, 1819, p. 280).

When addressing the Sun's theory, Nunes considered the determination of the parameters of the orbit. He also improved the values of the eccentricity of the orbit and position of the apogee, a work that was praised later by Clavius, Riccioli and Deschales. His second annotation dealt with the relations between the mean movement and the true movement of the Sun and tried to find its equality conditions. Nunes also presented for the first time a demonstration about the important Moon theory that stated the equation of the center of the moon had a maximum (his notes 1 to 8). This was a meaningful contribution since it solved a maximum value problem without the use of differential calculus.[44] The last notes are also very interesting and dedicated to the movement of the eighth sphere, comparing Alphonsine's predictions with Thabit's. Delambre and Riccioli remembered Nunes for these contributions as one important commentator of Thabit's text.

To conclude, this paper aimed to show Pedro Nunes' foremost output in astronomy, namely his work on translations of earlier texts, commen-

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[43] See (Gingerich, 2002).

[44] The Portuguese historian Francisco Gomes Teixeira called it "a masterpiece of ingenious work and art" (Teixeira, 1934, p. 146).

taries to those texts and original research. Although many aspects were not explored and developed here, plenty was shown about the facets of that work and about how astronomy was integrated in his activity as a cosmographer. At the same time, another goal was to show that, contrarily to many previous mathematicians and astronomers who worked frequently on highly technical issues originating in classical problems, most of the subjects that attracted Nunes were rooted in his contact with the difficulties of seamen and artisans.

Aknowledgments
I wish to thank Henrique Leitão for his critical reading throughout the different drafts of this paper.

References

ALBUQUERQUE Luís de (1988), *Astronomical Navigation,* Lisboa, Comissão Nacional para a Comemoração dos Descobrimentos Portugueses.

ALBUQUERQUE Luís de (1988b), *Instruments of navigation*, Lisboa, Comissão Nacional para a Comemoração dos Descobrimentos Portugueses.

ALMEIDA Bruno (2011), *A influência da obra de Pedro Nunes na Náutica dos séculos XVI e XVII: um estudo de transmissão de conhecimento*, Ph.D. Thesis, Universidade de Lisboa.

ALMEIDA Bruno (2012), "On the origins of Dee's mathematical programme: The John Dee–Pedro Nunes connection", *Studies in History and Philosophy of Science*, vol. 43, p. 460-469.

ALMEIDA Bruno & LEITÃO Henrique (2012), "A anotação de Pedro Nunes acerca da 'largura'dos climas", in Luís Semedo DE MATOS (ed.), *António Estácio dos Reis, Marinheiro por vocação e Historiador por devoção. Estudos de Homenagem*, Lisboa, Academia de Marinha, p. 123-142.

APIAN Peter (1524), *Cosmographicus liber Petri Apiani mathematici studiose collectus*, Landshut, J. Weyssenburger.

BALDI Bernardino (1998), *Le Vite de' Matematici. Edizione annotata e commentata della parte medievale e rinascimentale*, Elio Nenci (ed.), Milano, Franco Angeli.

CARVALHO Joaquim de (1952), *Uma obra desconhecida e inédita de Pedro Nunes: [defensão do tratado de rumação do globo para a arte de navegar], Inedita ac rediuiua: subsídios para a história da filosofia e da ciência em Portugal*, Coimbra, Universidade de Coimbra.

CLAGETT Marshall (1978), *Archimedes in the Middle Ages, Volume Three. The fate of the medieval Archimedes, 1300-1565,* Philadelphia, American Philosophical Society.

CLAVIUS Christoph (1593), *Astrolabium*, Romae, Bartholomai Grassi.

CLAVIUS Christoph (1611), *Operum Mathematicarum*, Tome I, Mainz, Anton Hierat.

COIGNET Michel (1581), *Instruction nouvelle des poincts plus excellens & necessaires touchant l'art de naviguer*, Anvers, Henry Hendrix.

COYNE G. V., HOSKIN M. A. & PEDERSEN O. (eds.) (1983), *Gregorian Reform of the Calendar: Proceedings of the Vatican Conference to Commemorate its 400th anniversary, 1582-1982*, Vatican, Pontificia Academia Scientiarum, Specola Vaticana.

DELAMBRE Jean-Baptiste (1819), *Histoire de l'Astronomie du Moyen Âge,* Paris, Courcier.

DENYS Guillaume (1666), *L'Art de naviguer perfectionné par la connaissance de la variation,* Dieppe, Nicolas du Buc.

DESCHALES Claude (1674), *Cursus seu mundus mathematicus,* Lyon, Anisson.

DESCHALES Claude (1677), *L'art de naviguer démontré par principes & confirmé par plusieurs observations tirées de l'expérience*, Paris, Estienne Michallet.

ELMES James (1852), *Sir Christopher Wren and his times,* London, Chapman and Hall.

EUTOCIUS OF ASCALON (1544), *Archimēdous tou Syrakousiou, ta mechri nyn sōzomena, hapanta. Archimedis Syracusani philosophi ac geometrae excellentissimi opera, quæ quidem exstant, omnia, multis jam seculis desiderata, atque à quàm paucissimis hactenus visa, nuncque primùm & graecè & latinè in lucem edita. Quorum catalogum versa pagina reperies. Adjecta quoque sunt Eutocii Ascalonitae in eosdem Archimedis libros commentaria, item græcè & latinè, nunquam antea excusa*, Bâle, Ioannes Heruagius.

FINE Oronce (1528), *La théoriques des cielz, mouvemens et termes practiques des sept planètes*, Paris, J. P. de Tours.

FINE Oronce (1532), *Orontii Finei Protomathesis : opus varium, ac scitu non minus utile quam iucundum*, Paris, Morrhius.

FINE Oronce (1544), *Orontii Finaei Delphinatis regii Mathematicarum Lutetiae professoris. Quadratura circuli tandem inventa & clarissimè demonstrata. De circuli mensura, & ratione circumferentiae ad diametrum, demonstrationes duae. De multangularum omnium & regularium figurarum descriptione, liber hactenus desideratus. De invenienda longitudinis locorum differentia, aliter quàm per lunares eclipses, etiam dato quovis tempore, liber admodùm singularis. Planisphaerium geographicum, quo tum longitudinis atque latitudinis differentiae, tum directae locorum deprehenduntur elongationes (...)*, Paris, Simonem Colinaeum.

FOURNIER Georges (1643), *Hydrographie contenant la théorie et la practique de toutes les parties de la navigation*, Paris, Michel Soly.

GARCÍA DE CÉSPEDES Andrés (1606), *Regimiento de Navegacion mando haser El Rei Nvestro Señor por orden de sv conseio real de las Índias a Andres Garcia de Cespedes sv cosmógrafo maior*, Madrid, Iuan de la Cuesta.

GASSENDI Pierre (1658), *Opera omnia*, Volume V, Lyon, Laurentii Anisson.

GINGERICH Owen (2002), *An annotated census of Copernicus' De Revolutionibus (Nuremberg, 1543 and Basel, 1566)*, Nuremberg/Leiden, Brill.

JARDINE Nicholas (1998), "The places of Astronomy in early modern culture", *Journal for the History of Astronomy,* vol. 29, p. 49-62.

KNOBLOCH Eberhard (2003), "Nunes' Book on twilights", in Luís TRABUCHO DE CAMPOS, Henrique LEITÃO & João Filipe QUEIRÓ (eds.), *International Conference Petri Nonii Salaciensis Opera, Lisbon-Coimbra, 24-25 May 2002. Proceedings*, Lisboa, Departamento de Matemática da Faculdade de Ciências da Universidade de Lisboa, p. 113-140.

LEITÃO Henrique (2002a), "Sobre a difusão europeia da obra de Pedro Nunes", *Oceanos*, vol. 49, p. 110-128.

LEITÃO Henrique (2002b), "Uma nota sobre Pedro Nunes e Copérnico", *Gazeta de Matemática*, vol. 143, p. 60-78.

LEITÃO Henrique & MARTINS Lígia Azevedo (eds.) (2002), *Pedro Nunes, 1502-1578: Novas terras, novos mares e o que mays he: novo ceo e novas estrellas*, Lisboa, Biblioteca Nacional de Portugal.

LEITÃO Henrique (2006), "Ars e ratio: a náutica e a constituição da ciência moderna", in María Isabel VICENTE MAROTO & Mariano Esteban PIÑEIRO (eds.), *Actas da XII Reunión de Historia de la Náutica y de la Hidrografia, La ciencia y el mar*, Valladolid, Los autores, p. 183-207.

LEITÃO Henrique (2007), "Maritime discoveries and the discovery of Science: Pedro Nunes and Early Modern Science", in Victor Navarro-BROTÓNS & William EAMON (eds.), *Más allá de la Leyenda Negra: España y la Revolución Científica. Beyond the Black Legend: Spain and the Scientific Revolution*, València, Instituto de Historia de la Ciencia y Documentación López Piñero, Universitat de València, CSIC, p. 89-104.

LEITÃO Henrique (2009), "Pedro Nunes against Oronce Fine: Content and context of a refutation", in Alexander MARR (ed.), *The Worlds of Oronce Fine: Mathematics, Instruments and Print in Renaissance France*, Donington, Shaun Tyas, p. 156-171.

LEITÃO Henrique (2013), "Pedro Nunes e a Matemática do Século XVI", in Carlos FIOLHAIS, Carlota SIMÕES & Décio MARTINS (eds.), *História da Ciência Luso-Brasileira. Coimbra entre Portugal e o Brasil*, Coimbra, Imprensa da Universidade, p. 19-33.

MOTA Bernardo & LEITÃO Henrique (2013), "Uma carta de Jacques Peletier a Pedro Nunes", in Maria Cristina PIMENTEL & Paulo FARMHOUSE ALBERTO (eds.), *Vir bonus peritissimus aeque. Estudos de homenagem a Arnaldo do Espírito Santo,* Lisboa, Centro de Estudos Clássicos, p. 589-599.

NUNES Pedro (1537), *Tratado da sphera com a Theorica do Sol e da Lua. E ho primeiro liuro da Geographia de Claudio Ptolomeo Alexãdrino. Tirados nouamente de Latim em lingoagem pello Doutor Pero Nunez (...)*, Lisboa, Germão Galharde. Repr. in *Obras*, vol. I, Lisboa, Fundação Calouste Gulbenkian, 2002.

NUNES Pedro (1542), *Petri Nonii Salaciensis, De Crepusculis Liber Unus, Nunc Recens et Natus Et Editus. Item Allacen Arabis Vetustissimi, De Causis Crepusculorum Liber Unus, A Gerardo Cremonensi Iam Olim Latinitate Donatus, Nunc Vero Omnium Primum In Lucem Editus*, Lisboa, Ludouicus Rodericus. Repr. in *Obras*, vol. II, Lisboa, Fundação Calouste Gulbenkian, 2003.

NUNES Pedro (1546), *De erratis Orontii Finaei regii mathematicarum Lutetiae professoris. Qui putauit inter duas datas lineas, binas medias proportionales sub continua proportione inuenisse, circulum quadrasse, cubum duplicasse, multangulum quodcunque rectilineum in circulo describendi, artem tradidisse et longitudinis locorum differentias aliter quam per eclipses lunares, etiam dato quouis tempore manifestas fecisse, Petrii Nonii Salaciensis Liber vnus*, Coimbra, ex Officina Ioannis Barrerii et Ioannnis Alvari. Repr. in *Obras*, vol. III, Lisboa, Fundação Calouste Gulbenkian, 2005.

NUNES Pedro (1559), *Sphaera Ioannis De Sacro Bosco Emendata. Eliae Vineti Santonis Scholia in eandem Sphaeram, ab ipso authore restituta […] et Petri Nonii Salaciencis Demonstrationem eorum, quae in extremo capite de Climatibus Sacroboscius scribit de inaequali Climatum latitudine, eodem Vineto Interprete*, Paris, Gulielmum Cauellat.

NUNES Pedro (1566), *Petri Nonii Salaciensis Opera, quae complectuntur, primum, duos libros, in quorum priore tractantur pulcherrima problemata. In altero traduntur ex Mathematicis disciplinis regulae et instrumenta artis nauigandi, quibus uaria rerum Astronomicarum* φαινόμενα *circa coelestium corporum motus explorare possumus. Deinde, Annotationes in Aristotelis Problema Mechani cum de Motu nauigij ex remis. Postremo, Annotationes in Planetarum Theoricas Georgii Purbachii, quibus multa hactenus perperam intellecta, ab aliisque praeterita exponuntur. Quae quemadmodum mole exigua uidentur, ita uirtute in gentia, Lector candide, intelliges*, Basel, officina Henricpetrina, 1566. Repr. in *Obras*, vol. IV, Lisboa, Fundação Calouste Gulbenkian, 2008 (*De arte atque ratione nauigandi*) and in *Obras*, vol. V, Lisboa, Fundação Calouste Gulbenkian, 2011 (*In Theoricas Planetarum Georgii Purbachii Annotationes*).

PELETIER Jacques (1554), *L'algebre de Jaques Peletier du Mans departie an deus liures*, Lyon, Ian de Tolurnes.

REGIOMONTANUS Johannes (1490), *Tabule directionum profectionumque Joannis Germani de Regiomonte in nativitatibus multum utiles,* Augsburg, Erhard Ratdolt.

ROSS Richard Peter (1971), *Studies on Oronce Finé (1494-1555)*, Ph.D. Thesis, Columbia University (New York).

SABRA A. I. (1967), "The authorship of the *Liber de crepusculis*, an 11th century work on atmospheric refraction", *Isis*, vol. 58, p. 77-85.

SMART W. M. (1931), *Text-Book on Spherical Astronomy,* Cambridge (UK), Cambridge University Press (Edition of 1971).

TEIXEIRA Francisco Gomes (1934), *História das matemáticas em Portugal,* Lisboa, Academia das Ciências de Lisboa.

TOVAR Simón de (1595), *Examen i censura, por el doctor Simón de Tovar, del modo de averiguar las alturas de las tierras, por la altura de la estrella del norte, tomada com la ballestilla*, Sevilla, Rodrigo de Cabrera.

VALLERIANI Matteo (2017), "The Tracts on the 'Sphere': Knowledge Restructured Over a Network", in Matteo VALLERIANI (ed.), *The structures of practical knowledge*, Cham, Springer, p. 421-473.

VILAR Carlos (2006), *O De Crepusculis de Pedro Nunes (uma leitura actualizada)*, Braga, CMAT (Centro de Matemática da Universidade do Minho).

VINET Élie (1559), *Sphaera Ioannis De Sacro Bosco Emendata. Eliae Vineti Santonis Scholia in eandem Sphaeram, ab ipso authore restituta [...] et Petri Nonii Salaciencis Demonstrationem eorum, quae in extremo capite de Climatibus Sacroboscius scribit de inaequali Climatum latitudine, eodem Vineto,* Interprete, Paris, Gulielmum Cauellat.

VINET Élie (1583), *La maniere de faire des solaires, que communement on appele Quadrans*, Bordeaux, Simon Millanges.

WERNER Johannes (1514), *In hoc opere haec co[n]tinentur: Noua translatio primi libri Geographiæ Cl. Ptolomæi Geographia quæ quidem translatio verbum habet e verbo fideliter expressum Præceptio super plana terraru[m] orbis descriptione Libellus de quatuor terrarum orbis in plano figurationibus Epistola ad Bessarionem de compositione et usu cuiusd. meteoroscopii Libellus Ioannis Verneri Nurenbergen[si] de quatuor aliis planis terrarum orbis descriptionibus propositio... De his quæ geographiæ debent adesse Georgii Amirucii oposculum In Georgii Amirucii Constantinopolitani opusculum: Ioannis Verneri Nurenbergen[si] appendices Ad Bessarionem Cardinalem Nicenum ac patriarcham Co[n]stantinopolitanum: de compositione Metheoroscopii*, Nürnberg, Johann Stuchs.

WESTMAN Robert S. (1980), "The astronomer's role in the sixteenth century: a preliminary study", *History of Science,* vol. 18, p. 105-147.

WRIGHT Edward (1599), *Certaine Errors in Navigation, Arising either of the ordinarie erroneous making or using of the sea Chart, Compasse, Crosse staffe, and Tables of the Sunne, and fixed Starres detected and corrected*, London, Valentine Sims.

ZIEGLER Jakob (1531), *Iacobi Ziegleri, Lancavi, Bavari, In C. Plinii de Naturali Historia librum secundum commentarius, quo difficultates Plinianae, praesertim astronomicae, omnes tolluntur. Item, Organum quo Catholica Syderum, ut apud Plinium est, Mira Arte Docetur. Item, Georgii Collimitii, et Ioachimi Vadiani, in eundem secundum Plinij scholia quaedam. Ad haec Index rerum quae hic disputantur praecipiarum, utilis. Opus nunc recens natum, & primum aeditium,* Bâle, Henricus Petrus.