TWO CENTURIES OF NAUTICAL ALMANAC CALCULATIONS (1792-2002). FIRST PERIOD

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1. Introduction

In the mid-18th century, Jorge Juan y Santacilia proposed to the Marquis of La Ensenada the founding of the Royal Observatory of Cádiz, whose missions included, from its origins, providing "precise astronomical anniversaries for the use of navigators"1 . These anniversaries were published as an annex to the *General State of the Navy* until 1791 when the *Nautical Almanac and Astronomical Ephemerides for the leap year of 1792 were printed in Madrid,* one of the first national anniversaries that appear in history, and which has been published continuously since then.

Throughout its more than two centuries of life, the *Nautical Almanac* publication has evolved both in its form and its content; The paradigm of this evolution is probably provided by the problem of determining longitude at sea, where the appearance of Mayer's Tables allowed the application of the method of lunar distances, which was later abandoned when marine chronometers were developed.

This work describes the various modifications undergone by the *Nautical Almanac* to adapt to the advances experienced by science and technology. Thus, on the one hand, the developments in the techniques and methods of astronomy have allowed a constant improvement in the precision of astronomical observations. This increasing precision has motivated the evolution of theories of celestial mechanics, from the classic Newtonian theory to modern gravitational theories including relativistic terms, terms that affect not only spatial coordinates but also time.

On the other hand, the development of mathematics together with the appearance of computing in recent years, has made it possible to develop increasingly precise algorithms that, with increasingly powerful calculation means, make it possible to apply theories with the precision provided by modern observations.

[1] Royal Order of December 3, 1790 from the Minister of the Navy, Antonio Valdés, to the Lieutenant General of the Navy, José de Mazarredo. General Navy Archive; Series: Observatory; Subseries: Generality; File: 1785—1830.

Another important aspect to consider is international cooperation, which Since the end of the 19th century it has been decisive in the way of presenting ephemeris for use by the international community. The evolution of the *Almana-que Náutico* is reflected in the information it provides. In this sense, it is obligatory refer to the works of Lafuente and Sellés [1988] and González [1992]. In the first of them the sources used in the preparation of the *Almana-que Náutico* until 1831 are documented; The second, which covers the dates between 1831 and 1924, uses another perspective, although it cites some sources used in the calculations until 1845. To detect this evolution, we have studied in depth the collection of almanacs that are preserved in the Observatory, in whose prefaces they used to collect the most relevant changes to the publication, although they were not always announced in the date on which they had occurred.

The reasons for the variation of the information in the *Nautical Almanac,* both in form and content, they must be sought fundamentally in the evolution of gravitation theories (Newtonian, perturbations, relativity) used in the calculations and in the constant improvement in the determination of the constants that appear in said theories. This motivated the appearance of successive new tables with specific theories for the movement of each star, which were used as sources for the preparation of the *Nautical Almanac.*

2. The *Nautical Almanac*

The appearance of the first nautical almanacs is closely linked with the problem of determining length. While marine chronometers were not sufficiently perfected, the method of lunar distances2 ; but the practical application of this method was not possible until the appearance of the Moon Tables by Tobías Mayer, in which the anniversaries Lunars offered sufficient precision for determining longitude at sea with the necessary accuracy.

Mayer's Tables were not in general use among sailors, due to the cumbersome and lengthy calculations necessary to obtain from them the places of the Moon and, from them, the lunar distances. In order to simplify these calculations to the navigator, *The Nautical Almanac and Astronomical Ephemeris for the year 1767* is published in England (hereinafter, NA), collection of ephemeris astronomical for the use of astronomers and navigators, where the tables of lunar distances that facilitated the practical resolution of determining the length. Although the Board of Longitudes *(Bureau des Longitudes)* in France published the *Connaisance des Temps* (CT in what follows) since 1679, the tables of the

[2] A brief description of the method and bibliographic references can be found in LAFUENTE AND SELLÉS [1988, pp. 41-44].

Lunar distances were taken from the English, who sent them to them as soon as they had them prepared so that they could include them in their anniversaries.

The Spanish sailors of the 18th century depended on foreign anniversaries, either French or English, which in addition to being difficult to obtain were referred to meridians other than the one corresponding to the Cádiz Observatory, origin of our cartography. For this reason it was decided to include a supplement annexed to the *General State of the Navy* with some astronomical anniversaries taken from the CT. However, the need to include more information regarding the meridian of Cádiz motivates that, at the end of 1790, Carlos IV dictates a resolution in which it is ordered that astronomical anniversaries be autonomously calculated and published to use of navigators, and this task is entrusted to the Royal Observatory of Cádiz. The first intention of publishing these anniversaries as a supplement to the *General State of the Navy,* it was decided that they would appear as an independent publication, and in 1791 the first nautical almanac was published: the *Nautical Almanac and astronomical anniversaries for the leap year of 1792.* Meritorious saving the historical vicissitudes that have occurred since that distant date of the first publication, the series of annual volumes in which nautical almanacs appear has had no interruption.

In the evolution of the *Nautical Almanac* we distinguish four eras based on tion of its content:

- First period: 1792—1854. It is characterized by the start of the publication, called *Nautical Almanac and Astronomical Ephemeris.* Despite the nautical origin of the publication, it is aimed at both astronomers and navigators, providing information that is useful to some, others, or both.

- Second period: 1855—1911. It is now simply called *Almanac Náuti-co,* trying to reflect the new orientation of the publication from this point onwards. date, in which it is about giving preference to practical navigation. However, practical astronomy is not neglected and the number of the apparent positions of stars that appear in the publication. For other part the ephemeris of the solar system is provided in average time and with higher density, so that the linear interpolation is sufficiently precise. Starting with the 1905 issue, the lunar distances are suppressed, as they are The use of chronometers is common among sailors.
- Third period: 1912—1950. The *Extract from the Nautical Almanac* appears where only the information necessary for sailors is included. International collaboration becomes effective, resulting in the distribution of work between different institutions, with the San Fernando Observatory being responsible for calculating the apparent positions of a certain number of hourly stars, a number that varied over time. for various reasons.

• Current era. In the volume for 1951 there is a change of name, and
The Extract is renamed *the Nautical Almanac for the use of sailors*
until the 1962 volume, which reduced its name to the current *Nautical Almanac;* To
avoid confusion, the publication dedicated to astronomers and geodesists,
which was called *the Nautical Almanac,* starting with the 1961 volume it was
renamed *Astronomical Ephemerides.* The information provided to sailors
remains without important variations from 1951 to date, counting on
an "Explanation" from the 1952 volume.

What follows describes the evolution of the *Nautical Almanac* (hereinafter hereinafter AN or Almanac, interchangeably) in its first period, leaving for subsequent opportunity the detailed study of the causes that motivated the changes subsequent consequences suffered by the publication.

3. The first era of the *Nautical Almanac* (1792—1854)

At this time we consider the 63 volumes for the years from 1792, the first Almanac, until 1854. It covers the one studied by Lafuente and Sellés, who in Chapter X of their book makes a detailed study of the causes that motivated the origin of the AN, as well as its content during the first years of publication.

The Almanac began with a preface highlighting the most relevant aspects of the publication; followed with an explanation of the characters used, the main articles of the calendar (year corresponding to other calendars, ecclesiastical computation, four temporas and movable festivals), the apparent obliquity of the ecliptic with the equation of the equinoctial points, and the eclipses of the Sun and Moon; The rest of the information was organized by month, and for each of them, a series of calendar data, including the Saints of the day and holidays, as well such as the phases of the Moon and some astronomical phenomena. Other phenomena relevant, such as the announcements of Mercury's passage through the solar disk (AN 1799, 1802, 1832, 1845 and 1848) and the disappearances and reappearances of the rings of Saturn (AN 1803, 1819, 1832, 1833, 1848 and 1849), appeared in the first pages or even in the same preface.

With respect to the ephemeris, basically the positions or places of the Sun are included, each day, and of the Moon, every 12 hours, except for the declination that occurs every 6 hours; The locations of the observable planets are presented every five days, except Mercury, every 3, and the planet Herschel (later renamed like Uranus) every 10 days. The lunar distances to the Sun and nine bright stars were presented every three hours. In addition, configurations of the satellites of Jupiter and the explanation of the use of the tables with examples. In this At that time the publication began, and due to the rush in the edition of the first volume, it is necessary to copy it from English in a substantial part. Thus, Cipriano Vimercati details us in the preface of the first Almanac:

"For the places on the Sun, reductions have simply been made from the Greenwich Meridian to that of our Royal Observatory.

For those of the Moon and Mercury, the method of interpolations has been applied, because the speed and irregularity of the movement of these planets did not allow one to be content with the proportional part: this was enough, as in the Sun, for Venus, Mars, Jupiter and Saturn.

The phenomena that depend on the parameters have been directly calculated. laxes, such as eclipses, and the occultations of stars by the Moon.

The same has been practiced for places on the new planet Herschell, which we do not find in the Greenwich Almanac, however which began to occur in a second edition of 1788 made in the year former; Well, they already appear from 1793 onwards: and we execute it using the tables published by Jeaurat in the Knowledge of Times of 1787.

In the eclipses of the Satellites of Jupiter, although the moment of the phenomenon has been deduced simply by the difference of Meridians, they have been determined with his opportune signal, those who do not see themselves in Greenwich will be able be observed comfortably in Cádiz, and suppressing the signs in those that the opposite can be done there and not here, because of the diversity in the depression of the Sun and height of Jupiter: also arranging the configurations of the Satellites, whose positions and aspects for the times indicated each month in Cádiz have been indicated with all possible care by the graphic method or jovilabio that is in use and explained by La Lande in his exposition of astronomical calculation.

At lunar distances it has seemed appropriate to leave the tables as which the English ones are, reducing their time to that of Cádiz with the subtraction of the 25' 09" of the difference of Meridians: fair testimony of our recognition to those who first undertook such painful tasks: and it cannot be so soon to vary this method, until we get rid of much preliminary work to round off originally our company."

Also appearing in this volume was a collection of auxiliary tables "for the uses of astronomy and navigation" with its corresponding explanation; between These tables included with number XI a catalog with the right ascension, the declination and its annual variations, of 120 stars of first, second and even third magnitude, reduced to the mean equator and equinox of 1791.

For the Almanac of 1793, the places of the
Sun and the Moon, although for the latter the position published for midnight on the Observatory meridian was obtained by interpolation of those
They calculated for noon. In this volume the general aberration tables (Table XIII), calculated by Delambre, and the nutation tables (three tables in the
Table XIV), by Lambert; Also included are the formulas from which
They had constructed these tables and the relevant explanations with examples. An errata appears for the first time in this volume, the editors' cross, in the
that those observed in the 1792 volume are listed, and that they are justified by the urgency of the print:

> "The work of that Almanac having been as executive as it indicated in his preface (p. VII), and a sum was therefore rushed in your impression,…"

In the 1794 volume everything is calculated except the lunar distances, which continued to be copied from the English until the 1810 volume, which was calculated entirely in the Observatory. In this 1794 volume, the aberration and nutation tables are suppressed and replaced by others related to transformations.
that link the mean solar time and the angular motion of the stars; I also know
replaces the table of "variation of the stars in height during a minute of time"
by "correction of angles observed with reflection instruments by the
deviation from the plane in which the contact is observed." In this issue, the AN provides an innovation with respect to CT and NA regarding concealments of
stars by the Moon, by referring the emergence of the star to the vertical that passes through the center of the Moon, rather than simply indicating the apparent difference in Latitude of the two stars at the moment of said event. This data offered greater
precision of the position where the star should appear, thus facilitating the observation of the phenomenon.

The one from 1795 remains essentially the same as the previous one, although some tables are replaced by another more useful for navigators. Announces the imminent appearance of the *Collection of Tables for various uses of navigation,* by the Ship Captain Joseph de Mendoza y Ríos (which will be published in 1800), which will excuse the insertion into the AN of auxiliary tables, providing space in the appendices for the dissemination of methods, formulas and new investigations[3] . In this volume The "Method to find the true distance of the Moon" appears as a scoop to the Sun, or to a star, known the apparent, or observed, and the apparent heights of

[3] As the TN Rodrigo Armesto will remind us in the preface of the 1801 volume, one of the main purposes of the publication of the AN, was "…to successively provide Navigators with knowledge of the methods, tables and instructions that can help them in the practice of his painful profession."

said stars", by Francisco López Royo, Ensign of the Royal Navy.
The list of works that appeared in the appendices of the AN until 1836 is found in LAFUENTE Y SELLÉS [1988, pp. 387-395]; This relationship is completed by González [1995], who adds a brief review to each of the memoirs cited by Lafuente and Sellés, and expands it with two memoirs: one in the AN for 1813 (printed in London) and another in the of 1845. The list should be completed with Sánchez Cerquero's report "On the latitude of the Royal Observatory of San Fernando", which appeared in the 1838 volume.

Many of the changes that appeared in the Almanacs of this period are minor, some affecting mere editorial aspects, such as the one that occurred in the AN for 1802 from which the places on the planet Herschel, which to date appeared as a supplement At the end of the anniversaries and before the Explanation, they begin to fill the monthly pages with the places of the planets; or those derived from the hardships of the War of Independence, due to which the edition of the AN for 1811 was delayed, which was printed in London (as well as those of 1812-1814) without the articles that were not considered essential for sailors. however, having been worked on (longitudes of the Moon, places of the Planets and the Eclipses of the Satellites of Jupiter), and from which the Explanation is also deleted, which will appear reduced in the following issues up to and including 1830. Also, from the 1818 volume the seasons of the planets go from the column of phenomena to the head of their respective tables along with the other phases, in the 1838 volume they go from leaflet to page, and in the 1839 volume they are no longer ordered. lunar distances by stars and are grouped by days.

Other changes were aimed at facilitating the interpolation of the tabulated quantities: thus, starting from the AN for 1810 the declinations of the Moon are stamped for 6 hours, and in the 1831 and following the difference is presented daily for both the right ascension and declination of the Sun.

The most relevant changes were: the change in the reference meridian, which occurred from the AN to 1801 with the change from the Cádiz Observatory to the Island of León; the insertion of the largest tides that will occur in the year, starting from the AN for 1809; the addition of a table for the reduction of the equatorial horizontal parallax of the Moon at any latitude4 , which appears for the first time in the AN for 1810 and which is definitively added to the Almanac starting in the 1815 volume; and the definitive incorporation from 1836 of tables of mean atmospheric refractions, which had already appeared in the ANs of 1822, 1829 and 1834.

Apart from the unwanted typos that were attested, some errors of various kinds also appeared, generally minor. Thus, in the preface of

[4] Until then, the horizontal parallax of the Moon was only reduced for the latitude of Cádiz.

taken for 1802, Rodrigo Armesto corrects the error of 1.8 seconds in the longitude provided in the previous volume for the Island's meridian, "certainly not a difference from the greatest entity, but one that does not allow us to ignore the accuracy and good faith that we profess." And in the 1824 volume, the last one signed by Julián Canelas, he takes advantage of the preface to briefly review the evolution of the calculations carried out to date; In that volume a “Warning” appears on an unnumbered page, in which Josef Sánchez Cerquero, signing as
Acting director of the Observatory, warns of an error in the mobile festivals and advise how to correct it:

> “The same ease of the rules that are used to find the Passover must have been the reason for this oversight, because it is common to use many means of verification, only for complicated operations, in which mistakes are feared with more reason. However, since I am in charge of the Directorate of the Observatory, I have taken measures, with which I believe is absolutely impossible for such a thing to happen again. mistake. Ultimately, this does not affect in any way the astronomical part of the Nautical Almanac, which constitutes its main purpose.
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> What has been said is enough for the satisfaction of the enlightened public. Before the Criticism, which nothing conceals, has some right to ask for indulgence person who was not the one who made the mistake; and the depressors of everything that is Spanish warns that same person who in most of The copies of the Paris Knowledge of Times of 1821 appeared offenses much more serious than the one in question in the mobile festivals of that year; which proves that he who does nothing is the only one who never “wrong.”

And Sánchez Cerquero himself warns in the preface of the 1830 volume of the mistake in all previous volumes of the number of years of the first Olympiad and the founding of Rome, and provides the rule that will be followed from from that moment.

However, the preparation of the AN was extremely careful and, in general, the errors introduced came from the sources used, which had been taken as good. Thus, in the AN for 1819, José M.ª de la Cuesta explains how correct an error in the calculations of the locations of the Moon that had affected the volumes 1810—18185. Another error is detected by Sánchez Cerquero after an exhaustive analysis of the Moon tables used to calculate its equatorial parallax.

[5] This error, detected by Colonel of the Royal Army Corps of Engineers Francisco Lemaur, and reported by Josef Joaquin Ferrer, came from the sources used (tables of Bürg, compiled by Delambre) and Delambre had already warned about it in the CT of 1810 (printed in August 1808), which had not been acquired at the Observatory.

error that he published in the preface of the AN for 1832, correcting the part of the wrong table[6], as well as other errors detected in those same Moon tables, and others in the tables used to calculate the passages of Mercury through the solar disk.

The rest of the modifications refer to the appearance of some auxiliary tables, and to the successive updates of the star catalogs that occurred in the volumes of 1798, 1799, 1830, 1840, 1841 and 1850. From this last volume, the catalog will be updated in the following volumes referring to January 1, year published. In the AN for 1842 the apparent positions of 38 stars are published for the first time: 36 main hourly ones of 10 in 10 days (as well as the average positions in the year) and ÿ (the Polaris) and ÿ of the Bear Minor daily. Although For the ordinary practice of astronomical navigation, the average positions obtained from the catalogs were used without appreciable error, the new tables were provided, in emulation of other almanacs, in order to satisfy the needs of astronomers to avoid correcting for aberration and nutation, when going from the average position given by the catalog to the apparent one observed.

4. Sources used in the first period

In this first period, the fundamental source for carrying out the calculations is Lalande's *Astronomy ,* in its second and third editions. In sayings treatises Lalande compiled tables from other authors, apart from his own. The sources used in the preparation of the almanacs are detailed below, except for the one from 1792, which was copied in large part from the NA of 1792, accompanying, in If applicable, details of the edition or editions that the Observatory has.

4.1. Places of the Sun

In the AN of 1793, the Mayer del Sol Tables were worked on, delivered to the Tribunal of Longitude after his death and published in 1770, the same ones that used in the NA 1792. Starting with the AN for 1794 and until the AN for 1810, They use the Wire Tables for the Sun, published in the III edition of Lalande's *Astronomy ,* where the position of the Sun was given with minor errors of 10". From the AN for 1811 the Sun is calculated with "the new tables of Mr. De Lambre, printed in Paris in 1806, and published by the Board of Longitudes of France in its first part of astronomical tables", although from the AN to 1822 the equation of time is not taken from Delambre's tables, but is calculated by the difference between the true and mean Right Ascensions of the Sun. of the AN for 1833, the Tables of Carlini, Royal Astronomer of Milan, published in 1810 are used (built on the same elements as the French ones of 1806, that until now were used, but arranged in a way that greatly facilitates

[6] A handwritten page appears loosely in the volume of the Observatory's collection where some of the values stamped in the table are corrected.

calculation, and more correct than the previous ones); starting from the AN for 1835, they apply the corrections resulting from Bessel's determinations, inserted in the additions of the CT for 1831, but using instead the table (I bis) of said additions
I of the collection published by Bessel in 1830 with the title of Tabulae Regio-montanae.

4.2. Places on the Moon

Until the AN of 1809, Mayer's Tables of the Moon were used, verified and corrected by Mason under the direction of the royal astronomer Maskelyne (called by Mason “tables of 1780”, as cited by Julián Canelas in the preface of the AN
by 1824). They were published in England in 1787, and provided the position of the Moon with precision of 30 seconds. According to Maskelyne (editor of the NA), equation 18 of these tables was not used, due to doubts that it was correct. Starting with the AN of 1799, the variations made by Lalande in the III edition of his *Astronomy.* From the AN of 1810, the very modern and exact lunar tables of Bürg[7] will be used , taken from the astronomical tables of De-lambre, although from the following volume the lengths are increased by 4” measures to conform them with the latest determinations of the precession made by Delambre himself. From the AN for 1819, Burckhardt tables are used, published in December 1812 by the Board of Longitudes of France, much superior to those of Bürg:

> “…from the simultaneous comparison with the Bürg tables […] the sum of the squares of the errors […] according to Mr. La Place's theory of probabilities.”

Since 1924, an expanded edition of Burckhardt's tables has been used, prepared at the Observatory to facilitate calculations. In these tables, as well as others errata, errors were detected in the equatorial parallax of the Moon, errors that were correct, in accordance with the analyzes carried out by Sánchez Cerquero, based on the AN for 1832. In the AN for 1835, due to a better determination of the point equinox in the stellar catalogues, for the calculation of lunar distances it is necessary to add 3” to the longitudes of the Moon obtained from Burckhardt's tables.

4.3. Planets

For the ANs of 1792 and 1793, the places of the planets, except Herschel, are took from the corresponding NA, which used the tables of

[7] Bürg's tables were previously available at the Observatory, as recognized in the AN of 1807: “…which we have managed to obtain handwritten by the Marine Brigadier, Head of the Hydrographic Deposit Don Josef Espinosa, who told us that he was indebted to that precious collection to the generosity of Messrs. Don Pascual Enriles and Mr. Mechain.”

Lalande inserted in the II edition of his *Astronomy.* The Herschel places were worked from the tables of Jeaurat, published in the CT of 1787. For the AN 1794-1846, the following tables, published in the III edition of Lalande's *Astronomy ,* are used : those of Lalande for Mercury , Venus and Mars; those of Delambre for Jupiter and Saturn, calculated according to Laplace's theory, where the position of the first was given with an error of less than half a minute, and that of the second with an error of a few seconds; and those of Delambre of 1789 for Herschel, where the position was given with an error of less than 8 seconds. Starting with the AN of 1847, Lindeneau's tables were used for Mercury, Venus and Mars, and those of Bouvard for the outer planets, published in Paris in 1821.

4.4. Satellites of Jupiter From

the AN of 1792 to that of 1824, the jovilabio method was used to calculate the configurations of the satellites of Jupiter, as described in the II edition of Lalande's *Astronomy .* Starting with the AN for 1825, the Delambre Tables published in the additions to the CT of 1808 are used, considering this method to be more expeditious and more accurate than that of the jovilabio. In the AN for 1849, the method that Damoiseau inserts at the end of his tables is used for the first time.

For the eclipses of Jupiter's satellites, Wargentin's tables published in the second edition of Lalande's *Astronomy* are used , except for the second satellite, which is taken from Wargentin's own tables published in the NA of 1779. These tables were based on empirical equations and were used until the AN of 1798 when they were calculated by the Delambre tables (III edition of *Astronomy),* calculated according to the theory of the mutual attractions of the satellites given by Laplace in the Memoirs of the Academy of the Sciences of 1784 and 1788. These tables would be replaced from the AN for 1825, by the new ones by the same author published in Paris in 1817. From the AN for 1842, the announcements of the eclipses of the Satellites of Jupiter are calculated by the Damoiseau tables, published in Paris in 1836.

4.5. Stars In the

AN for 1792, a catalog of average positions of 120 stars of first, second and even third magnitude (with right ascension, declination and their annual variations) is inserted, which is extracted from another of 358 stars. reduced by Delambre to the mean equator and equinox of January 1, 1791, in accordance with La Caille's observations, and published in the CT of that year. This catalog is updated in the AN for 1798, reducing it to January 1 of that year and updating some of the stars based on better determinations of their position on the most recent observations made by Delambre and Le Francais, taken from the catalog of 500 stars visible from Paris, which was published in the CT of 1797. In the following volume it is updated to January 1, 1799. In the AN of 1833 a catalog of 60 stars is inserted for January 1, 1830 and mean positions of the Polar for January 1, 1830, 40, 50 and 60, taken from the insert in the second

volume of the memoirs of the Astronomical Society of London printed in 1826. From the AN of 1835, the positions of the 9 stars for which distances to the center of the Moon were given are taken from the catalog inserted on page 162 of the NA for 1832, which takes into account the best determination of the equinoctial point on those dates.

From the AN for 1840, for the calculation of apparent positions the stars of Bessel (Regiomontanas Tables), Pond (Greenwich catalog of 1112 stars) and Johnson (catalog of 606 southern stars) are taken. Some positions of the stars in Bessel's Regiomontanas Tables were later corrected (from the AN of 1842 and then from 1845) based on better determinations of the polar distances, deduced from the observations made at the Observatory. These Regiomontanas Tables only lasted until 1849, so it is necessary to prolong their validity by adding new tables, which are calculated at the observatory based on the formulas presented by Bessel in the aforementioned tables and other sources presented in the AN of 1850. In that same volume the average positions are taken, apart from the 38 calculated by Bessel, from the catalog of the British Association printed in London in 1845.

4.6. Several

In the AN for 1793 there appear general tables of aberration (calculated by Delambre) and nutation (by Lambert) and the formulas to calculate them. A table appears for the first time in the 1798 volume for the calculation of latitude by polar height, taken from the report of the trip that De Lowenorn, Distinguished Officer of the Royal Danish Navy, made in 1782 and 1783 to examine the watches. Starting from the AN for 1809, the largest tides that will occur in the year are presented, calculated according to Laplace's theory presented in the CT for 1800 and already introduced in the Memoirs of the Academy of Paris for the year 1790. In this volume of 1809, signed in 1806, those corresponding to the years 1806—1809 are presented. The AN for 1822 presents the addition “Of the Refractions of the Stars”, with tables taken from the CT for 1821, constructed with the formula given by Laplace in his *Celestial Mechanics* (volume IV, page 271), and some tables of Sánchez Cerquero to facilitate the calculation of the equation of corresponding heights. The AN of 1829 takes from the NA for 1822 the tables of mean atmospheric refractions, calculated by the formula given by Young in the *Philosophical Transactions* for 1819.

In the AN for 1832, Sánchez Cerquero says that to calculate the passage of Mercury through the solar disk he used Zach's solar tables of 1804 (of which he corrected some errors) and those of Lindeneau for the elements of Mercury. Also in the preface he discusses the disappearance and reappearance of the rings of Saturn, for whose calculation he uses the formulas given by Delambre in his *Astronomy,* commenting on some differences with the results proposed by Dusejour in his *Traité analitique.*

4.7. Sources in the Observatory library

The sources used in the preparation of the AN that to date have been located in the Observatory's library, arranged chronologically, are detailed below, with their corresponding signature.

• Mayer, T.: 1767, *Theoria Lunae juxta systema newtonianum,* Richardson et Clark, Londini. (24995) •

Mayer, T.: 1770, *Tabulae motuum Solis et Lunae novae etcorrecte,* G. et Richardson, Londini. (02240)

• Lalande: 1771, *Astronomie* 2nd revised and enlarged edition (5 vol.), Desaint, Paris. (01920)

• Mason, Charles: 1787, *Mayer's lunar tables,* William Richardson, London. (02666)

• Lalande and others: 1792, *Connaisance des temps,* Academie Royale des Sciences, Imprimiere Royale, Paris. (10481)

• Lalande, Jérome (Le Français): 1792, *Astronomie* 3rd edition revised and author-mentada (3 vol.), Desaint, Paris. (01915)

• Lalande: 1792, *Tables astronomiques… pour serve à la troisème édition de l'Astronomie,* Desaint, Paris. (02698)

• Zach, Baron de: 1792, *Tabulae motuum Solis novae etcorrectas ex theoria gravitatis…,* Apud CG Ettioner, Gothae. (02953) •

Mendoza y Ríos, J.: 1800, *Collection of Tables for various navigation uses,* Imprenta Real, Madrid. (01421) • Bürg,

Delambre: 1806, *Tables astronomiques publiées por le Bureau des Longitudes of France,* Couscier, Paris. (25362, 02697)

• Bouvard, M.: 1808, *Tables astronomiques publiées par le Bureau des Longitudes of France,* Couscier, Paris. (02939)

• Carlini, F.: 1810, *Esposizione di un new method of constructing the astronomical table,* Stamperia, Milano. (02806) •

Burckhardt, M.: 1812, *Tables astronomiques publiées par le Bureau des Longitudes de France (Tables de la Lune),* Couscier, Paris. (02712, 23974) • Lindenau,

B.: 1813, *Investigatio nova orbitae a Mercury circa Solem descrip-tae,* Lib. Beckeriana, Gothae. (02261, 26948)

• Delambre, M.: 1817, *Tables ecliptiques des satellites de Jupiter,* Couscier, Paris. (02711)

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