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A MANUSCRIPT ON ASTRONOMY AND GEODESY OF AN UNKNOWN AUTHOR

Summary (Abstract). The present contribution concerns a text in the form of handwriting, written in French. The year is known, given on the first page - 1846, but the author not. The present authors believe that the manuscript was written by Hervé Faye (Hervé Auguste Étienne Léopold Alban Faye, 1814-1902), a French astronomer and geodesist. The manuscript belongs to a collection of 24 manuscripts which is a property of the Mathematical Institute of Serbian Academy of Sciences and Arts in Belgrade. The entire collection has been digitised and it is deposited in the Virtual Library of the Faculty of Mathematics in Belgrade. The manuscript containing almost 600 pages is subjected to an analysis which is reported here.

Introduction

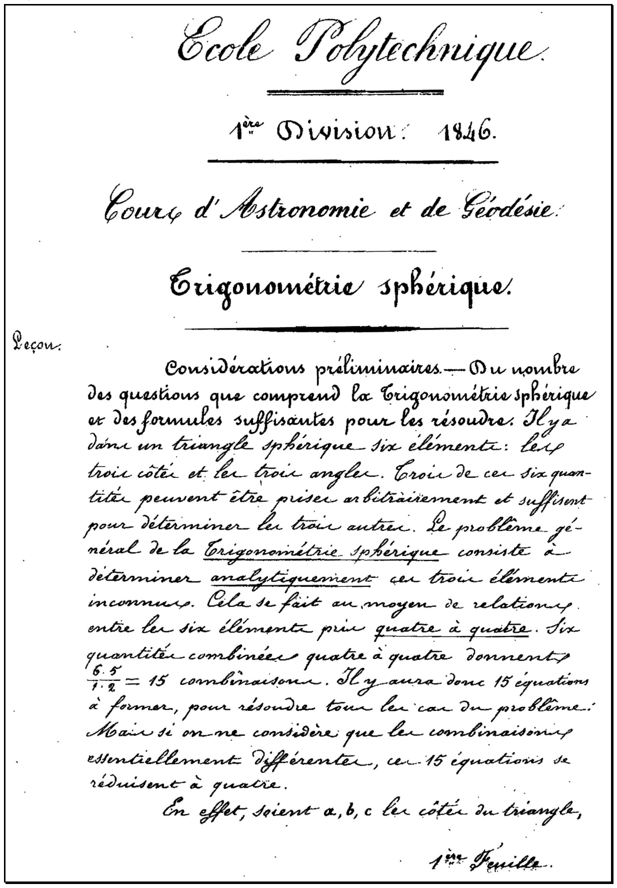
There exists a collection containing 24 manuscripts which concern mathematics and related sciences, see [3]. It is a property of the Mathematical Institute of Serbian Academy of Sciences and Arts. This collection has been digitised to be available at http://elibrary.matf.bg.ac.rs.

Among the manuscripts there is one existing in the form of handwriting only. From its title one can conclude that its field is astronomy and geodesy. The text was written in French, but the author is, unfortunately, unknown. More precisely, in the material we possess there is no signature, no indication who wrote this text. The information given on the first page (Fig. 1) contains the name of the institution (École polytechnique), the year and the general title (Cours d'astronomie et de géodésie, in English: A Course of Astronomy and Geodesy).

It is not known how this manuscript reached Serbia. It is possible that someone of the Serbs, who stayed in France as students in the XIX century, brought it. For instance, the two first Directors of the Belgrade Observatory, Milan Nedeljković (led the Observatory 1887-1899 and 1900-1924) and Đorđe Stanojević (1899-1900) both spent some time in France for the purpose of progressing their knowledge in astronomy, physics, geodesy and related sciences. The first page (Fig. 1) is preceded by two pages referred to as ex libris. In Fig. 2 one can see one of them. Both contain the signatures of persons thought to be the former owners of the Belgrade copy.

Though the manuscript has been never published, its copies do exist. For instance, several universities in France (e.g. Bordeaux and Lyon) possess a copy, also the Indiana State University in the USA. To the present authors it is also unknown if the text of the manuscript has been translated into any language. What is sure is that no translation into Serbian (Serbocroat) has been done.

We suppose that the author of the manuscript is Hervé Auguste Étienne Léopold Alban Faye (1814-1902). As it is usual, herein we shall use the name Hervé Faye.



École Polytechnique.

1re Division. 1846.

Cours d'Astronomie et de Géodésie.

Trigonométrie sphérique.

Leçon.

Considérations préliminaires.— Du nombre des questions que comprend la Trigonométrie sphérique et des formules suffisantes pour les résoudre. Il y a dans un triangle sphérique six éléments: les trois côtés et les trois angles. Trois de ces six quantités peuvent être prises arbitrairement et suffisent pour déterminer les trois autres. Le problème général de la Trigonométrie sphérique consiste à déterminer analytiquement ces trois éléments inconnus. Cela se fait au moyen de relations entre les six éléments pris quatre à quatre. Six quantités combinées quatre à quatre donnent $\frac{6.5}{1.2} = 15$ combinaisons. Il y aura donc 15 équations à former, pour résoudre tous les cas du problème. Mais si on ne considère que les combinaisons essentiellement différentes, ces 15 équations se réduisent à quatre.

En effet, soient a, b, c les côtés du triangle,

1re Feuille.

Fig. 1: The first page of the manuscript

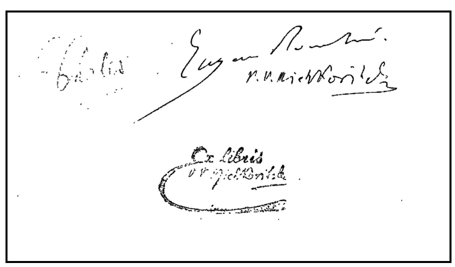


Fig. 2: Ex libris

Who was Hervé Faye

Hervé Faye (Fig. 3) was born at Saint-Benoît-du-Sault, in the Department of Indre, 278 km southwest of Paris. He studied at École polytechnique. In 1832 he joined the Paris Observatory thanks to François Arago. His activity was fruitful, In 1843 Hervé Faye discovered a periodic comet named after him (4P/Faye). This discovery brought him the Lalande prize in 1844. In gravimetry Hervé Faye corrected the Bouger formula which is known as Faye's correction. It is known that Hervé Faye spent some time as a teacher at École polytechnique; according to the existing data (Larousse 1930, Wikipedia) it should be


Fig. 3: Hervé Faye

between 1848 and 1854, but the year on the first page (Fig. 1) is 1846. Therefore, it seems probable enough that Hervé Faye taught the subjects of astronomy and geodesy at École polytechnique in the midforties of the XIX century and that then he wrote his course.

The authorship would, certainly, deserve a sufficiently large study. On the other hand, the present paper is merely a contribution article in a Proceedings, in other words it is not a thorough study concerning the authorship.

In 1847 Hervé Faye became member of the Academy of Sciences, to become its President in 1872; in 1876 he presided in Bureau des longitudes. In 1877 for a short time Hervé Faye was a Minister in (Public Instruction) in the French government. A lunar crater was named after him in 1935.

General analysis of the manuscript

The manuscript comprises 552 (main text) handwritten pages. After the main text there are another 25 pages. Most of these additional pages are to describe the text organization in lessons (leçons). Each lesson has a number, but without any title indicating the contents. The total number of lessons is 26. The information what a lesson contains is given in the organizational part. In this part there are titles containing the lesson number and the pages occupied by the lesson. After the description of the lessons there are two notes. The first note concerns the approximate calculation of angles; the second one is errata. It should be said that at the time when the manuscript appeared, radians were not used, at least as they are used in our time. The term radian was mentioned for the first time in a printed form in 1873 (Wikipedia). Though the manuscript was written as a book, there is no contents. The only information what it contains can be found by reading the description of the lessons.

The way in which the material is presented is somewhat different from the form expected from the point of view of nowadays. The first pages (about forty) are devoted to spherical trigonometry, which can be seen from Fig. 1. According to the lesson description spherical trigonometry appears within three lessons, only at the end of the third lesson one mentions the devices for time measuring.

Lessons from 4 to 6 are completely devoted to the equipment. One should be aware that in the late first half of the XIX century photography was at its mere beginnings only. Therefore, it is not surprising that all illustrations given in the manuscript are just drawings. The figures are not numbered. The same is true for the tables. Due to this if one wants to establish the total number of figures and tables, there is no choice, but to count them. There are many figures, but seldom more than one per page. A very rough estimate may be that on the average every five pages contain a figure. In this way one infers 110 figures in the manuscript as a whole. The total number of tables is much smaller, perhaps not more than about 15 tables at all. The equations are numbered, if they are referred to, but the numbers are repeated, even in the very same lesson one can find two equations with the same number.

There are footnotes in the text; they are not numbered, instead one can find a designation (*) behind a sentence. Then at the bottom of the page the same designation appears to be followed by the proper text. Sometimes on the same page there was no space enough, so the footnote had to be continued on the next page.

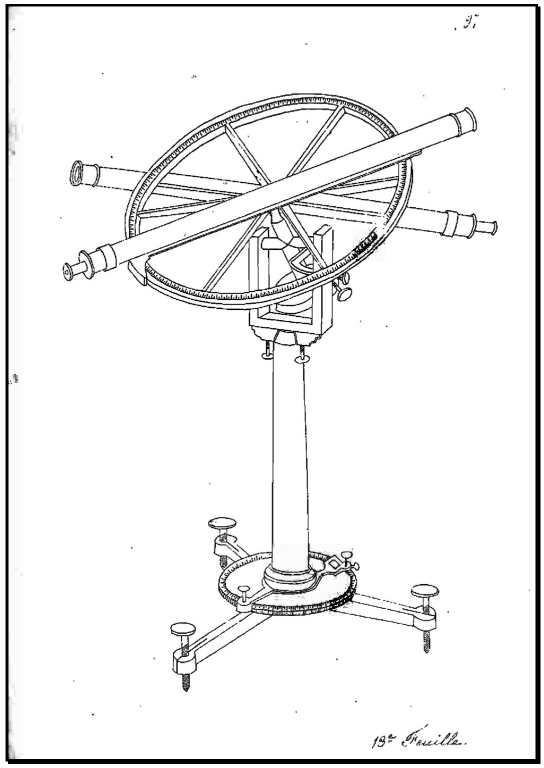
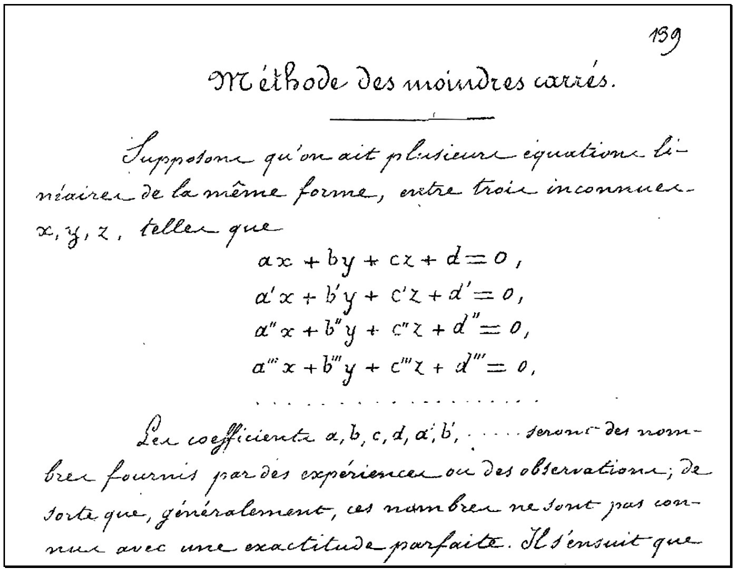


Fig. 4: Reflecting Circle

The comment concerning drawing becomes particularly interesting when the equipment is the topic. A nice example is Fig. 4 in which an instrument referred to as reflecting circle (cercle répétiteur) is presented. A substantial part of the instruments were (or are still) used mainly in geodesy. The theodolite was the only piece of equipment left for another lesson (lesson 7). In this lesson one starts with astronomical refraction. This phenomenon was paid a sufficient attention. It was explained that the refraction calculation is not simple. In this connection a table is given and also there is a part concerning the method of least squares (Fig. 5). The description of this method, still of much interest, occupies five pages. After a few pages dealing with some effects of refraction (de qulelque effets des réfractions) one finds within Lesson 8 a title named „Astronomy“ (astronomie).

It is of interest to note how astronomy was viewed by the manuscript author or, in general, in the time of the writing. It was defined as ”science of celestial bodies“ (science des astres) As its main subject one defines ”knowledge of their motion“ (connaissance de. leurs mouvements). Other characteristics are mentioned as ”also their distances, their size, their form, their physical constitution, etc“ (leurs distances, leur grandeur, leur forme, leur constitution physique). The author says that astronomy “is based on observations and calculations”, but the main calculation according to the author is spherical trigonometry (Son principal procédé de calcul est la trigonométrie sphérique). As the main instruments (les principaux instruments d’observation) the author mentions: chronometer, reflecting circle, theodolite, equatorial, meridian circle and mural circle (chronomètre, cercle répétiteur, théodolite, équatorial, lunette méridienne, cercle mural). Unlike the descriptions of the first three, which have been already mentioned in the present paper, the remaining three are the subject in later lessons. The reason is that the first three instruments are also used in geodesy.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Méthode des moindres carrés.

Supposons qu'on ait plusieurs équations linéaires de la même forme, entre trois inconnues x, y, z, telles que

$$a x + b y + c z + d = 0,$$
$$a' x + b' y + c' z + d' = 0,$$
$$a'' x + b'' y + c'' z + d'' = 0,$$
$$a''' x + b''' y + c''' z + d''' = 0,$$
$$\cdots\cdots\cdots$$

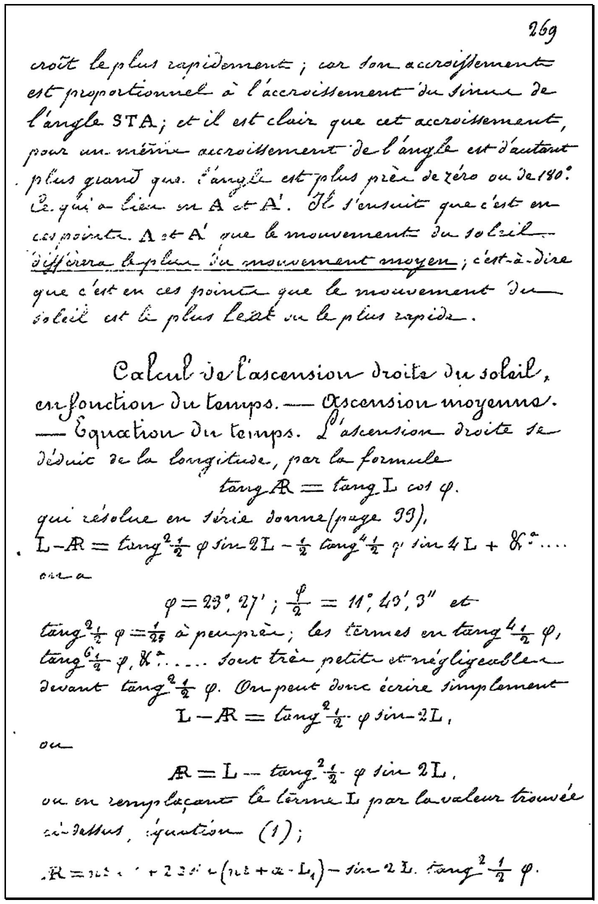
Les coefficients a, b, c, d, a', b', ... seront des nombres fournis par des expériences ou des observations; de sorte que, généralement, ces nombres ne sont pas connus avec une exactitude parfaite. Il s'ensuit que

Fig. 5: The page where the presentation of the least-square method begins

The notions of celestial sphere, immovable stars, constellations, rotation of celestial sphere are treated only in Lessons 8 and 9, together with the "typical astronomical instruments". Then the author introduces right ascension and declination. It is curious to note that the definition of right ascension is not preceded by that of vernal-equinox point. The right-ascension designation (Fig. 6) is also unusual (of course, to a modern reader). In the entire text one does not find the notion of hour angle.

The very end of Lesson 9 belongs to stars. There one finds classification of stars, which is a survey of their magnitude classes, just following the classical scheme of Hipparchus. The author says that stars of the first size (grandeur) are the brightest ones, but the role of the distance is not clearly stated. As well known, the first successful annual-parallax determinations originate from about 1840, but they were not mentioned in the manuscript. There is a short article within Lesson 9 entitled "About the star distance from the Earth" (De la distance des Etoiles à la terre) where the author states that such a distance is "immensely large" offering a comparison to the two main distance scales: diameter of the Earth and diameter of its orbit around the Sun. Finally the author mentions the speed of light (rather correct value depending on the ratio *lieue* to kilometre) saying even the light of a first-size star needs at least three years to reach the Earth (dont la lumière nous parvienne en moins de trios ans).

After a list of the most important constellations, within a new lesson (number 10) the zodiac and ecliptic are explained. Then, in the very same lesson (10) geodesy begins, in the sense that not its equipment is the subject only. The lessons to come afterwards (11, 12, 13) deal completely with the Earth.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croît le plus rapidement ; car son accroissement est proportionnel à l'accroissement du sinus de l'angle STA ; et il est clair que cet accroissement, pour un même accroissement de l'angle est d'autant plus grand que l'angle est plus près de zéro ou de 180°. Ce qui a lieu en A et A'. Il s'ensuit que c'est en ces points A et A' que le mouvement du soleil différera le plus du mouvement moyen ; c'est-à-dire que c'est en ces points que le mouvement du soleil est le plus lent ou le plus rapide.

Calcul de l'ascension droite du soleil, en fonction du temps. — Ascension moyenne. — Équation du temps. L'ascension droite se déduit de la longitude, par la formule

$$\operatorname{tang} Æ = \operatorname{tang} L \cos \varphi.$$

qui résolue en série donne (page 33),

$$L - Æ = \operatorname{tang}^2 \tfrac{1}{2}\varphi \sin 2L - \tfrac{1}{2}\operatorname{tang}^4 \tfrac{1}{2}\varphi \sin 4L + \&^a \ldots$$

on a

$$\varphi = 23°, 27' ; \tfrac{\varphi}{2} = 11°, 43', 3'' \text{ et}$$

$\operatorname{tang}^2 \frac{1}{2}\varphi = \frac{1}{25}$ à peu près ; les termes en $\operatorname{tang}^4 \frac{1}{2}\varphi$, $\operatorname{tang}^6 \frac{1}{2}\varphi$, &ª..... sont très petits et négligeables devant $\operatorname{tang}^2 \frac{1}{2}\varphi$. On peut donc écrire simplement

$$L - Æ = \operatorname{tang}^2 \tfrac{1}{2}\varphi \sin 2L,$$

ou

$$Æ = L - \operatorname{tang}^2 \tfrac{1}{2}\varphi \sin 2L,$$

ou en remplaçant le terme L par la valeur trouvée ci-dessus, équation (1) ;

$$Æ = nt [illegible] + 2 [illegible] (nt + \alpha - L_1) - \sin 2L . \operatorname{tang}^2 \tfrac{1}{2}\varphi.$$

Fig. 6: Note the designation used for right ascension

Lessons from 14 to 26 (the last) have astronomical contents. At first one treats the apparent motion of the Sun, time measuring, precession and nutation are introduced, diurnal parallax is also the subject and in Lesson 17, to be finished in the next one, solar physics is treated, especially sunspots and rotation. In Lesson 18 most of space is devoted to the Moon. The only natural satellite of our planet is also the subject in Lessons 19 and 20, its motion, eclipses and, finally, in the first part of Lesson 21 lunar physics becomes the subject. After this the author explains the facts about the planets, at first inner and outer planets, their motion, physics of planets and Kepler's laws. Though Kepler's laws are introduced in Lesson 22, their interpretation is given in Lesson 24 only, but the phenomenon of gravitation is explained in more detail in Lesson 25. The reason is that this explanation is closely connected to the question of free fall near the terrestrial surface. Also, since the gravity appears as the cause of other phenomena on the Earth, precession, tidal action, the last lesson (26) is devoted to them. In this part of the manuscript astronomical aberration has much space, in accordance with it the speed of light is treated, its first successful determination was astronomical, took place in the XVII century.

Information of interest in the text - historical notes

The manuscript contains parts referred to as historical notes (notice historique). They are usually followed by a comment "not required" (non exigé). Most likely this "not required" concerns the examination material; in other words the students were not expected to know the history of a problem on the same level as it was the case with the problem itself. Nevertheless, this matter deserves attention. Some facts concerning the history of a problem before the manuscript appeared (middle XIX century) may have faded into oblivion till our time. For this reason, any old manuscript can be a valuable source of information to historians of science. Of course, it is also possible that in the meantime, from the time when the manuscript appeared till nowadays, new facts have been discovered, in the light of which the history of a problem changes its character.

All historical notes treated in the manuscript cannot be the subject here. Since the manuscript concerns both geodesy and astronomy, each will have a problem presented here. The author (p. 212) emphasizes two questions related to the Earth, to determine its shape and to determine its size ("de déterminer la forme de la terre et de déterminer sa grandeur"). According to the author the size of the Earth seemed to be the subject of a great interest from early antiquity. The feat of Eratosthenes is well known to the manuscript author. On the beginning of the paragraph speaking about Eratosthenes one finds something, obviously added afterwards: "276 ans avant J. C.". If we cite modern data, say Wikipedia, this year appears as the birth year of Eratosthenes. However, in the preceding paragraph the author mentions Aristotle (384-322 BC), more precisely, Aristotle's treatise on the sky, Book 2, where the famous Greek philosopher says "they do not give it a circumference exceeding 400,000 stadia" (ne lui donnent guère que 400 000 stades de circonférence). Without regard to all uncertainties which concern the exact length of one stadia, say converted into kilometres, (e. g. Preti, 2002 p. 108), as well as the question if the stadia used by Aristotle is the same as that used by Eratosthenes, the value cited by Aristotle is quite different from that found by Eratosthenes (252,000 stadia). Since the latter value is recognised, even today, as a very good one, the former value (Aristotle's one) seems obsolete. Of course, later works are also mentioned, but the most exciting place in that part of the book is related to the determination of the shape of the Earth. The theories of Huygens and Newton predicted that the surface of the Earth cannot be a perfect sphere, more precisely the distance between the poles should be shorter than the equatorial diameter. However, the results of the first measurements were in favour of a prolate shape for the Earth. Finally, in the XVIII century, after new measurements, it became clear that the Earth is, nevertheless, oblate, as the two theories had predicted.

In the lesson treating the planetary motions there is a part devoted to the first measuring of the light speed. This is a well known event when Roemer observing a Jovian satellite established the value for the light speed. The text is followed by a footnote in which it is said that Descartes, as early as in 1634, had a similar idea. In one of his letters Descartes stated that in the case of a finite value for the speed of light one would observe a delay in the lunar eclipse. The author's comment is that Descartes failed to find a confirmation in the observational results because the Moon is too close to the Earth; if Descartes had applied this reasoning to a Jovian satellite, then astronomy would have owed him the nice discovery of Roemer ("l'astronomie lui eût été redevable de la belle découverte de Roemer").

Among other historical notes presented in the manuscript, of interest may be that concerning the discovery of attraction law ("découverte da la loi d'attraction"). This topic occupies four pages, several scientists are mentioned, some of them are very well known. The author says that Hook, like Kepler, Fermat and Roberval, expressed the principle of a mutual attraction comprising all celestial bodies ("le principe d'une attraction mutuelle de tous les coprps célèstes"). In the further text the author's words are that the law proposed by Hook to be found was exactly what Newton looked for, Newton who was fortunate to discover it

("Cette loi que le docteur Hook proposait de trouver, fut précisément celle que chercha Newton …, et qu'il eut le bonheur de découvrir").

State of the art at the time of manuscript appearing

When reading a text written sufficiently long ago, as it is the case with the manuscript under study, it becomes possible to view the state of the art in the given field (here astronomy and geodesy) at that time. As said above, the classical disciplines, spherical trigonometry, astrometry, celestial mechanics are presented in a way not very different from that usual nowadays. This is due to the fact that in these disciplines a substantial progress had taken place by the time when the manuscript was written. Therefore, it is not surprising that the Solar System is described with many details. In the physics of the Sun much was unknown at that time, but there is a footnote (p. 367) wher the author mentions "a third atmosphere of the Sun" (troisième atmosphère du solei). With regard that something quite new is borne in mind, we may speculate a little bit, an indication of the solar corona? Also interesting, on page 380, "the possibility that the lunar mountains have a volcanic character" (caractère volcanique des montagnes de la lune). The volcanic activity on the lunar surface has been the subject of many studies, but the modern point of view is that the eruptions belong to the distant past (more than billion years ago).

On pp. 382-383 the author mentions the absence of water and atmosphere on the Moon. Perhaps, the most intriguing concerning the Moon is the relationship between the lunar phases and weather. The author says that according to astronomers the Moon has no influence on weather (Les astronomes croyent que la lune n'influe pas sur le temps), but many people think the opposite, for instance the weather changes when the Moon changes its phases. Finally the author concludes that "it seems that an influence of the Moon (lunar phases) should be recognised" (Il semble donc qu'on doive reconnaître une certaine influence à la lune), "but the effect is not so strong as it has been usually thought from early antiquity" (mais qui n'est pas celle que la public lui attribute depuis le plus haute antiquité).

The basic facts about the Solar-System planets are given in the text. It would be of interest to comment them in the light of our time. On page 419 one finds a table containing the data on the orbital inclination (with respect to the plane of ecliptic). There are two columns, the left-hand one concerns the planets in the modern sense, of course without Neptune which was discovered as late as in 1846, approximately at the time when the manuscript was written. Neptune is nowhere mentioned. The orbital inclinations for the six planets (Earth not included) are just as we find them now. In other words, the inclination values were known rather precisely even long ago. The right-hand column concerns the objects referred to as minor planets (petites planètes) and it contains the data for Vesta, Juno, Ceres and Pallas, the only known minor planets at that time.

There is another table (p. 504) which contains data about the planets. This time the four minor planets and the Earth are included so that there are eleven rows in the table. Mercury occupies the place at the top, as closest to the Sun, Uranus is at the bottom, as the most distant. The columns (from left to right) give: the distance to the Sun, sidereal revolution, rotation period and diameter. As can be expected, the distances and periods are very accurate (we recognise the values we know today), also to note that the two quantities are related to each other (Kepler's third law). The rotation periods are not given for all bodies, they are missing for the four minor planets and Uranus. In the case of Mercury and Venus the values are completely erroneous from the modern point of view. As for Mars, Jupiter and Saturn, they are quite correct.

This table is preceded by a section dealing with the planet distances from the Sun in which the author mentions the rule, usually referred to as that of Titius and Bode. However, for the author it is Bode's rule, more precisely law (loi de Bode). It is said that at the time when the rule was formulated, no minor planet was known. The fact that soon after the discovery of the first among them - Ceres - the other three were also discovered, is connected with the hypothesis made by Olbers according to which "the four minor bodies could be the fragments of the same planet destroyed in an explosion" (ces quatre petits cops pouvaient être des fragments d'une meme planète brisée dans une explosion). The number of satellites for the Jovian planets could be mentioned - Jupiter 4, Saturn 7 and Uranus 2. It is, of course, not surprising that we know today that these planets have much more satellites.

Mentioning of Rudjer Bošković's name

Rudjer Bošković (1711-1787), the Southern Slav scientist whose three-hundredth anniversary from the birth was celebrated recently and who worked in France for a sufficiently long time, was mentioned in the text twice (p. 129 and p. 203). The first mentioning concerns a formula developed for the purpose of calculating the atmospheric refraction. In this case Bošković was mentioned together with Simpson and Duséjour. It is said that "several geometrists" (plusieurs géomètres) "have reached, through different considerations, a relation of the (same) form" (sont parvenus, par des considérations différentes, à une relation de la forme). The formula was written down and commented. It has two numerical coefficients to be determined observationally when the refraction is known. Also that its form is that of Bradley's formula. The present authors have been able to find this formula in the literature, but referred to as Simpson's formula. Perhaps, the fact that the other two scientists had obtained the same formula as Simpson, has faded into oblivion?

The second place where Bošković's name is mentioned concerns the geodetic measurements, in particular the meridian arc degree. A table is presented and in a row of its one finds Italy as the country where the measurements took place, then the mean latitude value, the grade length in metres and in the fourth (last) column giving the names of the observers two names - Bošković and Lemaire. On this topic one can also find in Battinelli's (2014) article. There is a slight difference in the family name of Bošković's coworker. According to Battinelli it is Maire, not Lemaire, as cited in the manuscript which is here under study. Battinelli also gives the first name and the years of birth and death. With these data a search via Internet (e. g. Oxford Dictionary of National Biography) leads to the Jesuit Christopher Maire born in England with exactly the same years of birth and death as given by Battinelli and for whom it is said that was engaged in the measurements on the terrestrial surface together with Bošković. Therefore, the family name given by the manuscript author is erroneous.

Conclusion

Old texts written sufficiently long ago can be very useful for history of science. The relevant facts about a discovery can always fade into oblivion. As a consequence, the information at our disposal concerning this discovery will be erroneous or, at least, incomplete. For this reason it is important to preserve our heritage. The digitisation is the best way to keep it in good condition. Then old manuscripts can be easily available.

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