Historical eclipses in Europe

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Abstract. An overview of total eclipses is given that have been observed and recorded by astronomers in Europe since antiquity till 20th century. A particular attention is payed to the computations that Kepler carried out in Prague to predict the eclipse 1605, further to some eclipses of 18th century that have been computed and observed by French astronomers (Madame Nicole-Reine Lepaute) and to the book *Elementa Eclipsium ... 1816 – 1860* that was published by F. I. C. Hallaschka in Prague 1816.

Key words: eclipses – history

1. Introduction

There is no doubt that eclipses have frightened man/woman living in caves and seeing, during clear days, his/her source of light and heat disappearing unexpectedly. But such a feeling has a long life and it is said that, even during the 19th century, it occured that some ladies 'tomberent en pâmoison' at the moment of such an event. Of course a woman, not a man... The next total solar eclipse to be seen, on August 11th 1999, will cross a large part of Europe. It affords an occasion to look at the eclipses which were seen in the past in that area.

2. Comprehension of solar eclipses in antiquity

On the occasion of the forthcoming eclipse, some legends on the subject have been recently recalled (Lerner and Savoie, 1998). Such is the one in relation with Thales de Milet (B.C. 6th) who, apparently, could not announce the eclipse which occured in 584 May 28 B.C.

These authors also recall the period of Thucydides (ca 460 to 395 B.C.) fortunate enough to live at a time when several eclipses could be seen from his region. From the *Canon der Finsternisse* (Oppolzer, 1887) and the *Canon of solar eclipses* (Mucke and Meeus, 1983) it can be seen, for the three most spectacular types of eclipses recorded, the following possibly observed: - 477 February 17, - 462 April 30 (but perhaps he was too young at that time), followed by - 433 October 4, - 432 Mars 30 if he went north, - 430 August 3 if he went north-east, - 403 September 3, - 401 January 18; that is to say about half a dozen.

After the spherical shape of the Earth was proven, probably by Aristoteles (384 B.C. - 322 B.C.), through lunar eclipses, and the comprehension of the existence of celestial bodies being able to produce light by themselves, it is thought that Geminus (ca B.C. 70 or 50) is the first preserved author to give a clear account of the eclipse mechanism with the alignment of the centres of the three bodies to produce lunar and solar eclipses. In the last case, he understood too that it was not the same phenomenon, the solar eclipse being indeed the occultation of the Sun by the Moon.

3. Sixteen centuries of solar eclipses

The dates of eclipses around the beginning of the first millenium do not permit to identify any of them with the one occurred at the cruxifiction which, on the other hand, occurred at the time of a Full Moon. Sacrobosco (ca 1200-1250) having raised the question of the character of this darkness, the answer was - as recalled by Lerner and Savoie - that it was already known that solar eclipses could occur only at New Moon.

From the point of view of the calculation of eclipses, after the prediction by the Babylonians, came in the Almagest of Ptolemy (ca 100 A. D. - 170 A. D.) employing tables and being able to say if an eclipse would be visible or not. During his epoch, between 100 and 200, for a large area, five important solar eclipses can be found: 114 November 15, 118 September 3, 120 January 18, 121 July 2, 125 April 21. And one can imagine that, having been able to determine if the eclipse will be seen as partial or total, for a given place, its duration and the timings, Ptolemy could have manage to travel where possible.

Nothing special will occur on the subject during centuries, the method given in the Almagest having been used by the Middle Ages astronomers, with small improvement only. Even Copernicus (1473-1543) did not brought so much, despite the fact that - during the 16th century - tables could predict, a long time before the occurrence, the visibility of solar eclipses. For central Europe, at the time of Copernicus, there were the following, of which none is mentioned as having been observed by Copernicus: 1491 May 3, 1502 October 1, 1518 June 8, 1540 April 7 (still in Julian calendar). The observations of Tycho Brahe (1546-1601), from Denmark and from Bohemia, have been of great importance for the following astronomers, mostly Kepler (1571-1630). For the period of Tycho Brahe, there are no important eclipses to be seen from Europe.

4. Kepler's method and his observations of solar eclipses

The quality of Tycho's observations led Kepler to improve the theory of the motion of the Moon and of the Sun, excluding his famous work on the theory of Mars which led him to his laws. Kepler observed the lunar eclipse dated 1598 February 21 from Graz during the time a collaborator of Tycho Brahe was observing it in Uraniborg. By this observation Kepler could determine a good value of the longitude difference and he became interested more generally into eclipses.

It is known that Kepler observed, in 1600, the solar eclipse of July 10. This eclipse was partial for Graz, being a short total one (about 2 minutes) for some countries such as Spain. It is on that occasion that he designed an apparatus to observe the image of the Sun on a piece of paper; this instrument was improved in the perspective of the solar eclipse to occur on 1605 October 12, another total short one, of less than 3 minutes.

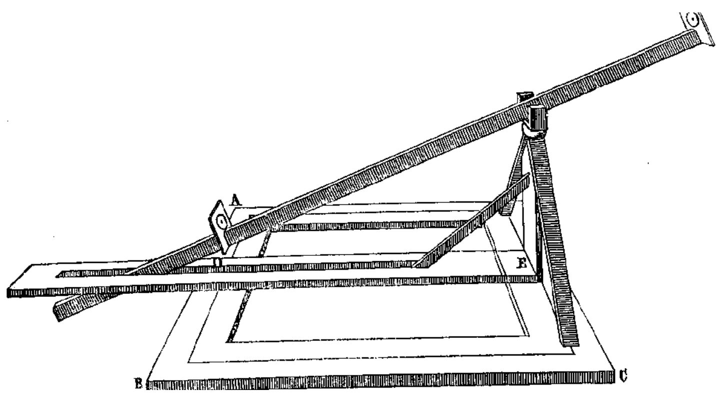

Figure 1. Kepler's apparatus for imaging of solar eclipses

In the part of his book *Ad Vitellionem...* entitled *Astronomia Pars Optica*, published in 1604, Kepler gives the representation, the description of his apparatus and the method for the observation. It is said that, after the death of Tycho, Kepler found in his papers a description of a parallactic machine which enabled him to determine the diameter of the Sun, using a vertical slit giving on the floor an elliptic image. Kepler's apparatus is a successful improvement of Tycho's machinery.

Delambre (1749-1822), who had apparently a great admiration for him, recalls: *Pour les éclipses du Soleil, il calcule de même l'éclipse générale ; mais les problèmes suivans n'avaient pas été résolus, ni même proposés avant Kepler.* In his Bibliographie Astronomique, about *Ad Vitellionem*, Lalande (1732-1807) had written that, having found a mistake in Kepler's work, he published a correction in 1798. Delambre, a new time, defends Kepler: *La méthode est restée, les fautes des chiffres que Kepler y a commises sont aujourd'hui comme non avenues.*

5. Flamsteed, Cassini, Lalande and others

In 1680, Flamsteed (1646-1719) gave a method for the calculation of solar eclipses allowing him to determine the occurrence of the phenomenon, its character, and the locations from where it could be seen. He has, as assumed by Delambre, probably forgotten his lecture of the *Tabulae Rudolphinae* in which Kepler was one of his predecessors. He was not the only one to have forgotten that matter and rediscovered some of its parts, being in good company with his friend Wren (1632-1723), Cassini (1625-1712), Halley (1656-1742) and others.

Delambre adds: *... car il est impossible de supposer que ces astronomes ne connussent pas les Tables Rudolphines. Ainsi, ils n'ont fait que développer l'idée de Kepler, pour faire uniquement, par une opération graphique, ce que Kepler, qui était lui-même en possession de l'opération graphique, obtenait sans plus de peine et avec plus d'exactitude par le calcul.* It is to be noted that his *Tabulae Rudolphinae* (1627) were established with the use of logarithms, about which he had previously published the *Chilias logarithmorum*.

In his Tables, Kepler - of course - pays hommage to Tycho and to all the observations made on which they are based. His work related to the eclipses is the third part of the *Tabulae Rudolphinae*, considering first how to find the months of the year during which they can occur. The importance of Kepler's Tables is recalled by Lalande for the year 1627: *C'est dans ce livre qu'on trouve la méthode pour calculer les éclipses, dont on se sert encore actuellement* (1804). What will be also mentionned by Delambre, writting two decades after Lalande: *Enfin la théorie des éclipses de Soleil, et le calcul des différences des méridiens par les éclipses sujettes à la parallaxe, date également de ces tables.*

6. Seventeenth and eighteenth century total solar eclipses

The total solar eclipse, dated 1600 July 10 and already mentioned, was the last one for the 16th century. The one, observed in detail by Kepler in 1605 October 12, was total for the south of France, Italy, Greece, Turkey, ... The list of the eclipses total or annular for the 17th and 18th centuries, crossing one part or another of Europe, is given in Table 1. The one, on 1706 May 12, was observed as total from Montpellier (in the south of France). Lalande remarks: *C'était la premiere éclipse totale qu'on eut observée depuis le renouvellement de l'astronomie.* The duration of totality was 4 min 10 s. The 1708 eclipse was observed by several astronomers and a teacher of mathematics, Müller, near Nürnberg.

The 1715 total solar eclipse was fortunate enough to be observed by the Astronomer Royal himself, Halley (1656-1742) at the date April 22, Great Britain being not yet in the Gregorian Calendar. The data concerning this eclipse, as seen from England, was in the recent years used by Morrison from Royal Greenwich Observatory and Stephenson, from Durham University, to check the value

Table 1. 17th and 18th century eclipses

Year	*Month/Day*	*Year*	*Month/Day*
1605	October 12	1708	September 14
1614	October 3	1715	May 33 (April 22) Halley
1630	June 10	1724	May 22 Paris
1654	August 12	1760	June 13
1679	April 10 (?)	1762	October 17
1695	December 6 (?)	1764	April 1 Mme Lepaute
1706	May 12	1778	June 24 (at sea) Ulloa

of the diameter of the Sun given, for this epoch, by other authors. An important total solar eclipse, was favourable to both Ireland and France and, in the last case, came to the Paris Observatory on 1724 May 22. Of course, the calculations were made in several countries, Great Britain, Germany, Italy,... The duration was 4 minutes and a half. A painting, in the Paris Observatory collections, recalls this observation, which is the only total one observed from Paris.

The following ones were in 1760 for Greece and Turkey, and in 1762 for Scandinavia. It was there observed in Uppsala before going through Russia, being the last total solar eclipse to be seen from Europe for the century. But I have mentioned two others. The 1764 one was annular for France; the map was calculated by Nicole-Reine Lepaute (1723-1788), wife of the horologer and the very efficient helper of Lalande for astronomical calculations. It was also, of course, calculated in London, Utrecht, Mannheim,... and observed in several places. I have also mentioned the 1778 total solar eclipse, partial for Europe, but observed at sea (north Africa) by Uloa, the Spanish officer who was in the Peru expedition sponsored by the french Académie des Sciences in Equator between 1735 and 1744/45.

7. Some total eclipses observed during the 19th century

During the 19th century, the interest for eclipses grew up. Long passed was the time when Kepler was designing an instrument for their observations. The observers better equipped made numerous drawings; they can be found in many books and articles. The interest of astronomers was limited to total eclipses (Table 2), being the most important in view of the increasing of knowledge.

One remarkable book - *Elementa eclipsium ...* - was published in Prague in the year 1816 by Franz Ignaz Cassian Hallaschka (1780 - 1847). It contained the maps for eclipses between 1816 and 1860 and was followed by a second volume with maps of eclipses until 1910 (Šolc, 1999). The geometric constructions used by Hallaschka anticipated the standard theory of eclipses developed later by Friedrich Wilhelm Bessel. In the introductory chapter, most of contemporary European authors of eclipse calculations are listed - Du Sejour, Monteiro, Goudin, Delambre, Wolf, Mayer and other authors of eclipse papers like Euler, Lalande, T. Mayer, Lagrange, Lexell, Cagnoli, Gerstner, Kluegel and Bohnenberger. However, Hallaschka developed his own method determining the umbral size and position according to the work of Cl. Wurm and geometric projections on the Earth's surface were based on the books by Lalande and Rüdiger. Hallaschka wrote his text in Moravia and so he decided to express all the time indications in the local time of Brno, the Moravian metropole (the differences of local time between Brno, Wienna, Berlin, Paris and zero meridian of Ferro are given). After moving to Prague, in the years 1817 - 1832, Hallaschka carried out regular daily astronomical, meteorological and geomagnetic observations.

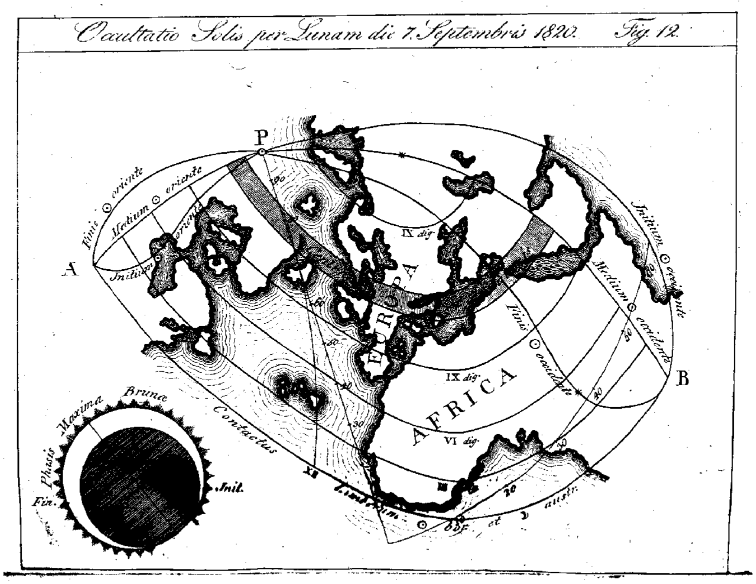

Figure 2. F. I. C. Hallaschka *Elementa eclipsium* ..., Prague 1816

During the first part of the century, eclipses occurred in 1816 and in 1842. In 1845 Fizeau (1819-1896) and Foucault (1819-1868) succeeded in photographing for the first time the Sun. This was the very beginning of solar research through photographic technique.

The searches for total solar eclipses to be seen from a given place have been greatly improved by the important work performed, and published 1887, by Oppolzer. Under the general title *Canon der Finsternisse* he gave three volumes on the subject: I - Canon der Sonnenfinsternisse, II - Canon der Mondfinsternisse and III - Iconographie zum Canon der Sonnenfinsternisse. The period covered lies, for the Sun, between the year 1208 B.C. up to 2161 A.D. The maps, given in the iconography, are very well made and very clear. Oppolzer divided the

Table 2. 19th century eclipses

Year	*Month/Day*	*Remarks*
1816	November 19	
1842	July 8	
	1845	The first photograph of the Sun by Fizeau and Foucault
1851	July 28	Le Verrier: Mercury - Vulcain ?
1860	July 18	
1870	December 22	
1887	August 19	
1896	August 9	
1900	May 28	

solar eclipses into total, annular and annular-total. During the 20th century, when the irregularities in the rotation of the Earth were clearly seen, the map appeared to need some improvement: Oppolzer could not take into account the not known phenomenon of the difference between the time as defined by the rotation of the Earth and a really uniform one.

The modern calculations of the eclipse timings, in bureaus in charge of the ephemerides, take into account the difference between UT and TAI with a present value of the order of half a minute. This was already the case in the *Canon of solar eclipses* by Meeus, Grosjean and Vanderlen (1966), as well as the more recent *Canon of solar eclipses* by Mucke and Meeus (1983). As an example of the difference introduced by the UT-TAI difference, the 2026 total solar eclipse to be seen from the southern part of France, according to Oppolzer, will be seen from the northern part of Spain (Rocher, 1998).

During the second part of the 19th century, the interest for taking photographs of the solar eclipses increased and examples are found, from the French side, for 1889 and 1893. They are not in Table 2: the reason is that they were observed from Cayenne and from Central Africa, not from Europe. At that time the development of steamers made quicker the travel to go to places were such total solar eclipses could be seen. This was the beginning of solar research through any total solar eclipse to occur in any place in the world, except when the location is not attainable...

8. Total solar eclipses and the 20th century

After the discoveries made during the 19th century, it became obvious that only total solar eclipses would be of interest to astronomy. The longitude problem, for which they were used at the time following Kepler, was solved in England with Harrison's marine chronometer from the 18th century; the parallax of the Sun was determined, no longer with Mars but through the transits of Mercury and of Venus over the Sun, and astronomers were waiting for Eros in 1907.

The main interest for observing total solar eclipses would not be any more for astrometry but for astrophysics.

This appears clearly when reading, as an example, the book written - as early as 1905 - by Bigourdan in the perspective of the first total solar eclipse of the 20th century crossing Europe on August 30. Photography takes a large part and also photometry, spectroscopy, polarisation but also - still vivid - the subject of the search of intramercurial planets. This story began with the evidence which appeared to Le Verrier (1811-1877), in 1843, about discrepancies regarding the motion of the perihelion of Mercury. After his announcement of the place of a new planet after the discovery, by Herschel (1738-1822) in Bath in 1781, of Uranus and the discovery of Neptune, in Berlin by Galle (1812-1910) and d'Arrest (1822-1875) in 1846, Le Verrier went more deeply to the motion of Mercury, thinking of a new planet being inside the Mercury orbit.

This interest became more important with, in 1859, the assumption of a new body having crossed the solar disk. The subsequent total eclipse, in 1860, was - in this respect - of importance. A French expedition was sent to Spain. Le Verrier was its chief and Foucault was in the party. So was in Spain the Italian astronomer Secchi (1818-1878) who, in his report, recalls that no planet close to the Sun was seen during the totality. But other considerations of such one or several possible bodies came from Great Britain (1862), Turkey (1865), Germany (1876).

9. Total solar eclipses and relativity

All subsequent total solar eclipses, from the end of the 19th century to the beginning of the 20th century, were partly used for this research of a new planet and, if only one, it would be named Vulcain. Among the astronomers there were not only Europeans but also north American ones, launching campaigns in 1901, 1905 and so on. It is now known that these campaigns stopped not only because of the World War I, but because of Einstein (1879-1955) and his discovery in 1915, explaining the particular motion of the perihelion of Mercury.

The subject was discussed by Tisserand (1845-1896) in Volume IV of his *Mécanique céleste* (1896) under the title *Hypothèse des planètes intra-mercurielles* in which he wrote: *...l'insuccès des recherches faites prendant plusieurs éclipses totales, semble indiquer que l'explication de l'anomalie du périhélie de Mercure, donnée par Le Verrier, ne peut guère être maintenue.* Several hypothesis were made by Newcomb (1835-1909), by Hall (1829-1907), etc., but none of them will survive careful examination and observations. The famous total solar eclipse dated 1919 May 29, brought the final solution, following the previous one (1914 August 21) to be seen over Scandinavia and Earstern Europe and not observed. 'Final solution', because this eclipse allowed to measure the deviation of the light of stars passing in the close vicinity around the Sun, confirming the theory of relativity and, doing so, confirming the explication of the motion of Mercury perihelion.

From this epoch, it was clear that the importance of total solar eclipses must engage astronomers to travel in any country from where the phenomenon could be seen and to choose the best weather conditions and location. But partial, as well as total eclipses, are still of interest for the general public like in the past. The difference is that, being well informed by the astronomers, people will not be afraid as the Parisians were in 1654 when, after the announcement of an eclipse *Paris tout entier fut en émoi, et beaucoup d'habitants allèrent se cacher dans les caves lorsque le phénomene se produisit.*

10. Conclusion

The history of solar eclipses is a long one with many fluctuations in the consideration to be given to the phenomenon to be observed. Besides the interest for astrophysics, there are still some problems to be solved from the side of astrometry regarding the timing and the diameter of the Sun. Observers of the recent total solar eclipses have said that they noticed some differences between the predicted and the observed beginning of the eclipse and the totality. So all people being in the totality zone must do their best to get the various timings for all over Europe. The discrepancies could be related to the diameter of the Sun and of the Moon employed in their theories, the constants they have used, or to any other phenomenon to be discovered.

In any case a particular credit must be given to Kepler. Quoting Delambre when he wrote on the subject it can be said that were studied, four centuries ago, problems which *n'avaient été résolus, ni meme proposés avant Kepler*, as already mentioned. So, nowadays, astronomers must be grateful to him when waiting for the next one to cross a large part of Europe, after the previous one (1961 February 16) and before the next one to come to Spain (2026 August 12), that is to say the one dated 11th of August 1999.

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Discussion

Comment (S. Koutchmy): Regarding the Nov. 29 total eclipse, we were curious to know more about it and found, after computing the map with the path of totality, that the total eclipse occurred near the noon almost exactly above the 'old' town of Jerusalem... (Note: the map is reproduced in the book *Eclipses Totales*, 1998, Masson, Paris).