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Franz Ignaz Cassian Hallaschka and his book "Elementa Eclipsium"

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Praha*)

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On August 11, 1999, the Moon's shadow will traverse the Northern Hemisphere. A total eclipse of the Sun will be visible from within a narrow strip (ca 110 km wide) that begins in the Atlantic Ocean at sunrise, crosses southern England, France, Germany, Austria, Hungary, Romania, Turkey, Middle East, India and ends in the Bengal Bay at sunset. A partial eclipse will be visible from a much larger area, reaching several thousand kilometers to both sides of the umbral path. Detailed maps of the umbral and penumbral tracks with time marks, duration of the eclipse and some other characteristics were computed long before the eclipse day, e.g. by F. Espenak and J. Anderson [1] (March 1997). The computations were carried out on the basis of the contemporary theories of the motion of Earth and Moon, including all known effects influencing it: planetary perturbations, precession according to the theory accepted by the International Astronomical Union (IAU) in 1976, nutation theory IAU 1980, polar motion, irregularities in the rotation of the Earth, the shape of the Earth etc. Differences between the computed solar resp. lunar ephemerides and the observed apparent positions are now of the order of miliarcseconds. This allows us to predict the position of the intersection of the geometric shadow conus and the Earth's surface with a precision well below the limits of a common eclipse observation.

However, such predictions and maps have already been constructed in the past. Johannes Kepler invented an instrument for projecting the eclipsed Sun onto paper and making drawings of the eclipse progress (Rem. 1). These drawings then helped Kepler to determine the size and positions of the total lunar shadow and enabled in such a way to reconstruct the umbral path on the Earth's surface.

A standard catalogue of eclipses appeared later, in the 19^{th} century – it was Theodor von Oppolzer's book *"Canon der Finsternisse"* [3] from 1887. It served for more than one century as a reference catalogue and a very useful tool not only for astronomers, but also for historians (Rem. 2) and replaced and enlarged the

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older and less precise catalogue of historical eclipses by Alexandre-Gui Pingré [6].

"Canon der Finsternisse" was probably the largest computational project of that time. It contains a short account of how the computations were made, twenty pages of instructions, 320 pages of tables of geometric elements for all 8000 solar eclipses in the interval between 1208 B. C. and 2161 A. D., 52 pages listing 5200 lunar eclipses for the same interval and then 160 maps of solar eclipse umbral paths. The original manuscripts of the computations were bounded in two sets containing 121 volumes each. One set is preserved at the Vienna Observatory and the other set is in the Austrian National Library. Oppolzer worked on the computations between 1881 and the end of 1885, together with five volunteer collaborators.

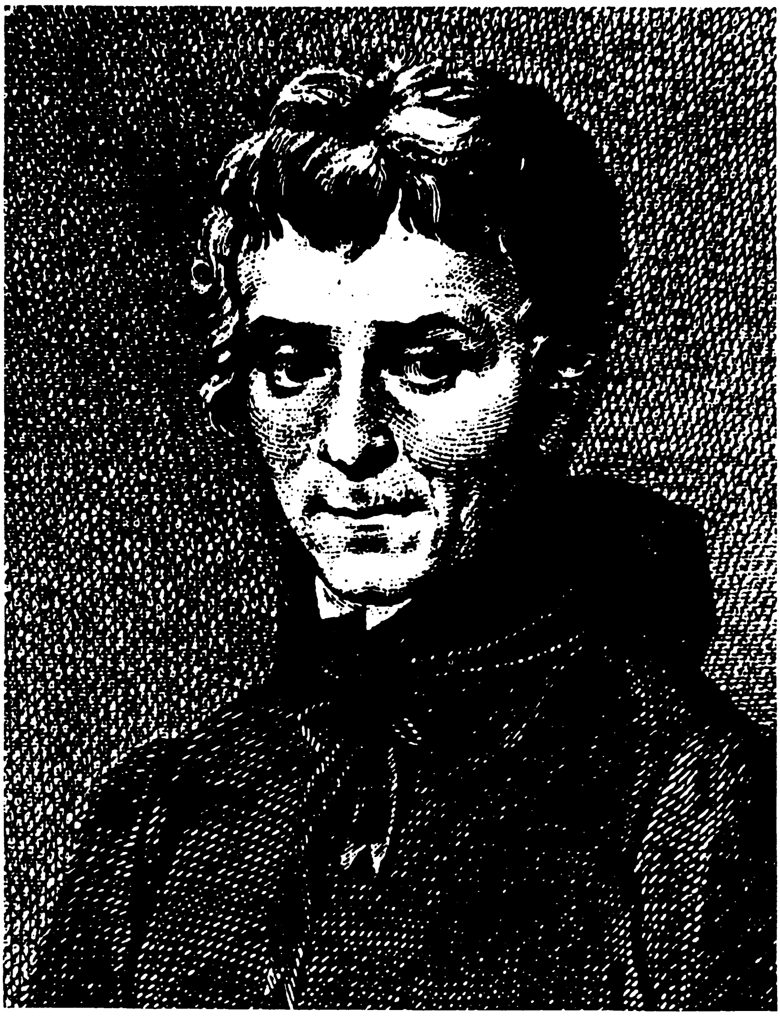


Fig. 1. Franz Ignaz Cassian Hallaschka (July 10, 1780—July 12, 1847)

The coming solar eclipse on August 11, 1999, that will be visible as a total eclipse in Europe, is an occasion to mention one older remarkable book on solar eclipses of 19th century, Hallaschka's *Elementa eclipsium* [8], that appeared in 1816 and contained calculations of solar eclipses for the period 1816 – 1860.

1. The life and work of F. I. C. Hallaschka

Franz Ignaz Cassian (Cajetan) Hallaschka (Fig. 1) was born on 10th July 1780 in Budišov (Bautsch) in Moravia. During his studies in Moravia, he entered the Piarists, the Catholic educational order ("Clerici regulares scholarum piarum") in 1799, and started his career as a teacher of mathematics and physics at secondary schools in Strážnice, Mikulov and Kroměříž (1801 – 1803). In 1804 he was appointed as a lecturer at the Theresianum Accademy in Wienna and became praefect of this school. He continued to study physics and after obtaining the degree "philosophiae doctor" in 1807, he returned back to Moravia as professor of physics and mathematics at the piaristic colleges in Mikulov (Nikolsberg) and Brno (Brünn). A small astronomical observatory was built for him in Brno. The years 1814 – 1832 he spent in Prague as a professor of physics at the University. For the academic year 1832 he was elected as the Chancellor of the University ("rector magnificus"). His next appointment was in Vienna, as a member of the governmental high commission for education. He was responsible for philosophical, technical, nautical university studies and education at technical high schools, mining academies and forest academies. He substantially improved physics teaching in the monarchy, initiated and supported the creation of "Cabinets of Physics" in schools and accented demonstration of experiments. In 1844 he was named as councillor at the imperial court and at the same time, from 1838, he became probost in Stará Boleslav (Altbunzlau) and landespraelat of Bohemia. He died in Prague on July 12, 1847.

Hallaschka is characterized by his contemporaries as a bright personality of unusual charm and diplomatic capabilities. Even if he mainly had positions in teaching physics, his publications (see list in Rem. 3) on experimental physics, optics, thermodynamics, electricity and magnetism did not exceed the standard level of university courses. On the other hand, his astronomical works show an excellent skill in computation, detailed knowledge of contemporary astronomical literature and invention in improving computational methods. As will be shown later, his method used in *Elementa eclipsium* anticipated the standard theory of eclipses by Friedrich Wilhelm Bessel [7].

During his stay in Prague, Hallaschka lived in the Convent of Piarists in Herrengasse No. 856 (now Panská Street) in the New Town of Prague. He adapted one part of the top floor of this building to serve as an astronomical observatory and equipped it with some instruments of high quality (see list in Rem. 4),

ELEMENTA ECLIPSIUM

QUAS PATITUR

TELLUS, LUNA EAM INTER ET SOLEM

VERSANTE,

AB A. 1816 USQUE AD A. 1860,

EX

TABULIS ASTRONOMICIS RECENTISSIME CONDITIS

ET

CALCULO PARALLACTICO

DEDUCTA,

TYPO ECLIPTICO ET TABULIS PROJECTIONIS GEOGRAPHICIS COLLUSTRATA

A

CASSIANO HALLASCHKA,

E SCHOLIS PIIS, AA. LL. ET PHILOSOPHIAE DOCTORE, ALMAE ET ANTIQUISSIMAE CAROLO - FERDINANDEAE UNIVERSITATIS PRAGENAE C. R. PROFESSORE PHYSICAE P. ET O., REI OECONOMICAE PER BOHEMIAM C. R. SOCIETATIS MEMBRO ACTUALI, ET SOCIETATIS C. R. GEORGICAE, NATURAE, ET HISTORIAE PATRIAE STUDIOSAE PER MORAVIAM ET SILESIAM SODALI CORRESPONDENTE.

Pragae, 1816.
Typis Theophili Haase.

Fig. 2. Title page of *Elementa eclipsium*

comparable to the equipment of the largest Prague observatory at Clementinum College. Here, in the years 1817 – 1832, he carried out regular daily astronomical, meteorological and some geomagnetic observations that were published later in two bands (see Rem. 3). These records represent an independent source parallel to the observations at Clementinum College; both observatories were in the centre of the city and had a mutual distance of less then 1 km. Hallaschka collaborated with

Fig. 3. Frontispice of *Elementa eclipsium*

astronomers of Clementinum, mainly with Martin Alois David (1757–1834), the director of the Clementinum observatory, and also lectured astronomy (Rem. 5).

2. The book *Elementa eclipsium*

Even if Hallaschka listed almost all the European authors of eclipse calculations in the introductory chapter (with exception of England) – 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, he later developed his own method of geometric calculations of the umbral sizes and positions based on the work of Cl. Wurm [9] and geometric projections on the Earth' surface based on the books by Lalande [10] and Rüdiger [11]. The geocentric positions of the Sun and Moon he took from Triesneckers ephemerides [12] and times instances of new Moon he found in tables by Lambert [13] and Vega [14]. He knew also the methods by Lagrange [15] and Laplace [16], but did not use them.

Hallaschka wrote his *Elementa Eclipsium* when still living in Moravia and so he decided to express all the time indications in the local time of Brno, the Moravian metropolis. In the introduction, he determined the differences of local time between Brno and Vienna, Berlin and Paris. Introducing the local time of Brno instead of the universal time defined by the zero meridian of Ferro, or another commonly used time like e.g. that of Paris, was undoubtedly an obstacle of a swith use of Hallaschka's work. Probably for this reason, in Chapter 72 Hallaschka included a table of basic eclipse data (times of the begin, maximum, end of the partial eclipse, and eclipse magnitude) for Berlin, Buda (now Budapest), Prague, Vienna and Lvov, probably computed in advance by Ignaz Kautsch (Rem. 6).

As the main projection plane, Hallaschka used the place perpendicular to the direction given by the centre of the Moon and of the Sun at the time of maximum eclipse. Figure shows how the size of umbra and penumbra were constructed in this plane. Bessel introduced the projection on the so called "fundamental plane" that remains all the time perpendicular to the line connecting the centres of the Moon and Sun, which represents also the axis of the umbral and penumbral conus. Hence, the fundamental plane changes the inclination to the above mentioned projection plane, and Hallaschka corrected the difference using a similar formula as in the correction due to parallax. Fig. 4 to 7 demonstrate the way in which the construction of the umbral path proceeded from the West to the East and then how the lines of the constant partial eclipse were drawn parallel to the totality path. In the projection to the Earth' surface, Earth flattening 333 : 334 was applied. Next Figures show the maps for eclipses on Nov 19, 1816; May 5, 1818; Sep 7, 1820; Nov 29, 1826; Jul 17, 1833; May 15, 1841; Jul 8, 1842, May 6, 1845; Oct 9, 1847; Jul 28, 1851; Mar 15, 1858 and Jul 18, 1860.

Since the projection on the Earth' surface was constructed geometrically and arcs of circles were replaced by straight lines, the precision of the drawings could not be better than several tens of kilometers at the middle point of the projection and much more at the limb. One can conclude that Hallaschka's maps were well

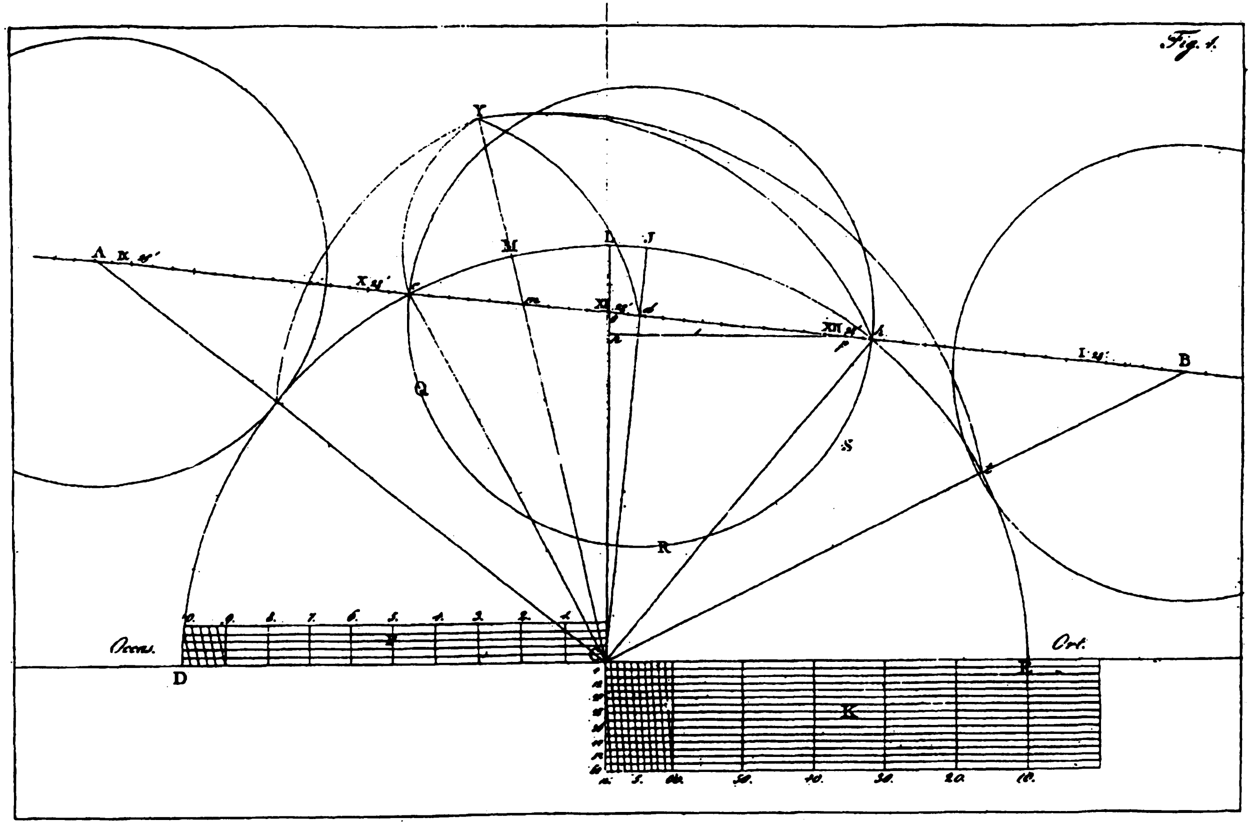


Fig. 4. Nomogram for the eclipse on November 19, 1816, local time of conjuction in Brno 11h 28m 11.9s

DLE position of the Earth as seen from the centre of the Moon
C centre of the Earth, CD radius 60′8″, D is West, E East side
CM direction to the north pole
DCE ecliptic
A, B relative trajectory of the lunar centre, A at 9h 20m 18.6s; B at 13h 53m 37.2s

Cd minimum distance, QRS corresponding penumbra
K, P auxiliary scales for interpolation
Ar, Bt radius of the lunar penumbra 32′40.5″
IX, X, XI, XII, I lunar centre at hours 9 – 13 of local time in Brno

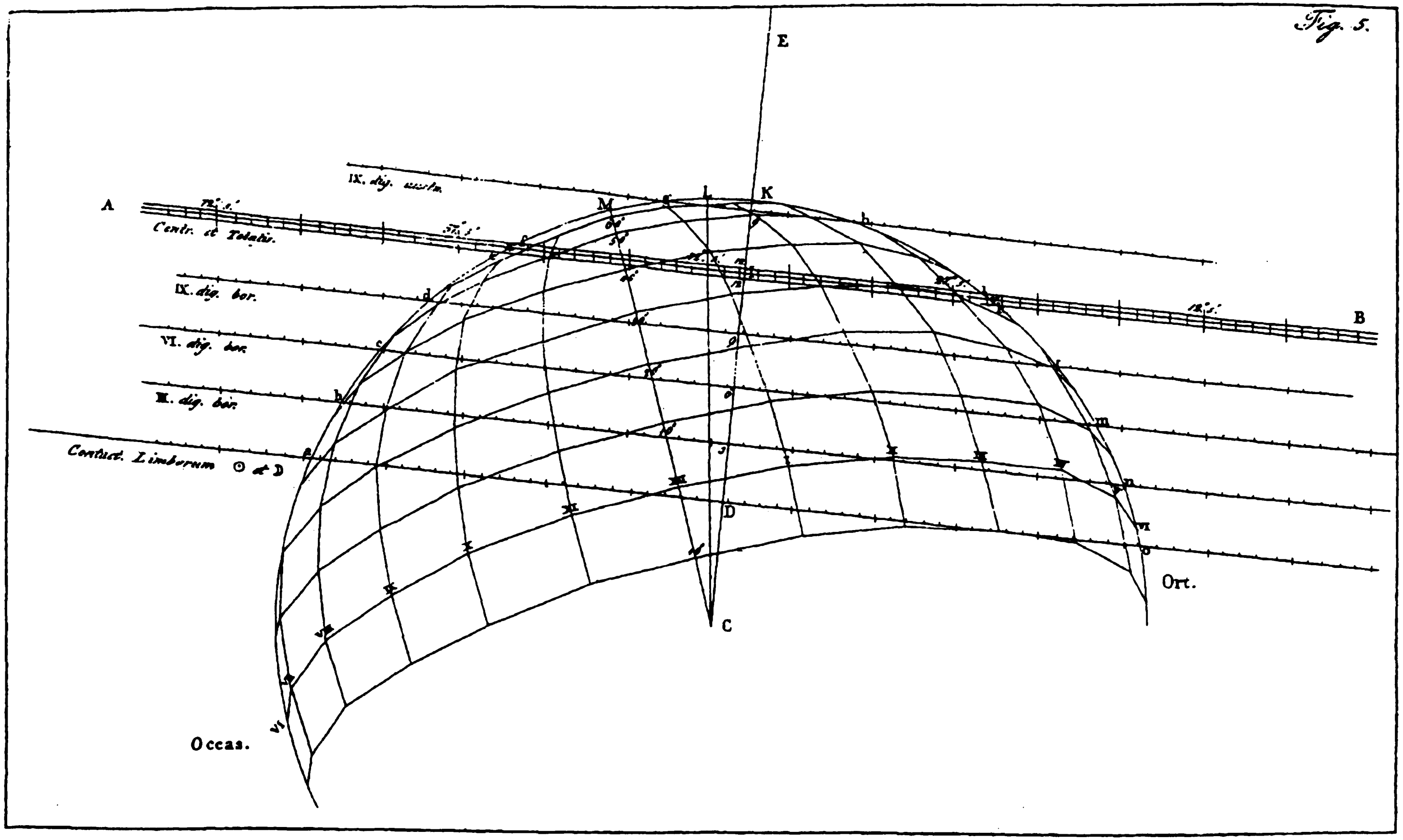


Fig. 5. Position of the geographic coordinates corresponding to Fig. 4. Points A, B, M, L are identical on both pictures

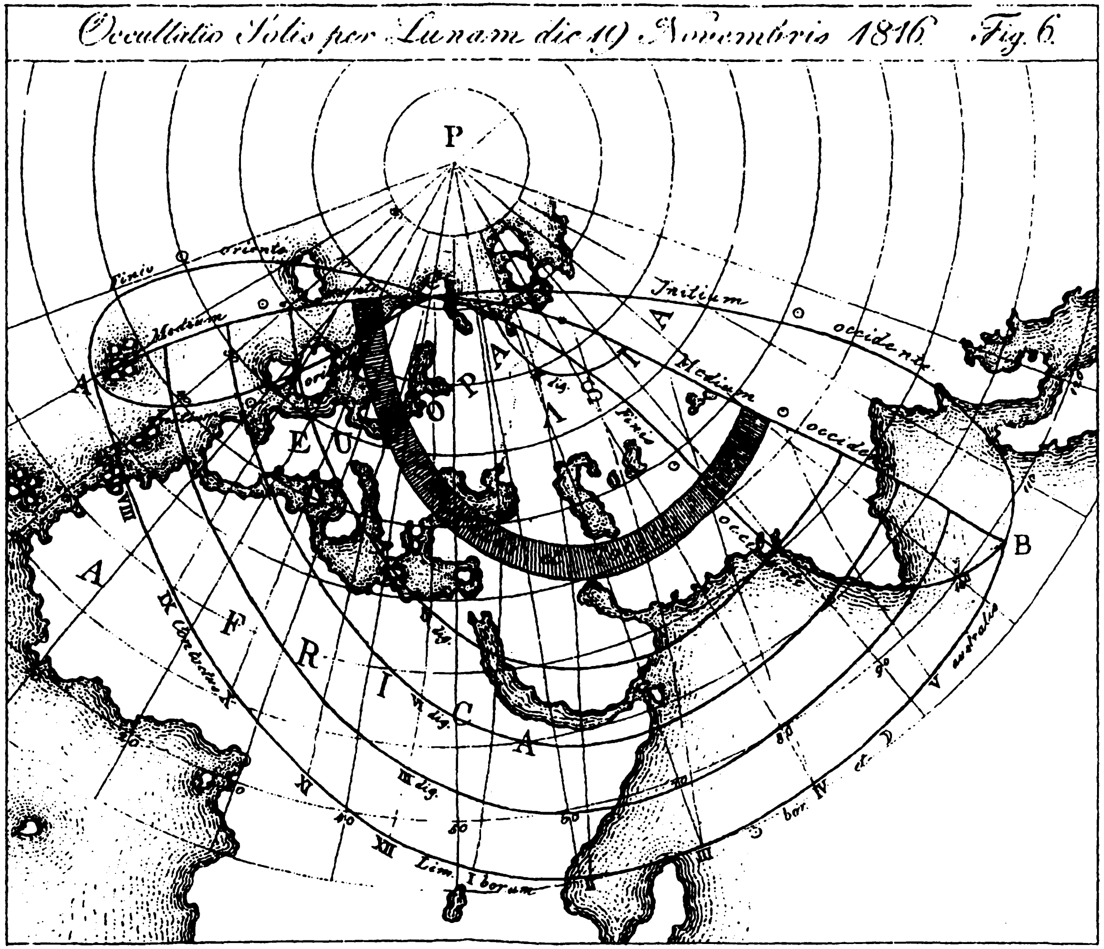


Fig. 6. The eclipse on November 19, 1816

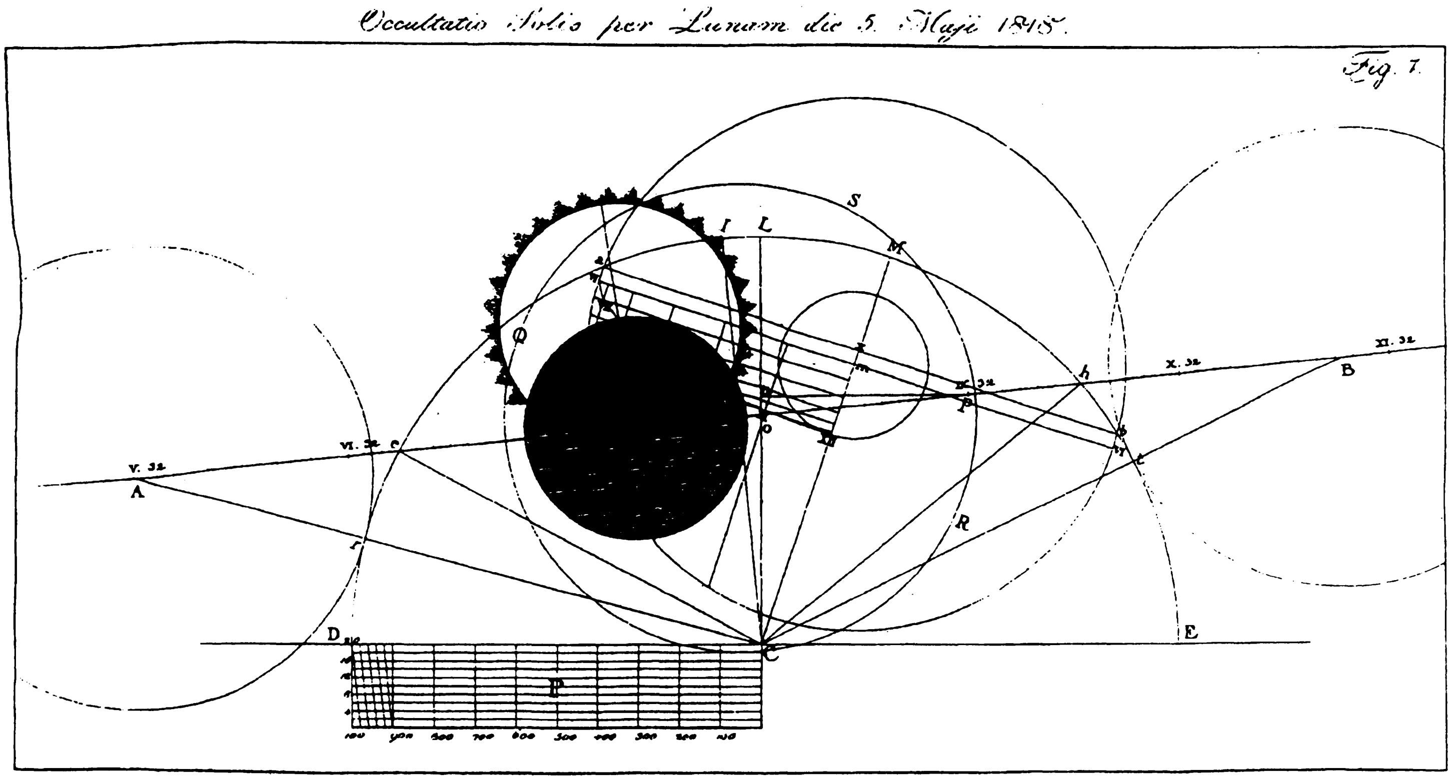


Fig. 7. Nomogram for the eclipse on May 5, 1818 (points are denoted as in Fig. 4, but numerical values are different; solar and lunar discs are merged from another nomogram)

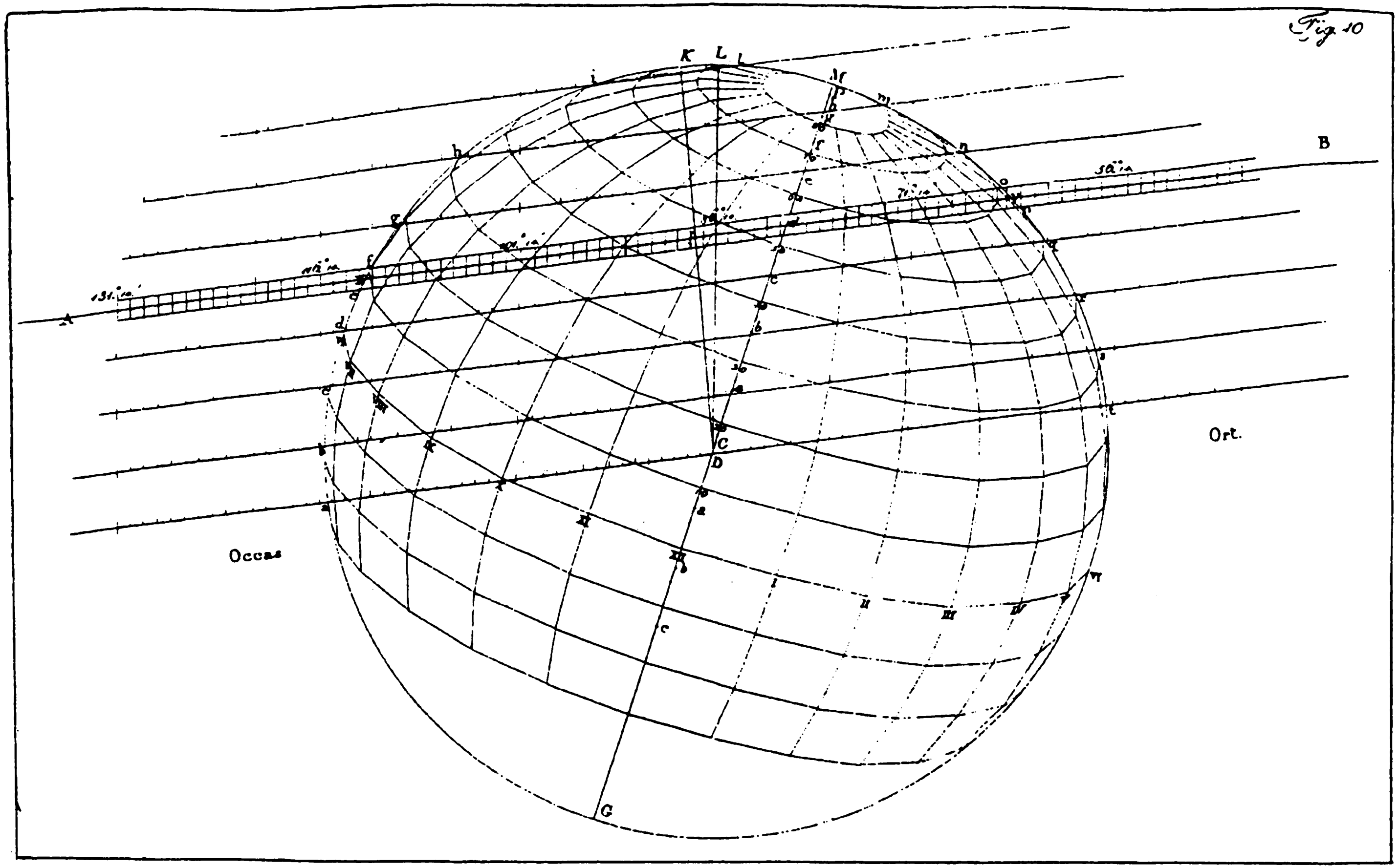


Fig. 8. Position of the geographic coordinates corresponding to Fig. 7. Points A, B, M, L are identical on both pictures

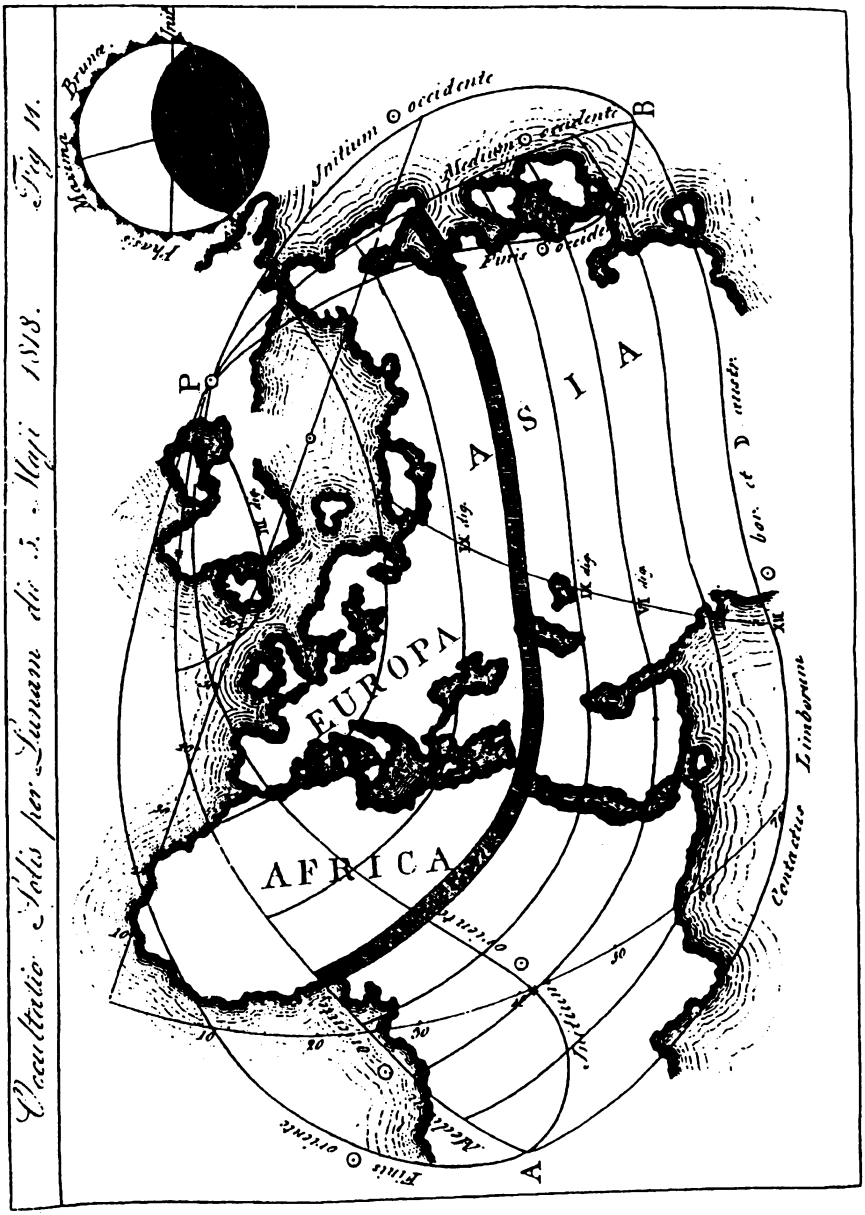


Fig. 9. The eclipse on May 5, 1818

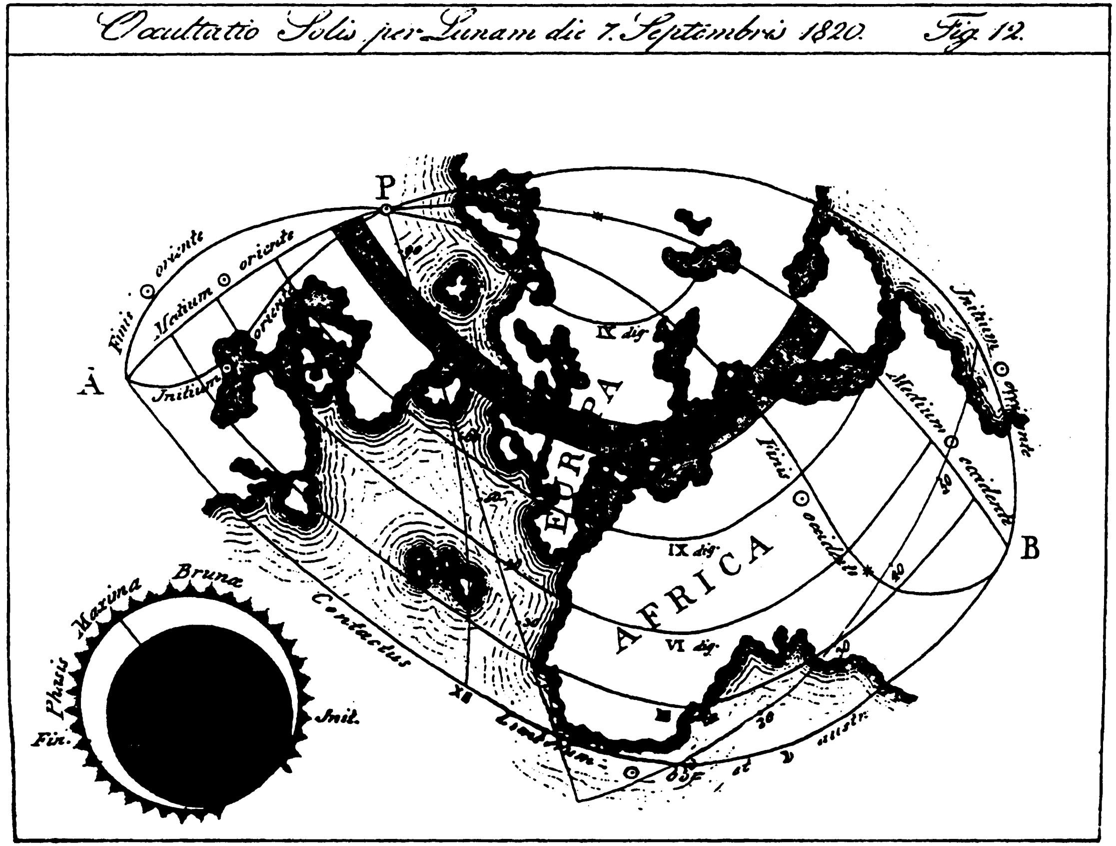


Fig. 10. The eclipse on September 7, 1820

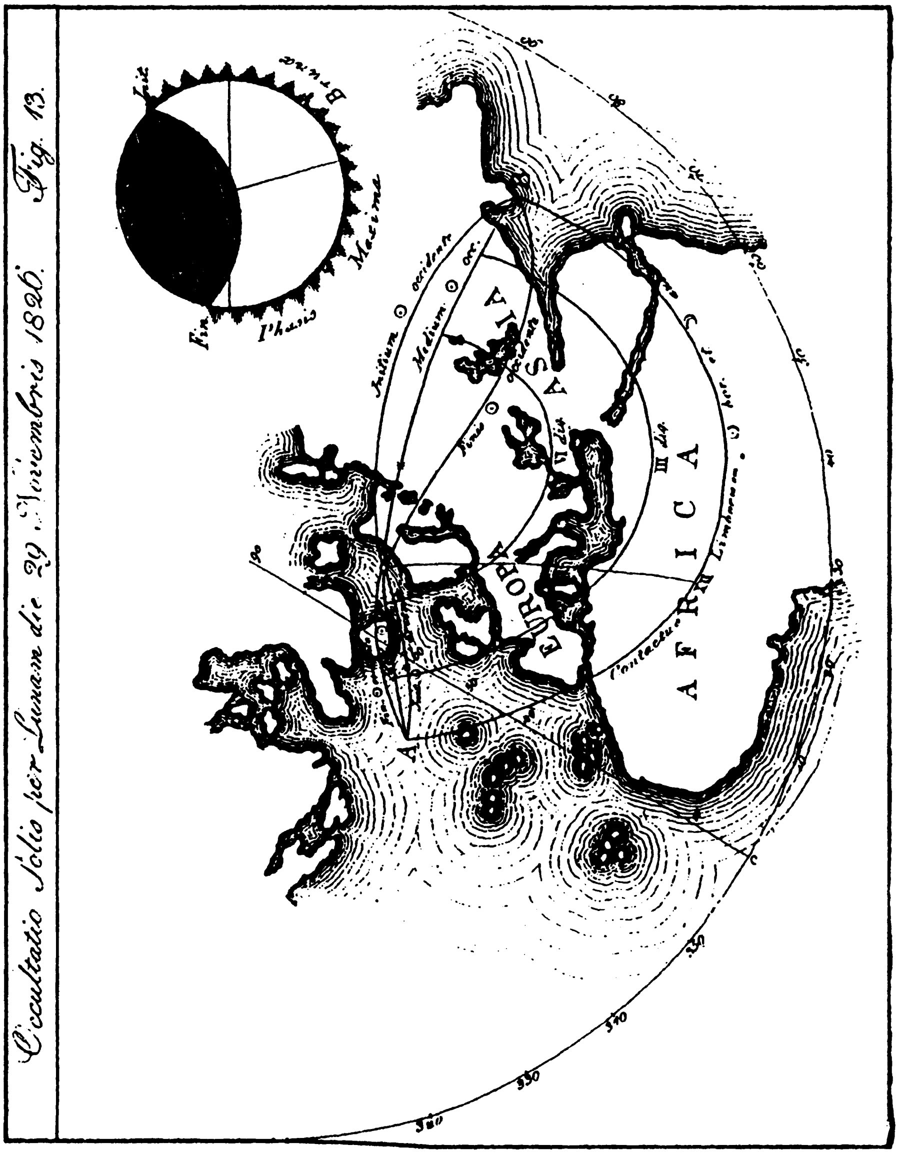


Fig. 11. The eclipse on November 29, 1826

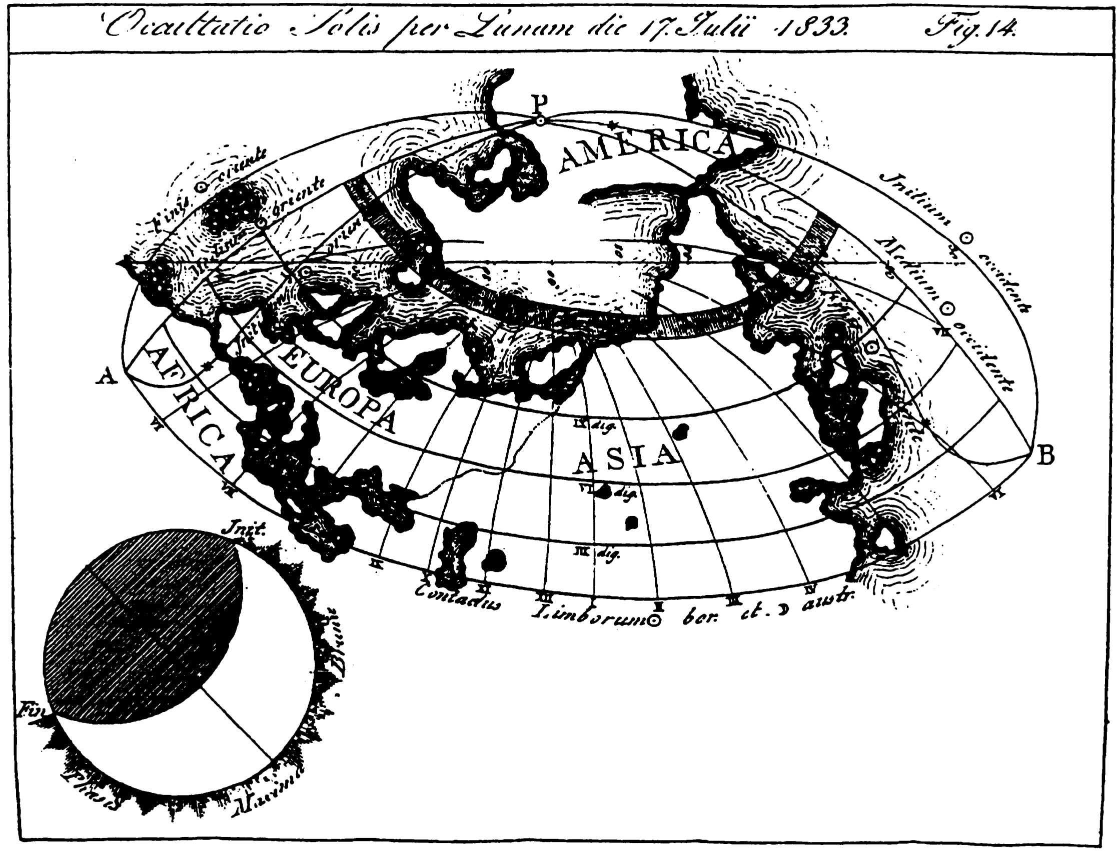


Fig. 12. The eclipse on July 17, 1833

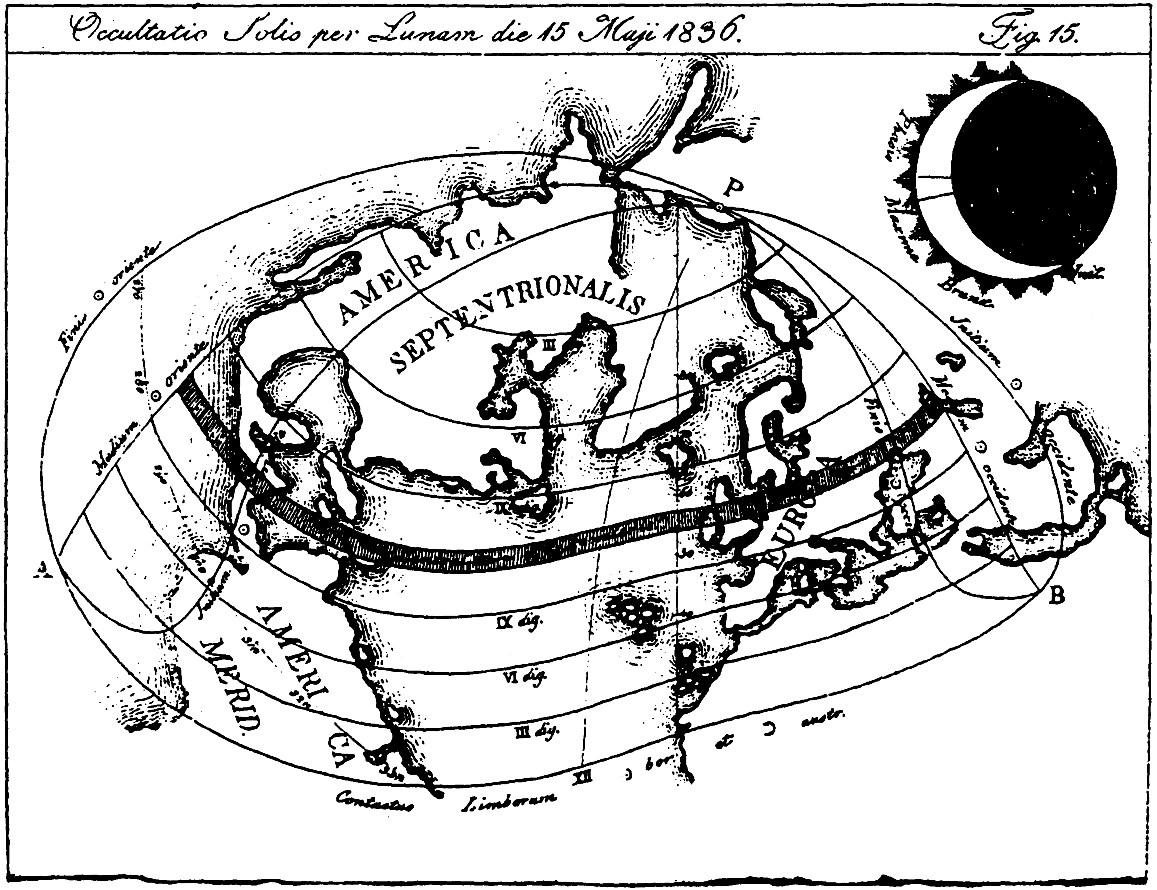


Fig. 13. The eclipse on May 15, 1836

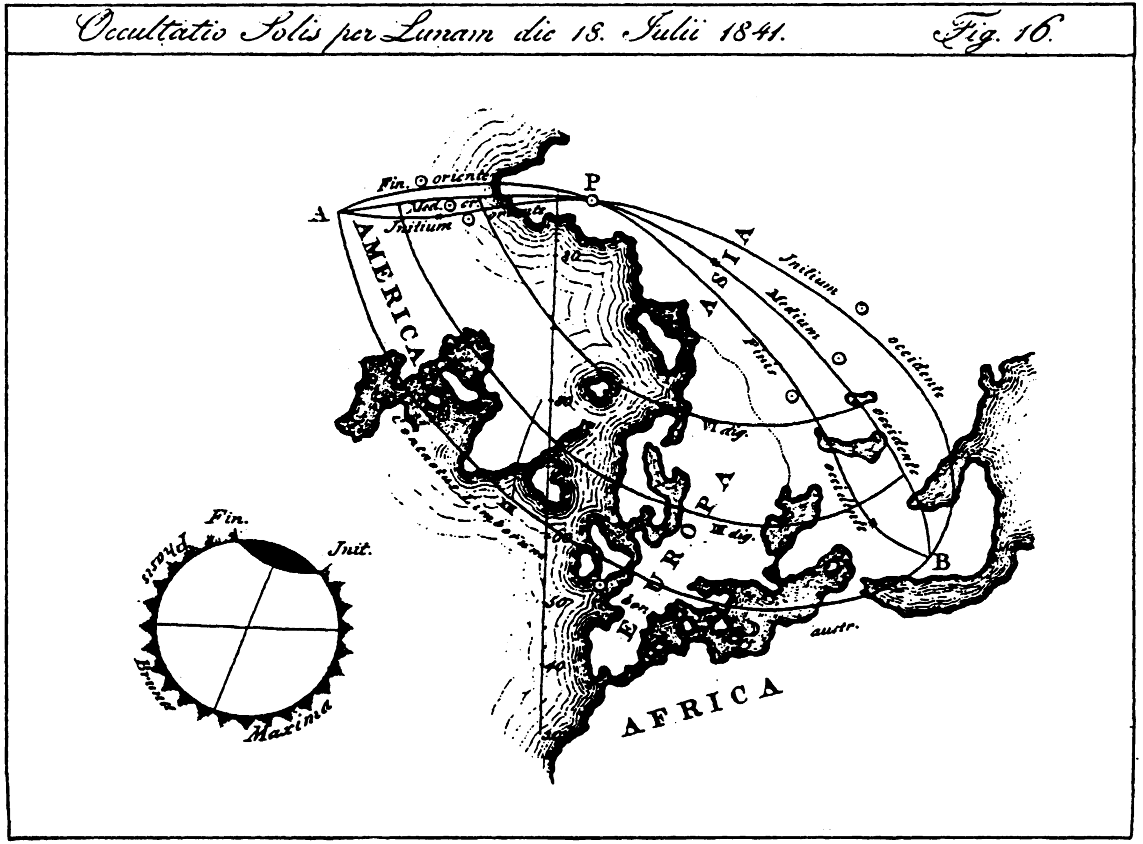


Fig. 14. The eclipse on July 18, 1841

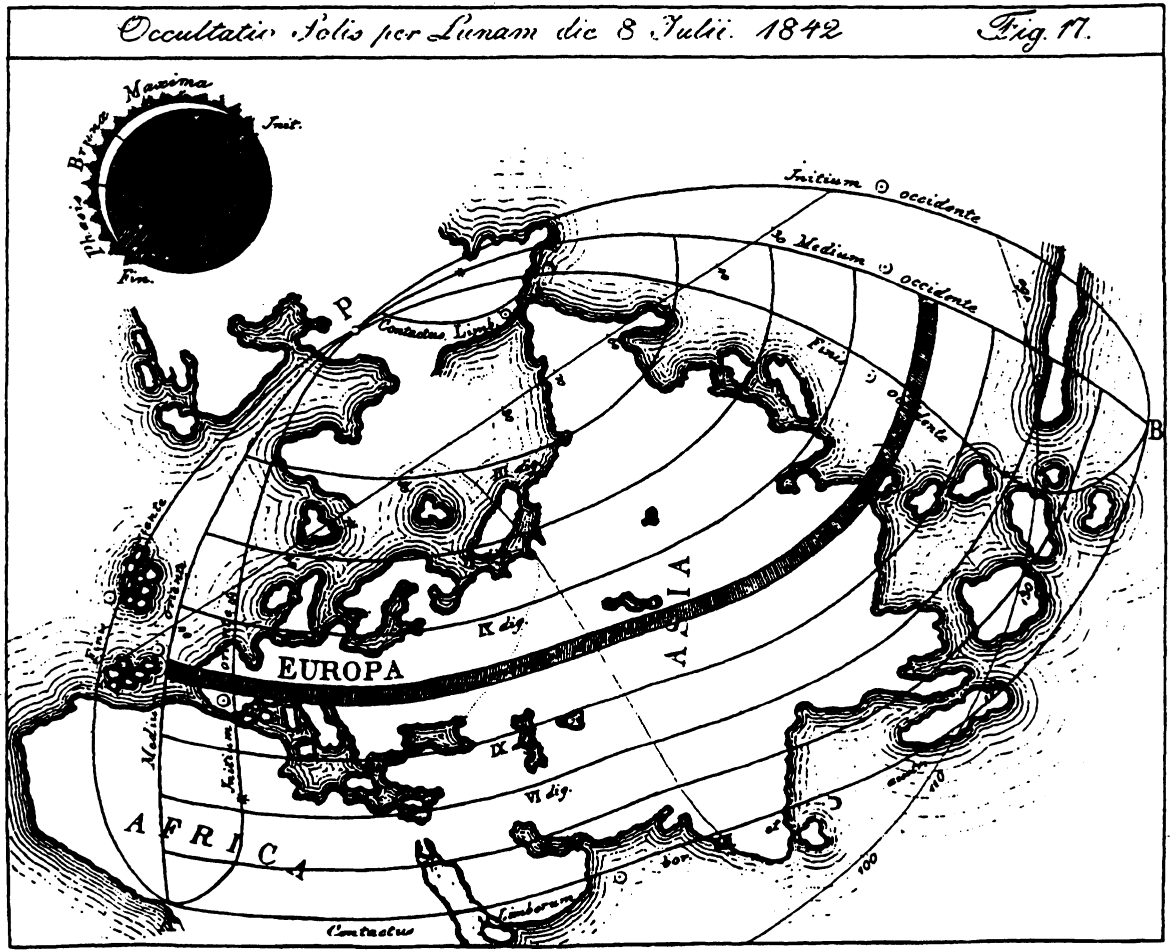


Fig. 15. The eclipse
on July 8, 1842

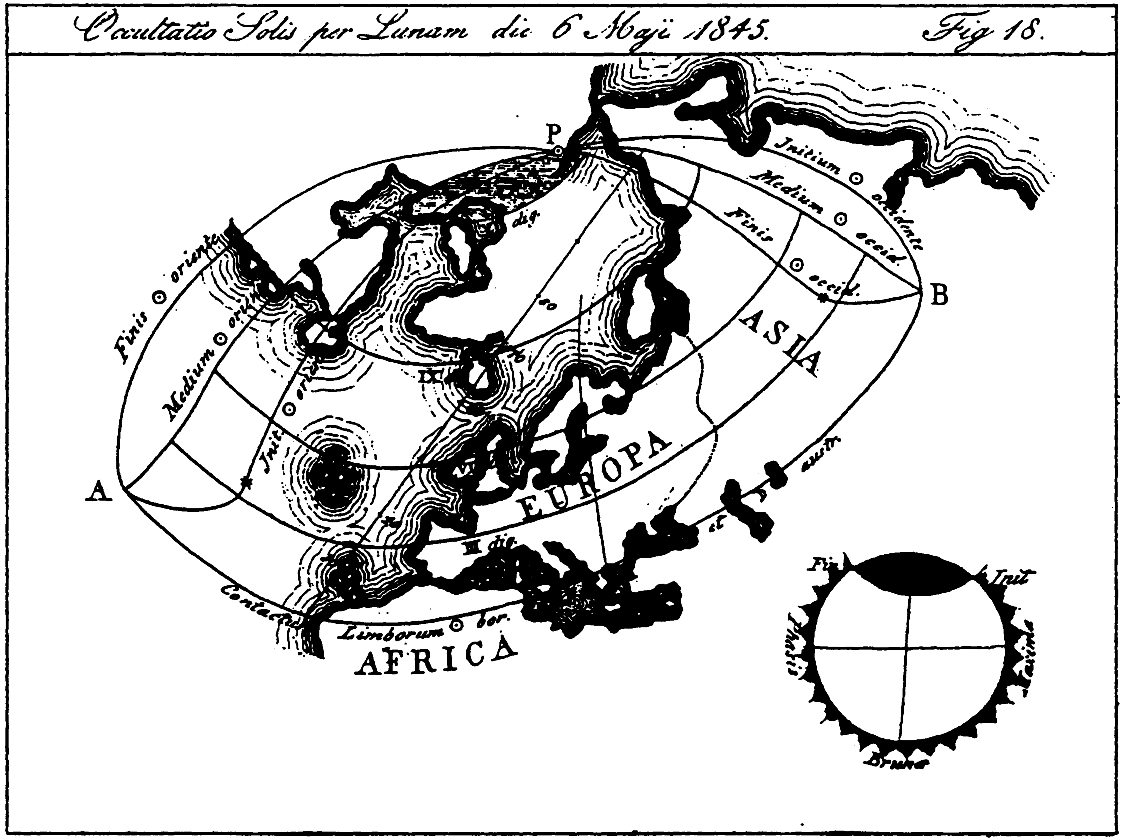


Fig. 16. The eclipse
on May 6, 1845

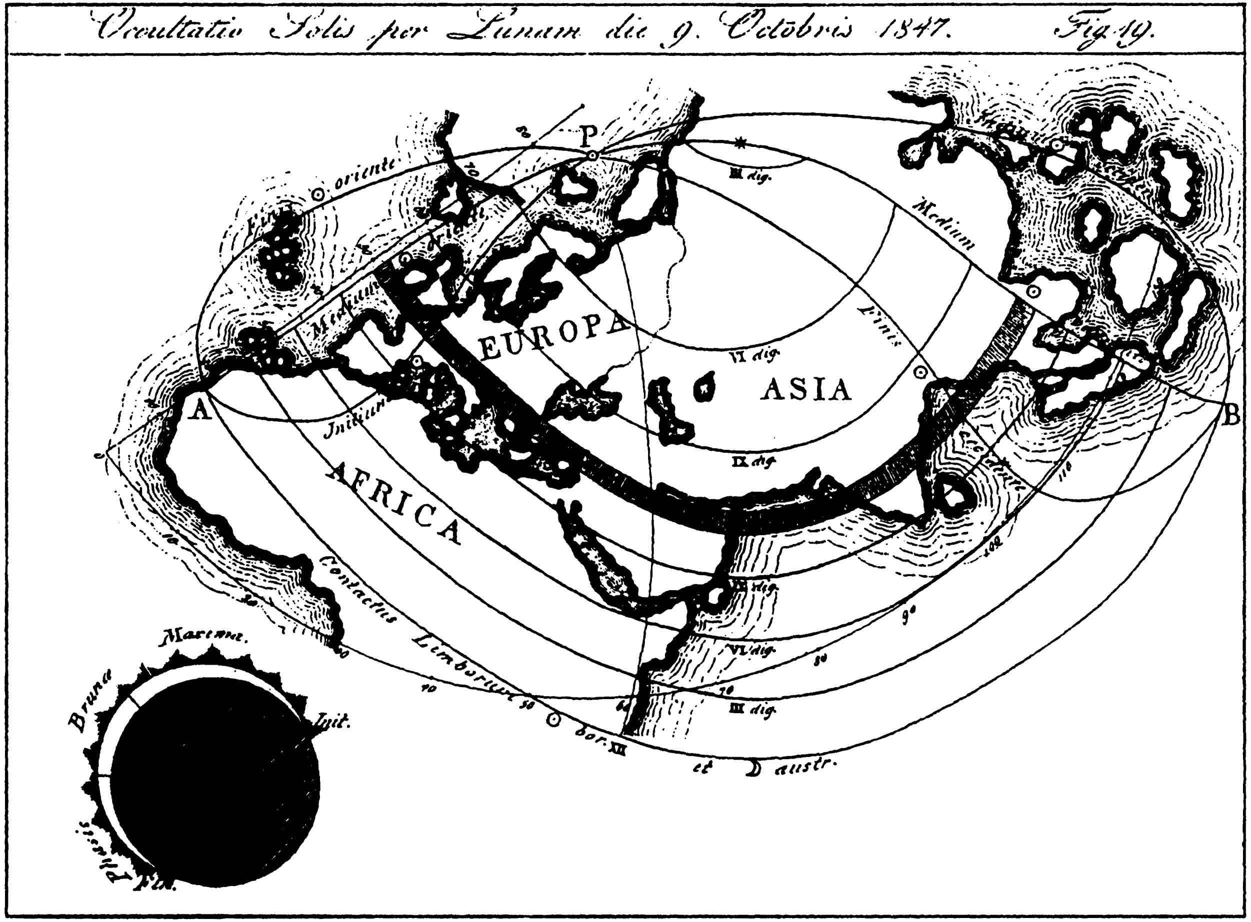


Fig. 17.
The eclipse
on October 9,
1847

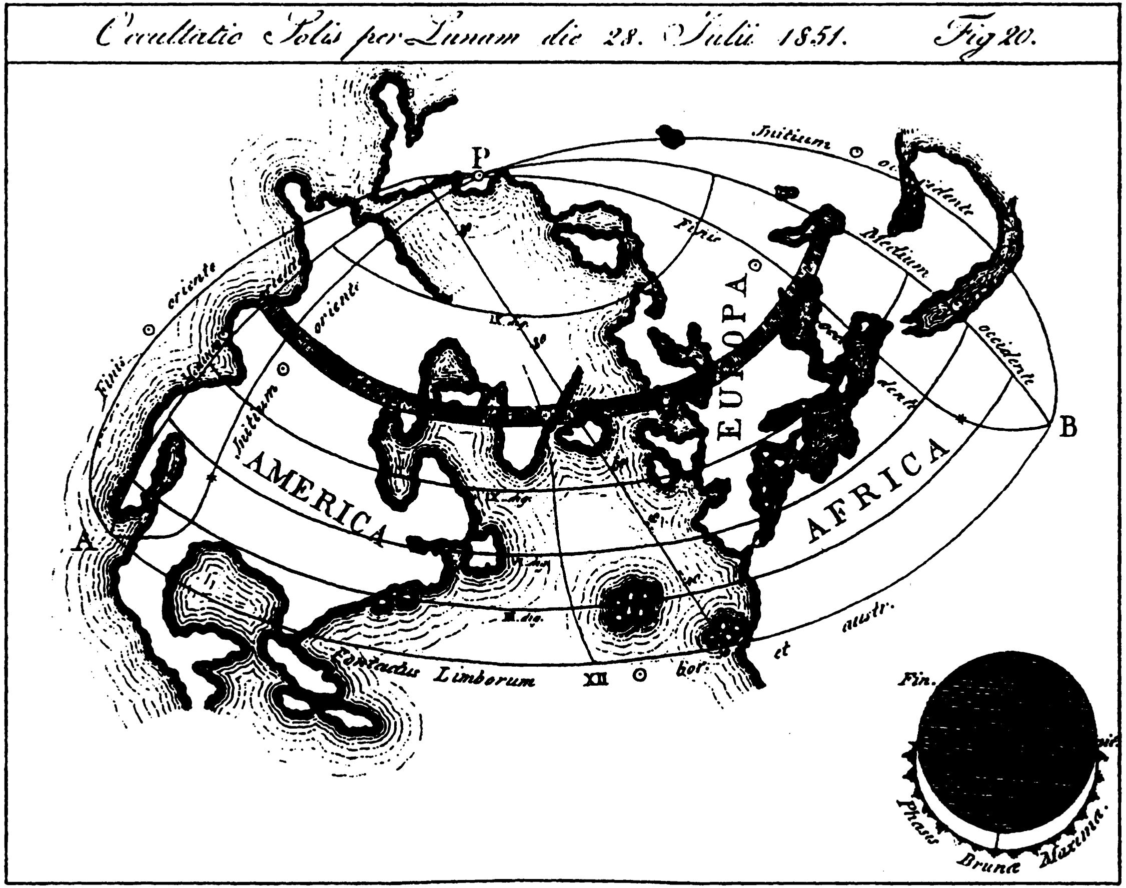


Fig. 18. The eclipse on July 28, 1851

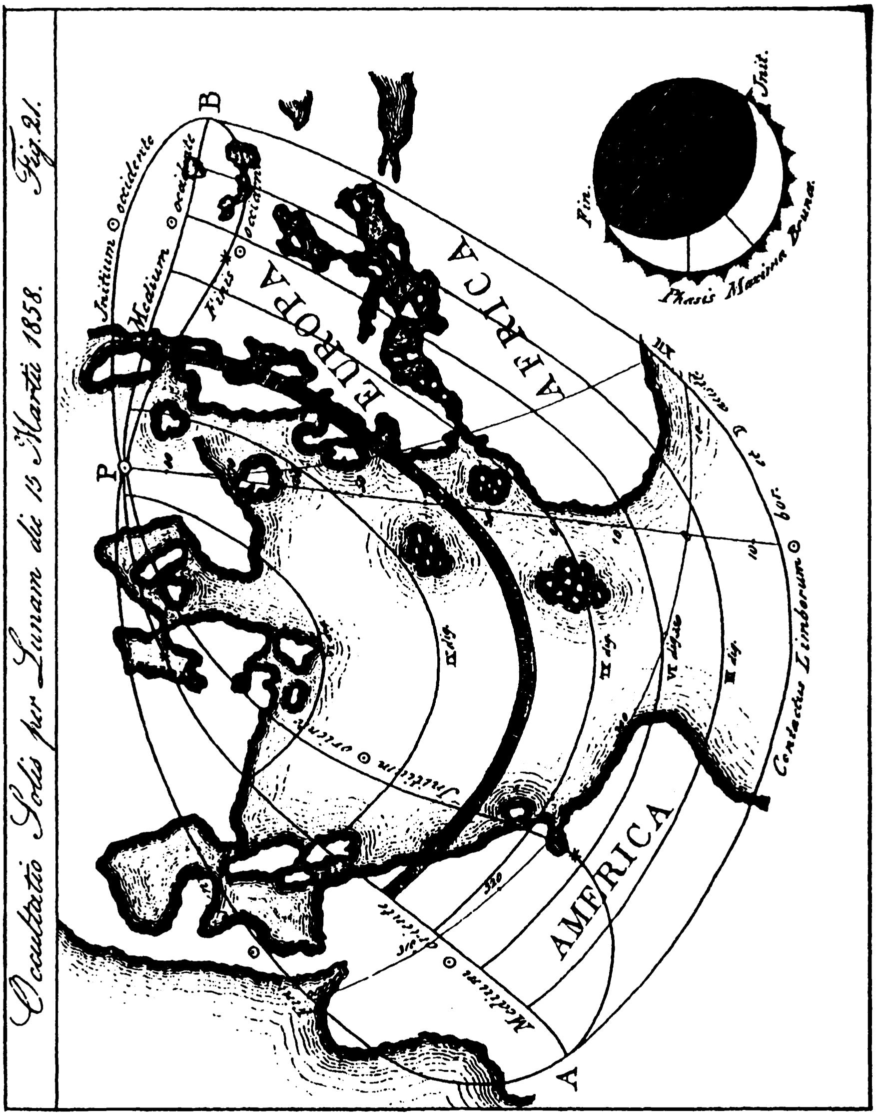


Fig. 19. The eclipse on March 15, 1858

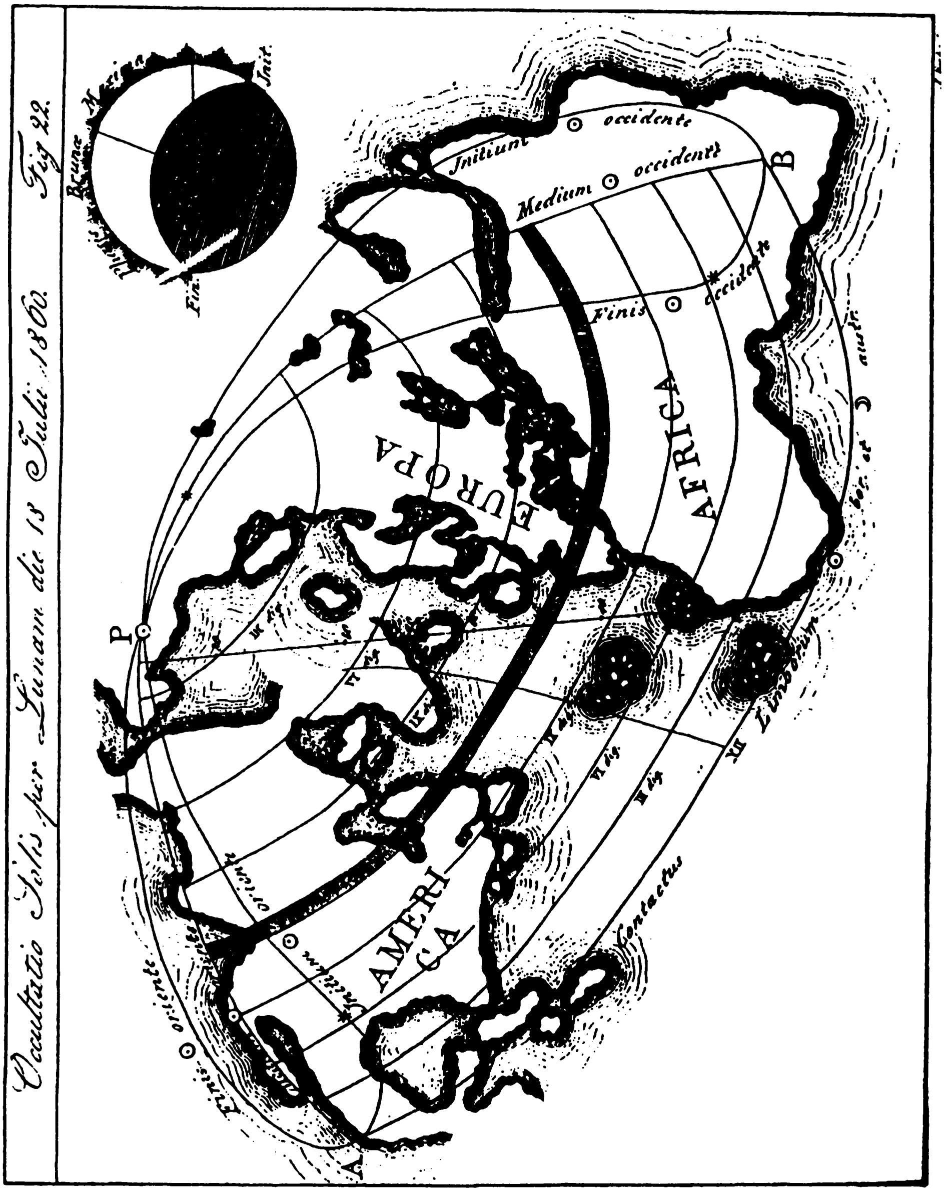


Fig. 20. The eclipse on July 18, 1860

comparable with maps by other authors of that time. The main contribution of Hallaschka was, however, that he published an atlas of solar eclipses until 1910 (together with the extension volume) which was surpassed only later e.g. by Oppolzer. The precision of the eclipse maps increased with better theories of lunar motion, first by Hansen [17], [18], later by Newcomb [19]. At the beginning of the 20^{th} century there appeared a more concise theory of lunar motion by Brown [20] and a paper on eclipses by Andoyer [21], which allowed together with the standard Bessel's theory as it is given e.g. in [22], a new generation of eclipse computations, as e.g. [23] and [24], roughly 100-times more precise than in the time of Hallaschka.

Remarks

1.

This instrument (Fig. 21) was described in Kepler's *Astronomiae pars optica* [2] and was used by Kepler for observation of the eclipse on July 10, 1600, in Graz. Later he constructed an improved version in Prague for the eclipse on October 12, 1605. This instrument is in principle a "camera obscura" and a similar one was equipped later with the newly invented telescope and served for observations of sunspots.

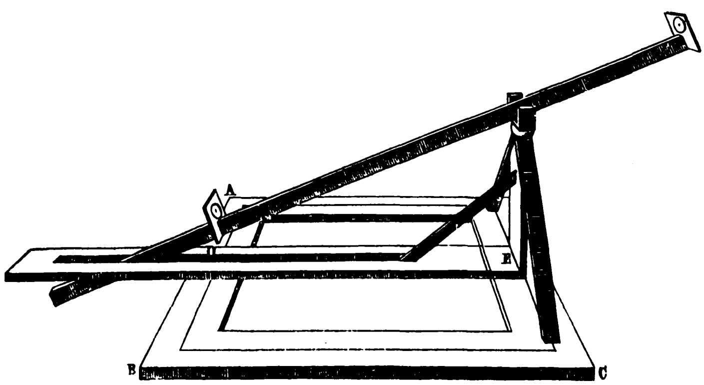
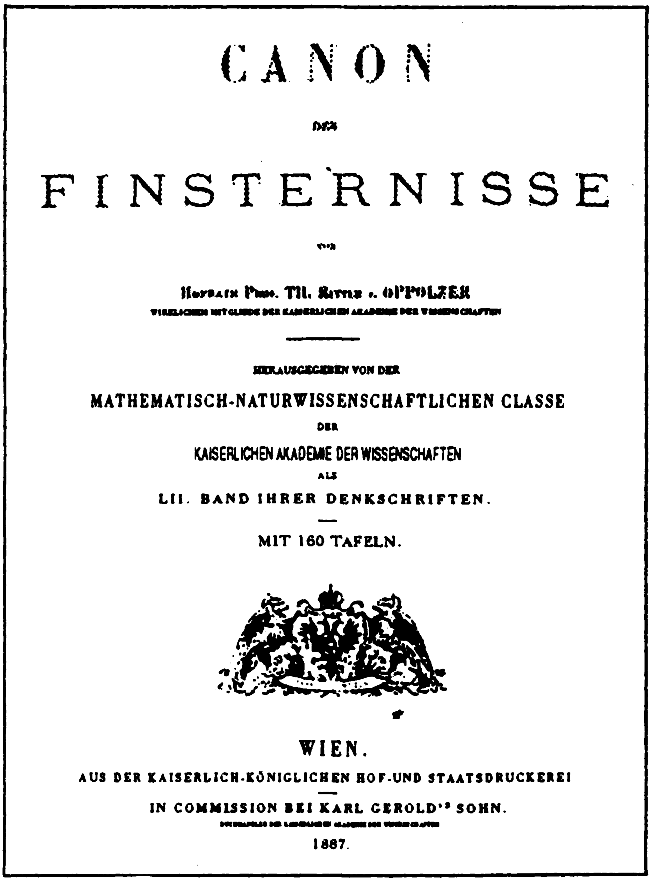


Fig. 21. Kepler's instrument for projecting solar eclipses on paper sheets

2.

Theodor von Oppolzer was born in Prague on October 26, 1841. His father was a famous Prague surgeon, his mother was from a family of a chemists. The Oppolzer's moved to Vienna in 1850. Theodor studied medicine at Vienna university and was a brilliant student, deeply interested in mathematics and the natural sciences. His early astronomical papers comprise computations of 56 orbits of comets and asteroids. His mother financed the building of his private observatory with a revolving dome, that was equipped with a 7-inch refractor, a wide-field



CANON

FINSTERNISSE

MATHEMATISCH-NATURWISSENSCHAFTLICHEN CLASSE

KAISERLICHEN AKADEMIE DER WISSENSCHAFTEN

LII. BAND IHRER DENKSCHRIFTEN.

MIT 160 TAFELN.

WIEN.

AUS DER KAISERLICH-KÖNIGLICHEN HOF-UND STAATSDRUCKEREI

IN COMMISSION BEI KARL GEROLD'S SOHN.

1887.

Fig. 22. Title page of Oppolzer's *Canon der Finsternisse*

comet seeker and a meridian circle. In 1866 he became private teacher of dynamical astronomy at Vienna university and after publishing a new method of orbit determination in 1870, that substantially simplified the previously used method by Gauss, his position was changed to extraordinary professor at the university. He was very skilled in laborious numerical computations, he knew about 14000 values of logarithms by heart and the number of his published computational papers exceeded 200. He became interested also in computing eclipses, which was another problem of that time that required extensive numerical calculations. The eclipse catalogue published by the French astronomer Alexandre-Gui Pingré [6] did not satisfied him because of its lacking precision, and Hallaschka's *Elementa Eclipsium* comprised only a limited period of 19th century. Moreover, both catalogues were computed before Bessel created the standard procedure of computing eclipses [7]. Oppolzer carried out some preparations for creating a much more extended catalogue, he published *Syzygien-Tafeln fuer den Mond* [4], *Tafeln zur Berechnung der Mondfinsternisse* [5] and started the work on *Canon der Finsternisse* [3]. Five collaborators, who were later partly remunerated from his own pocket, helped him in computations and on October 22, 1885, the 242 volumes of the manuscript with more than 10 million figures and logarithmic computations were submitted to the Imperial Academy of Sciences in Vienna. He succeeded to correct the proofs and then died on heart attack at the untimely age of 45, 1886, on December 26, shortly before the print was finished (Fig. 22).

3.

Selected publications by F. I. C. Hallaschka

Elemente der Naturlehre, Brünn 1814

Kurze Anleitung zur Kenntniss der Sternbilder, Brünn 1814

Dissertatio de constructione et usu barometri et thermometri etc., Brünn 1814

Dissartatio de lege dilatationis per calorem quorundam fluidorum stillatitiorum etc., Prague 1818

Geschichtliche Darstellung der Arbeiten aus der Experimental-Physik an der k. k. Carl-Ferd. Universität in Prag, 1818

Dissertatio de phaenomenis tuborum capillarium etc., Prague 1819

Dissertatio de phaenomenis electro-magneticis etc., Prague 1822

Dissertatio de luminis inflectionis et deflectionis phaenomenis etc., Prague 1823

Hanbuch der Naturlehre, 1st, 2nd Bds. Prague 1824, 3rd Bd. Prague 1825

Elementa ecclipsium, quas papitur tellus, luna eam inter et solem versante, ab A. 1816 usque ad A. 1860 etc., Prague 1816

Calculus ecclipsis solis etc. cui accedunt elementa ecclipsium 1861 – 1910, Prague 1820

Längen- un Breitenbestimmung mehrerer Örter, 1821

Sammlung der von 1817 bis 1827 im Piaristenconvict zu Prag angestellten astronomischen, physikalischen und meteorologischen Beobachtungen, Prague 1830 (Fortsetzung fuer 1828 – 1832, Annalen der Wiener Sternwarte XXIII, 1843)

Astronomical observations, mainly occultations of stars by the Moon and occultations of Jupiter's satellites, were published in Abhandlungen der koeniglichen Boehmischen Gesellschaft der Wissenschaften, in Bode's Berliner Jahrbuch und Schuhmachers journal Astronomische Nachrichten.

4.

Instruments at the observatory of F. I. C. Hallaschka, Piaristenconvict Herrengasse 856, New Town of Prague (according to *Sammlung der von 1817 bis 1827 im Piaristenconvict zu Prag angestellten astronomischen, physikalischen und meteorologischen Beobachtungen*, Prague 1830)

1. Achromatic telescope by Fraunhofer, 4 feet 10 inch long brass tubus, mounting with fine vertical motion, objective aperture 37″, focus 48 inch, 2 terrestrial eyepieces 50 × and 70 ×, 4 astronomical eyepieces 56 ×, 84 ×, 130 ×, 200 ×, solar filter.

Later supplied 1 astron. eyepiece 30 ×, Ramsden eyepiece with micrometer, circle-micrometer by Fraunhofer, pancratic eye-tube by Kitchiner (London), wooden transport box

2. Achromatic telescope by Dollond, 5 feet 10 inch long, wooden tubus, objective aperture 32″, focus 60 inch, terrestrial eyepiece 56 ×, solar filter, astronomical eyepieces 60 ×, 90 ×
3. Achromatic telescope by Lincoln, brass tubus 15.5 inch, objective focus 7,5 inch, aperture 13″, brass stative, box
4. Cometseeker by Fraunhofer, wooden tubus, parallactic brass mounting, focus 24 inch, aperture 34″, 1 eyepiece 10 × magnification, field 6 degrees, micrometer with an adjustable horizontal thread
5. Microscope by Voigtlaender (Vienna), box, 4 objectives, 1 eyepiece
6. Multiplicating theodolite by Liebherr (Munich), 8 inch diameter, silver limbus divided by 10′, with 2 achromatic telescopes of focal length 12 inch, aperture 12″, mercury horizon, 1 astronomical eyepiece with a prism, solar filter, 2 holders for illumination, Vernier 5 arcseconds, stative
7. Mirror sextent by Liebherr (Munich), 10 inch radius, silver limbus divided by 10′, with achromatic telescope of focal length 12 inch, aperture 12″, mercury horizon with glass cover, 2 astronomical eyepieces, Vernier 5 arcseconds, stative
8. Pendulum clock by Wollenik, Grahams anchor equipment, wooden pendulum rod, going 8 days
9. Clock by Barraud No. 355
10. Mercury barometers, some with Vernier 1/100, other with 1/10
11. Several thermometers (glass, brass, some mounted on a wood plate with a scale)
12. Hygroscope by Danielli
13. Hygroscope by Danielli simplified by Koerner
14. Electroscope by Bennet
15. Magnetic needles for measuring geomagnetic declination and inclination

5.
A prominent personality among Hallaschka's pupils was Joseph Morstadt (1797 – 1869), a state clerk and amateur astronomer, who recognized the periodicity of one comet from 1772 and encouraged his friend Wilhelm von Biela (1782 – 1856) to look for this comet during its apparition in 1826. On February 28, 1826, Biela actually found this remarkable comet, that later split, giving thus origin to the meteor shower of Bielids.

6.
Ignaz Kautsch (Caecilius Cyprianus a.s. Cornelio), astronomer and Piarist monk in Litomyšl (July 20, 1729 – September 23, 1803).

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