THE ROLE OF HISTORICAL OCCULTATION OBSERVATIONS

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Sources of information

- Astronomical reports, periodicals and treatises
- Historical works
- Annals, chronicles, diaries, memorials, letters
- Other (official and church books, graphics….)

Problems with dating, places, authorship, authenticity (possible copies from other sources…)

Methodology of searching

- Collections in libraries and archives: books, old prints, manuscripts
- Internet archives : many valuable data, digital sources not always fully accessible

Keywords: solar eclipse, Sonnenfinsternis, eclipse del sol, eclipse de soleil, zaćmienie słońca, zatmeni slunce, солнечное затмение, solförmörkelse, ηλιακή έκλειψη….
eclipsis solis, [defectus solis, sol nigra, sol disparuit, obtenebratus est sol…]

Keywords cannot be used for manuscripts and some of old prints.

Problems with old languages – spelling, vocabulary and grammar.

Solar eclipses (many records)
Lunar eclipses (valuable records from antiquity)
Lunar occultations (rare valuable untimed records)

Quite precise eclipse and occultation timings started with 17th century only

Multifarious effects
of solar eclipses

- Recognition of the Sun’s structure
- Dating historical events
- General development of astronomical knowledge
- Social and cultural aspects
- Investigation of rotation of the Earth and of orbital movement of the Moon

Previous works and analyses

- G. B. Riccioli (1651): Almagestum novum….
- S. Newcomb (1878): Researches on the motion of the Moon.
- F. K. Ginzel (1883-4): Astronomische Untersuchungen über Finsternisse.
- J. K. Fotheringham (1921): Historical eclipses.
- A.N. Vyssotsky (1949): Astronomical records in the Russian chronicles.
- R. R. Newton (1970): Ancient astronomical observations and the acceleration of the Earth.
- R.R. Newton (1972): Medieval chronicles and the rotation of the Earth.
- S. Williams (1996): UK solar eclipses from year 1.
- F. R.Stephenson (1997): Historical eclipses and Earth's rotation.
- P.J. Huber, S. de Meis (2004): Babylonian eclipse observations from 750C to 1 BC.
- R.Stephenson, L.V. Morrison, C. Hohenkerk (2016): Measurement of the Earth's rotation: 720 BC to AD 2015. *(revised 2020 +M.Z.)*
- G. Gonzales (2017).: Constraining ΔT from Babylonian lunar appulse and occultation observations, Monthly Notices of RAS, 470, 1436–1441.

THE CATALOGUE OF THE HISTORICAL OBSERVATIONS OF SOLAR ECLIPSES
FROM EUROPE AND THE MIDDLE EAST

by Marek Zawilski

ver.7.0

Łódź, May 2021

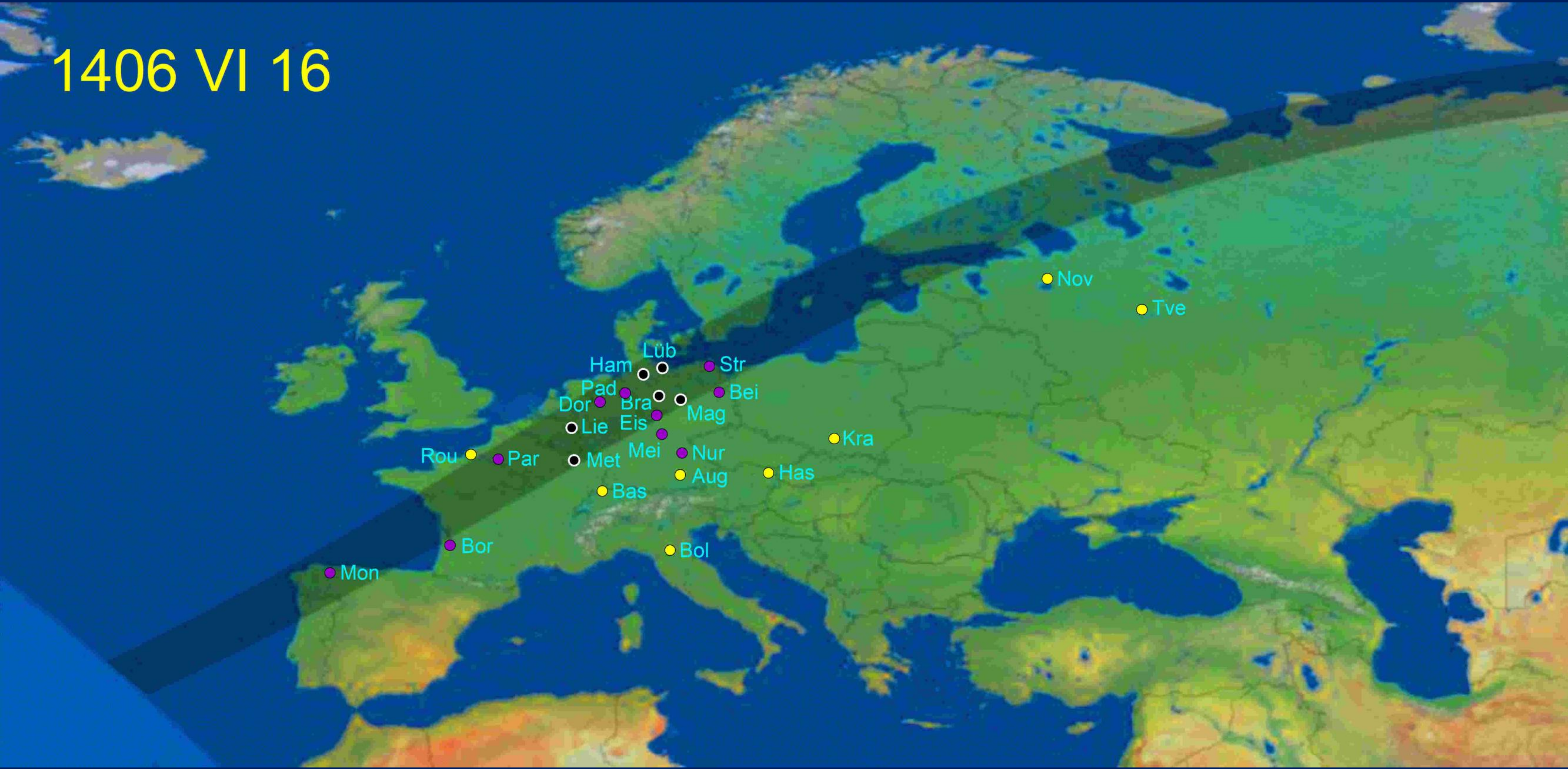
About 2000 records till 1914 Aug 21

https://www.historia.ptma.pl/cat_hist_obser/

No.	Date	Place	Observer	Timed	T	A	Dis	P	PH	GD	TW	SV	WD	Source
1	1406 VI 16	Mondoñedo								◆				Calendario de la Catedral de Mondoñedo
2	1406 VI 16	Paris (?)	Jean Juvenal	6-7 h AM						◆				Jean Juvenal des Ursins: Histoire de Charles VI
3	1406 VI 16	Paris	N. de Baye							◆				Journal de Nicolas de Baye
4	1406 VI 16	St.Denis	Religieux	6-7 h AM						◆			◆	Religieux de St.Denis : Chronicorum ...
5	1406 VI 16	Metz		6 h AM	◆							*		La chronique de Philippe de Vigneulles
6	1406 VI 16	Liege		6-7 h AM						◆				Chronique latine de Jean de Stavelot
7	1406 VI 16	Rouen						C						Le Victorial Chronique de Don Pedro Nino
8	1406 VI 16	Bordeaux								◆				Archives municipales de Bordeaux
9	1406 VI 16	Basel		6-8 h				CR2						Röteler Chronik
10	1406 VI 16	Braunschweig		1 hd	◆					◆				Bothonis Chronicon Brunsvicensis picturatum
11	1406 VI 16	Beiersdorf								◆				Chronik der Gemeinde Beiersdorf
12	1406 VI 16	Haselbach (?)	Th.Ebendorffer	6 h AM				◆			◆			Th.Ebendorfferi de Haselbach Chr.Austriacum
13	1406 VI 16	Nürnberg		3 hd						◆				Chronik aus Kaiser Sigmundus Zeit
14	1406 VI 16	Augsburg		6 h AM				C						Chronik von 1368 bis 1406
15	1406 VI 16	(Thuringia)								◆				Thüringische Chronik by J.Bangen
16	1406 VI 16	Eisenach	J.Rothe	M	?									Düringische Chronik by J.Rothe
17	1406 VI 16	Magdeburg		9 h AM	◆					◆				Magdeburger Schoppenchronik
18	1406 VI 16	Lübeck		5 h AM	◆									Detmar-Chronik. Zweite Fortsetzung
19	1406 VI 16	Lübeck		6 h AM	◆					◆				sog.Rufus-Chronik.Zweiter Theil
20	1406 VI 16	Lübeck	H.Korner	6 h AM						◆				Hermanni Corneri Chronicon
21	1406 VI 16	Hamburg	A.Traziger	6 h AM	◆									Adami Trazigeri Chronica Hamburgensis
22	1406 VI 16	Stralsund		7 h AM						◆				Stralsundische Chroniken
23	1406 VI 16	Paderborn	Gobelinus	5 h AM						◆				Gobelini Personae Cosmidromius
24	1406 VI 16	Saxony		1 hd						◆				Matthaeus Dresser:Sächsisch Chronicon
25	1406 VI 16	Kraków (?)		10 h AM				10^{d}	◆					Annalium Trascae cont.de Szamotuły
26	1406 VI 16	Dortmund								◆		*		Chronik der Reichsstadt Dortmund bis 1618
27	1406 VI 7	Dortmund		6-7 h						◆				Johannis Kerkhörde: Chronicon
28	1406 VI 16	Münster								◆				Chronik der Bischofe von Münster
29	1406 VI 16	Meiningen								◆				Poligraphia Meiningensis
30	1406 VI 16	Mühlhausen								◆				Chronik der Stadt Mühlhausen in Thüringen
31	1406 VI 16	Gr.Novgorod (?)		4 hd				CR3			◆			Troitskaya Letopis'
32	1406 VI 16	Tver (?)		4-6 hd				CR4						Tverskaya Letopis'
33	1406 VI 16	Bologna						3/4						Continuatio Chronici Bononensis
1	1415 VI 7	(Spain) Euskal								◆				Mil noticias insólitas del país de los vascos
2	1415 VI 7	Navarra								◆				Annales de Navarra
3	1415 VI 7	Montpellier		1.5 hd								*		Les chroniques célestes du Petit Thalamus

1406 VI 16

Adami Tratzigeri Chronica Hamburgensis
A.1406 am Tage Annunciat. Mariae, des Morgens umb 6. Uhren, wurd die Sonne gantz bedeckt, und so eine grosse Finsternisse, dass die Leuthe vermeineten, ess solte die Welt vergangen sein [...]
Hamburg Chronicle by Adam Tratziger
In the year 1406, on the day of the Annunciation of the Virgin Mary, in the morning at 6^{th} hour, the sun was entirely covered, and [there was] such a great eclipse that people believed it should be the end of the world.
Hamburg, GERMANY
s.ca 1557
West.Monum.Ined.
Stephenson, p.405


1406 VI 16
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1630 VI 10

Johann Conrad Emmrich
Historia coelestis: complectens observationes astronomicas varias ad historiam coelestem spectantes

Observatio Tubingensis

Pro compendio observationis habendae; ceperam pridie magno Δ altitudines Solis, a vigesimo gradu per singulos usque ad 3° ½ scilitet quam alte mons supra Horizontem permiserat, & ad earum momenta signavi speciem ☉ per foramen intrantis in opposite pariete. Intermedia spacia in partes minutas subdivisit, ut sic expeditissime, & omni momento sciretur ☉ altitude, sine laboriosa inquisition. Nam parallelus ☉ pridianus non differebat (prope Tropicum) sensibilitera a postridiano, aut si quid diseriminis forte esset, id facili reduction posset emendari.

Quia multum refett scire quantitatem foraminis, per quod radius est intromissus, appinxi eum sic accurate: ut sciretur quantum ubique superflui luminis imaginibus deficientis Solis esset detrahendum.

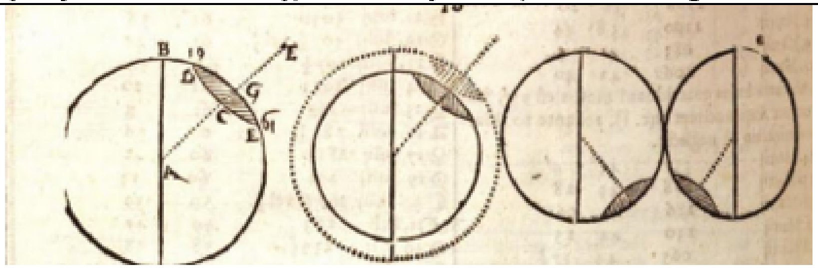
Et pinxi singulas apparitiones quadrifariam, in quales intus accepi, auctas limbo superfluae lucis 2. correctas resecta illa luce. 3. inversas semel, ut situantur sub cavo caelo.4. Dupliciter inversas, ut in globo convexo.

The Tübingen observation

The summary of obtained observation; earlier I began on the large triangle of the altitude of the Sun, the twentieth degree per a single up to 3° ½, that is until the high mountains above the horizon permitted and I recorded to those moments on the opposite wall the appearance of the Sun, entering through a hole. The intermediate spaces I subdivided into small parts, as so the Sun's altitude should be known expeditiously and at any moment, without laborious inquisition. In fact, the yesterday parallel of the Sun did not differ (close to the tropic) sensibly from the next day, or if it indiscriminately might be, could easily be corrected by a reduction.

Because a lot [of readers] want to know the size of the hole, the ray were introduced through, I punctured it accurately: in order to know the quantity of the superfluous light of the image of the eclipsed Sun was removed.

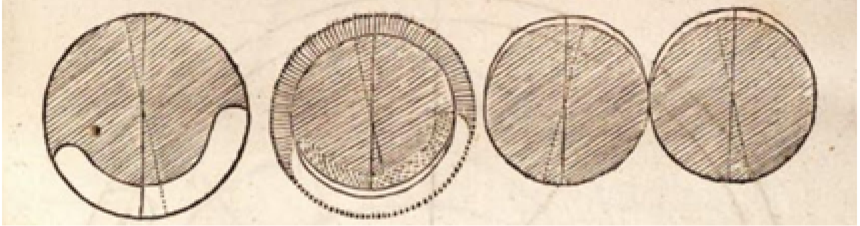
And I punctured it for a single appearance of four, for which I obtained an increased border of superfluous light, 2. to correctly resect this light, 3. [the Sun's image] to be inverted once they are placed in the concave sky, 4. to be doubly inverted, as on the convex globe.



8°.35' hoc est H.6.56'. nondum plane sesqi digitus deficere putabatur, sed revera plus deerat ut in correcto Schemate cernitur. Arcus KM. inter 15° & 65° inclinationis extensus, vel amplior etiam. Itaque media Inclinatio I.H.O. patum differebat a priori, adhuc fere 40°.	**proportione diamentrorum & digitorum.**	**1 $^{2}/_{3}$. fere. Inclinatio 40°.**	
The next phase recorded carefully, at the Sun's altitude 8°35', i.e. 9^h56^m, supposedly not entirely over half digits were lacking, but in reality more was lacking as is visible in the correct scheme. The arc K-M extended between the inclination of 15° and 65°, or even greater. Therefore, the mean inclination I-H-O differed from the previous one slightly, still being of almost 40°.	The same next phase according to the true proportion of diameters and digits.	The same in the sky with almost 1 $^{2}/_{3}$ digits and inclination of 40°.	The same on the globe.

Postea Furtivas quasdam apparitions habuimus, cum ☉ altus esset 5° ¼ videbatur semissis diametri decesse (scilicet intus in specie incorrecti radij) rursus cum elevaretur 4° $^{2}/_{3}$. notabiliter ultra medium defectus erat progressus: Verum quia ambae phases fuerunt subitaneae, nec satis accurate potuerunt excipi; omisi eas Residua lux Solis valde Flava, quasi croco tincta fuit.

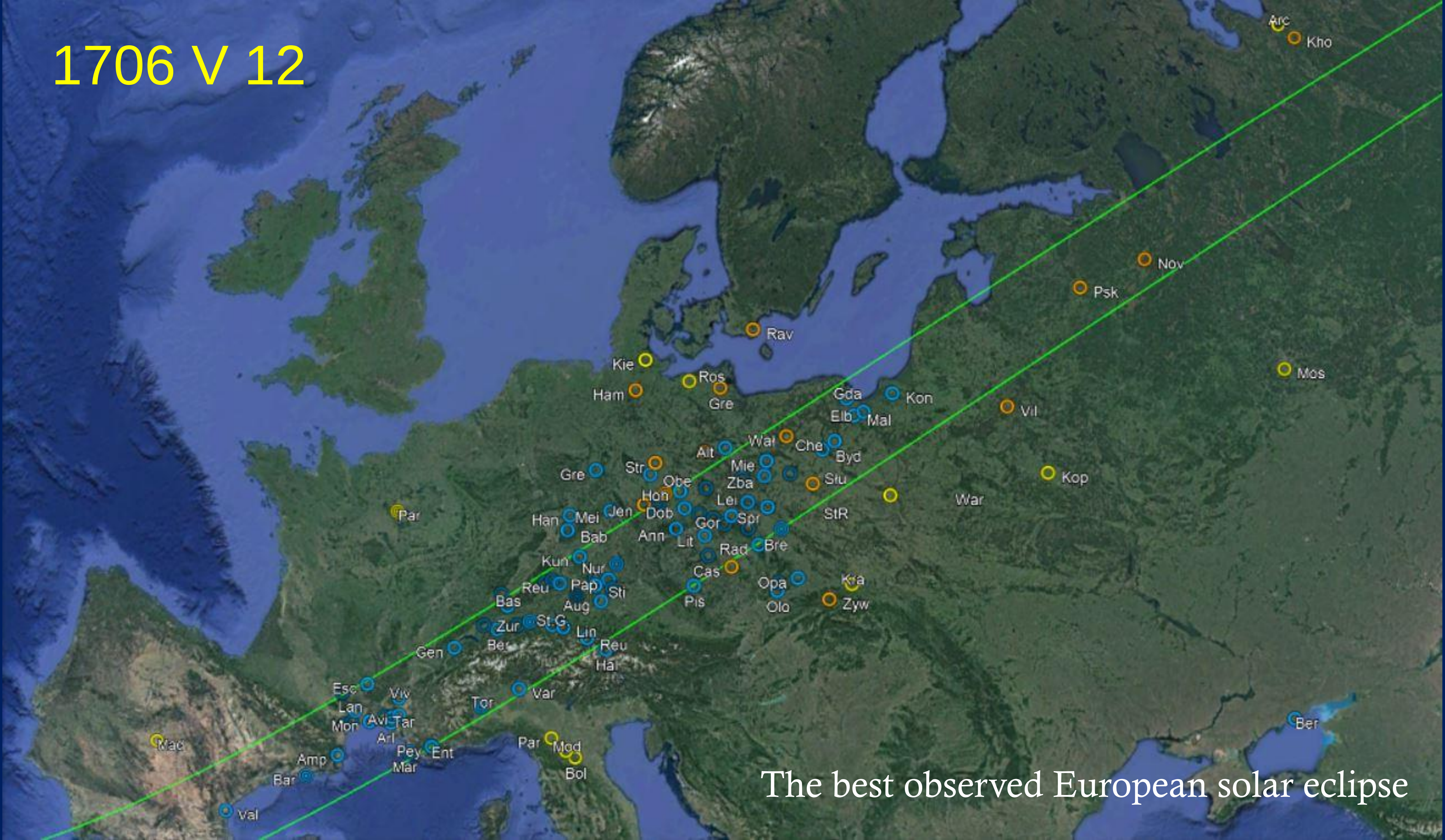
Thereafter, we had some problems with visibility, with the altitude of the Sun being 5° ¼, the half of the diameter deceased to be visible (namely in particular because of incorrect rays) and again with the altitude of 4° $^{2}/_{3}$ noticeably more than a half eclipsed Sun was progressed. But because both phases were sudden, they could not be taken with a sufficient accuracy; I missed their residuals, the light of the Sun very yellow, as if as if tinged with saffron.



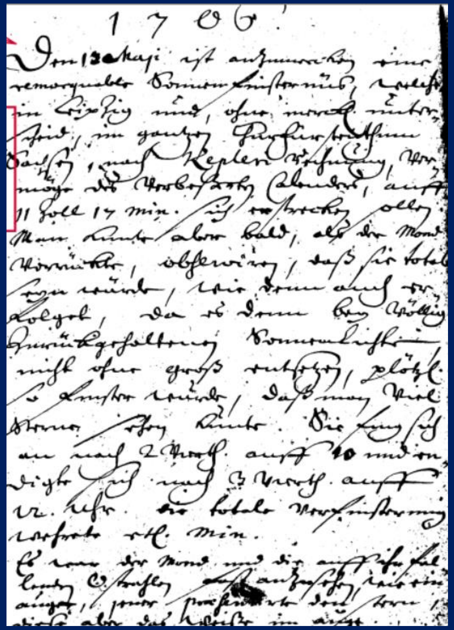
Phasis ultima, cum ☉ post montes	**Eadem correcta. Sed ex hoc veriori**	**Eadem sun cavo Caelo, quails**	**Eadem in convexo globo serviens**

Detailed methodology of eclipse observations in 16-17th century established.
Camera obscura (later eyepiece projection) and measurements of positional angles and the Sun's altitude using quadrants applied.

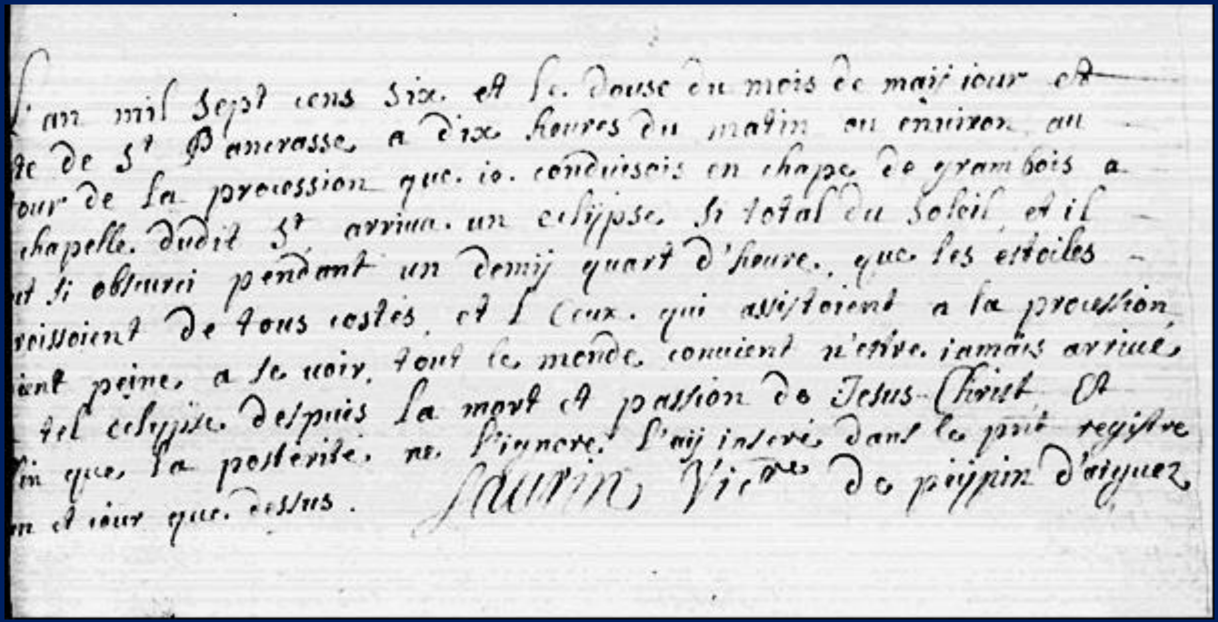
1706 V 12



The best observed European solar eclipse

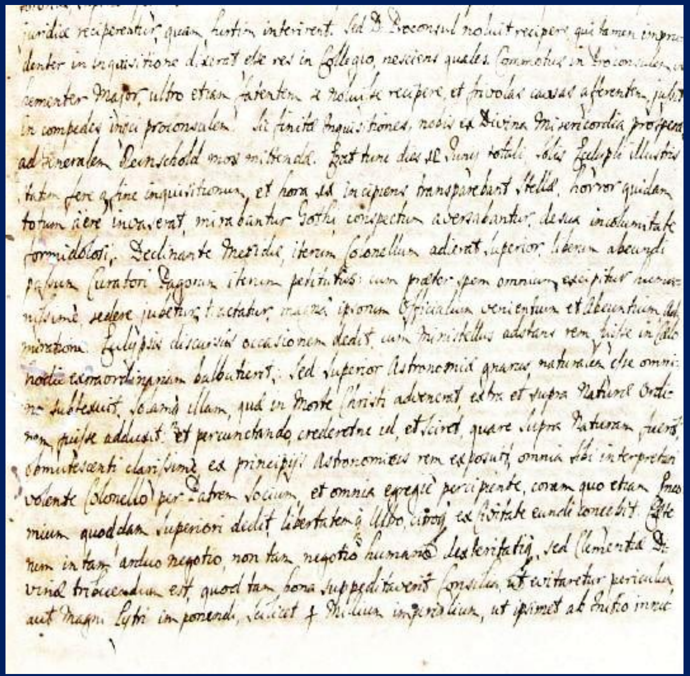


The dark sun with many stars at Görlitz, DE

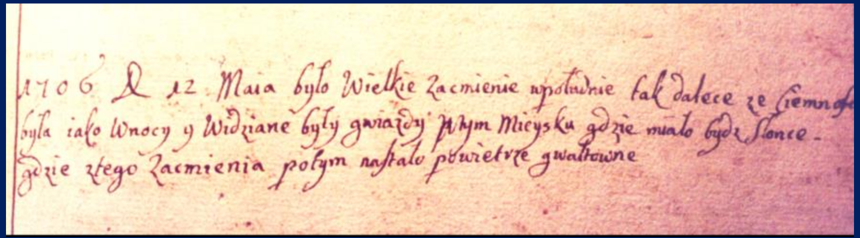


'an mil sept cens six et le douse du mois de may jour et
te de St Pancrasse a dix heures du matin ou environ au
our de la procession que je conduisois en chape de grambois a
chapelle dudit St arriva un eclipse si total du soleil et il
t si obscurci pendant un demij quart d'heure que les estoiles
roissoient de tous costes et ceux qui assistoient a la procession
ient peine a se voir, tout le monde convient n'estre jamais arrivé
tel eclipse despuis la mort et passion de Jesus Christ et
in que la posterite ne l'ignore l'aij inseré dans le pnt registre
n et jour que dessus. Saurin Vicre de peypin d'aiguez

Total eclipse with stars in all sides, Peypin-d'Aigues, FR

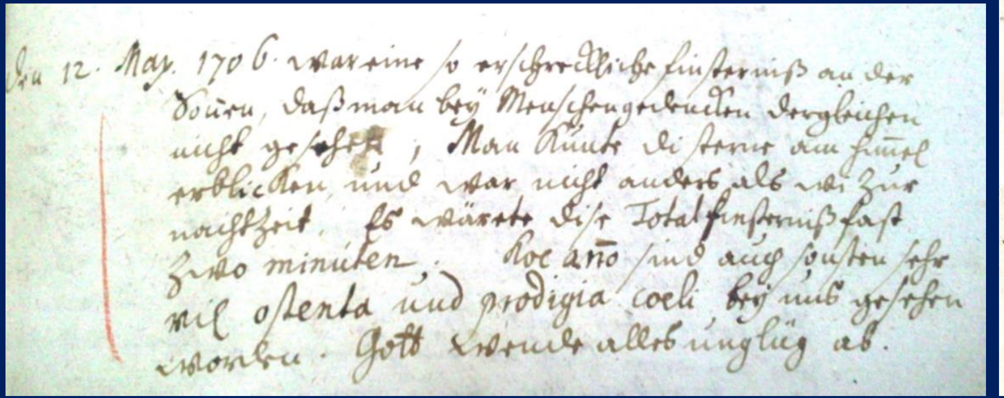


„illustrious eclipse with stars and a great horror" at Bydgoszcz, PL



1706 D 12 Maia było Wielkie Zaćmienie wpołudnie tak dalece że ciemno
była iako wnocy y Widziane były gwiazdy wtym Miejscu gdzie miało być Słonce
gdzie z tego Zaćmienia potym nastało powietrze gwałtowne

„stars instead of the Sun" at Zbąszyń, PL



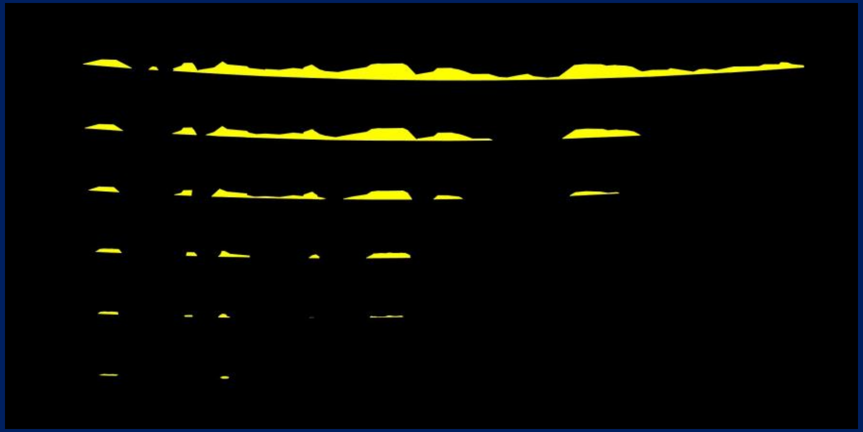
Den 12. May 1706 war eine so erschreckliche finsterniß an der
Sonnen, daß man bey Menschengedenken dergleichen
nicht gesehen; Man kunte die Sterne am Himmel
erblicken und war nicht anders als wie zur
Nachtzeit. Es währete diese Totalfinsterniß fast
zwo minuten. Hoc anno sind auch sonsten sehr
viel ostenta und prodigia coeli bey uns gesehen
worden. Gott wende alles unglück ab.

2.5 minutes of totality at Międzychód, PL

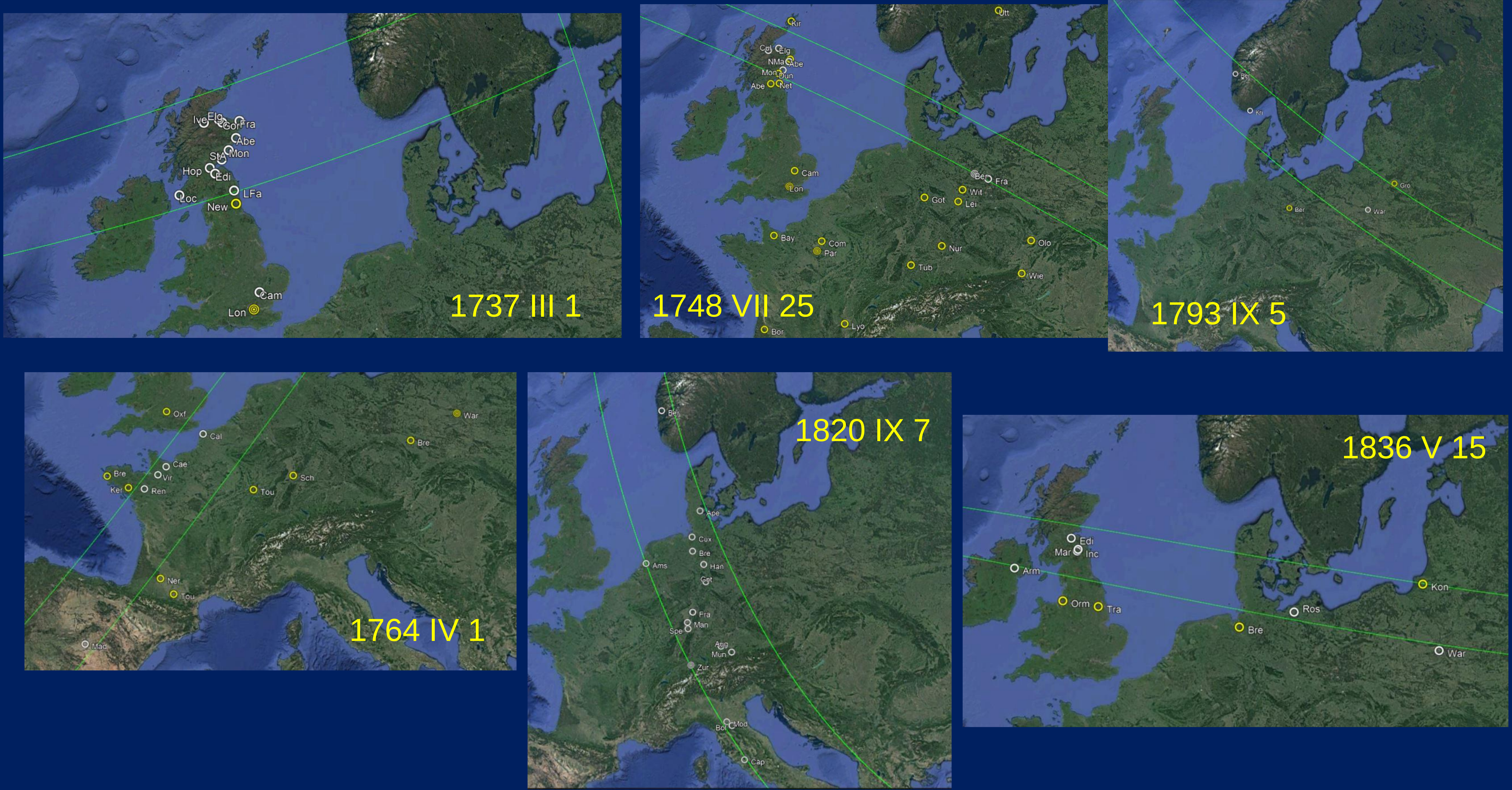
Acta Eruditorum, 1706, p.335 and subseq. Leipzig, 1706. (Christopher Heinrich at Breslau)

[…] Tempore totalis obscurationis stellae complures libero oculo visae, etiam duae prope Solem, Lunam circulus dubiae lucis ambibat, Halonis instar. Simul apperebat inaequalis superficiei Lunaris; sed praecipue sub initium luminis distinguebantur, in effigie per telescopium in chartam albam projecta, montes & valles Lunares, intermicantibus Solis particulis.

[…] At the time of the total obscuration, very many stars were seen with the naked eye, also two near the Sun, the lunar disk was surrounded by a weak light, like a Halo. Simultaneously, inequalities of the lunar surface became to be visible; but especially they were distinguishable at the beginning of light, in the image projected through the telescope onto a white card the particles of the Sun were flashing between the lunar mountains and valleys.



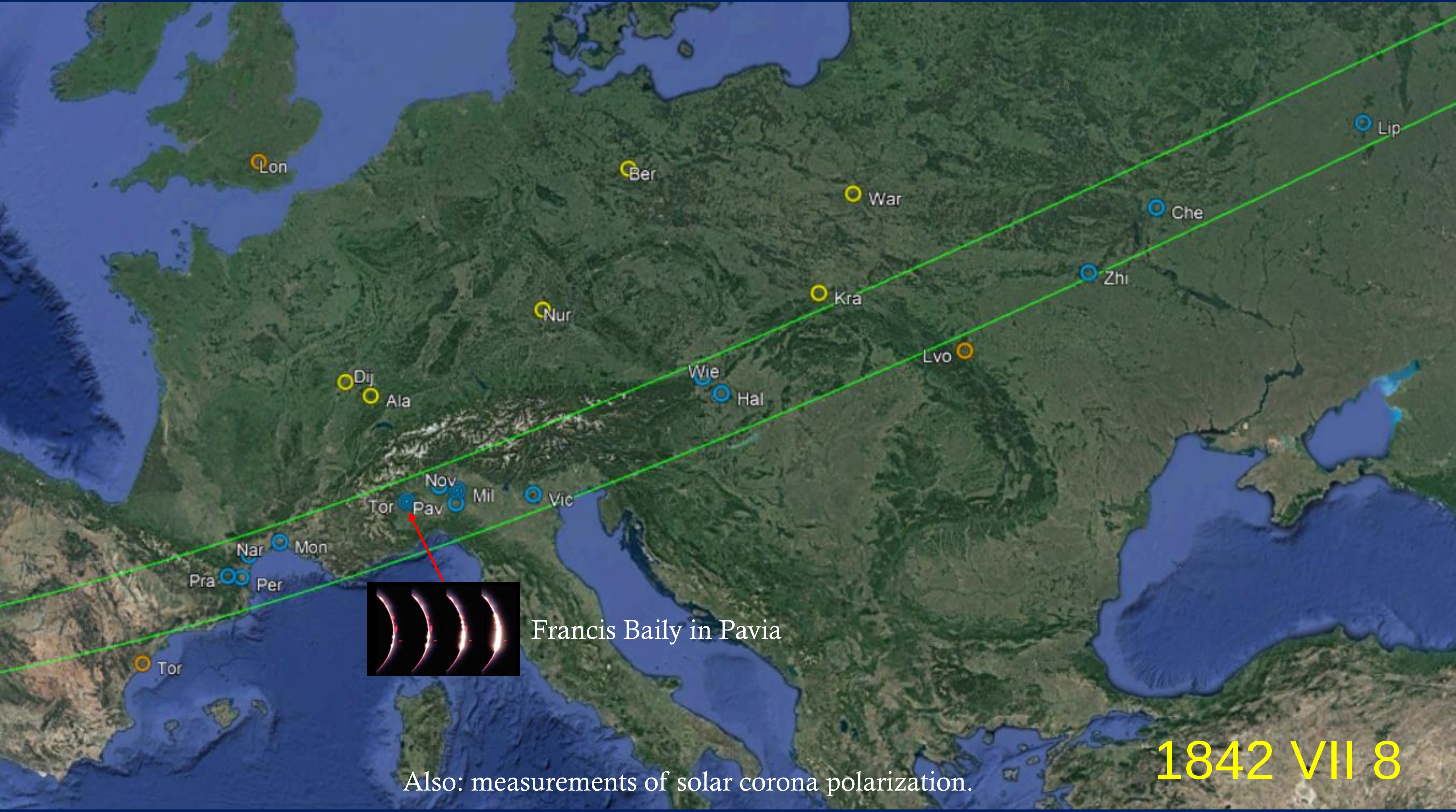
The reconstruction of Baily's beads as seen from Breslau by Ch.Heinrich (Occult software used)



The series of annular eclipses observed from Europe in 18th and 19th century

Bernhard Nicolai's observation on September 7, 1820 at Mannheim, DE

Die Bildung des Sonnen-Ringes geſchah auf eine höchſt merkwürdige Art. Die ungemein feine Ringlinie der Sonne erſchien nämlich, etwa 1 Sekunde vor der vollkommenen Bildung des Ringes, an ein Paar Stellen unterbrochen, und die einzelnen Theile derſelben floſſen dann in einem Augenblicke in einander, etwa wie zwei Waſſer- oder Queckſilber-Tropfen die mit einander in Berührung kommen. Die Urſache dieſer Erſcheinung liegt unſtreitig in den bedeutenden Unebenheiten am Rande des Mondes, deſſen flächere Theile das Sonnenlicht ſchon erblicken lieſsen, während die höheren es noch zurück hielten. Ueberhaupt konnte man während der ganzen Finſterniſs mehrere hohe Randberge des Mondes, beſonders an deſſem ſüdlichem Theile, deutlich unterſcheiden. Eine ähnliche Erſcheinung fand auch bei dem Verſchwinden des Sonnen-Ringes Statt; die feinere Ringlinie der Sonne trennte ſich nicht an Einer Stelle, ſondern an mehreren zugleich, ſo daſs auf einem Augenblick dieſe zarte Lichtlinie in mehrere Theile getrennt erſchien *).

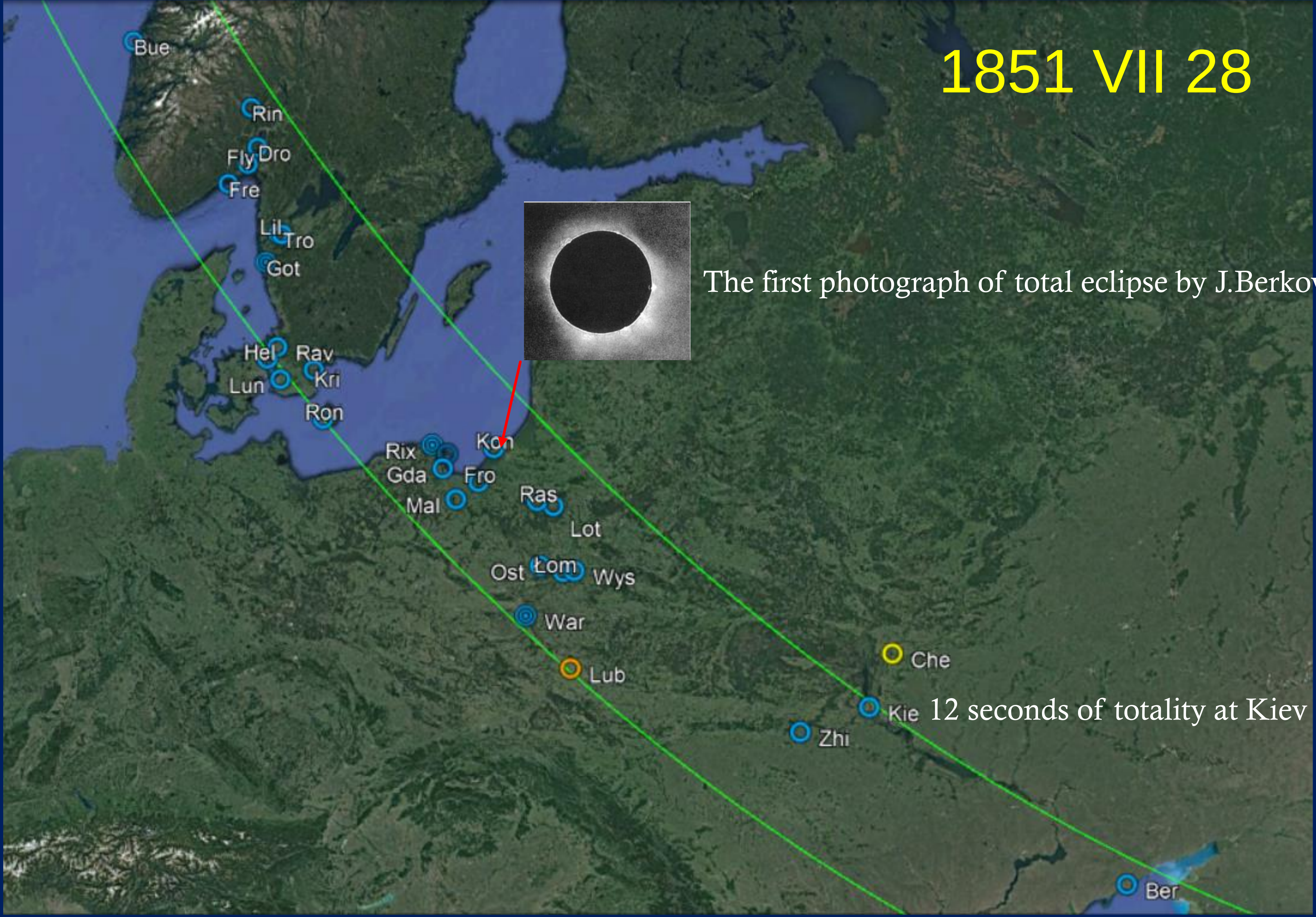


Francis Baily in Pavia

Also: measurements of solar corona polarization.

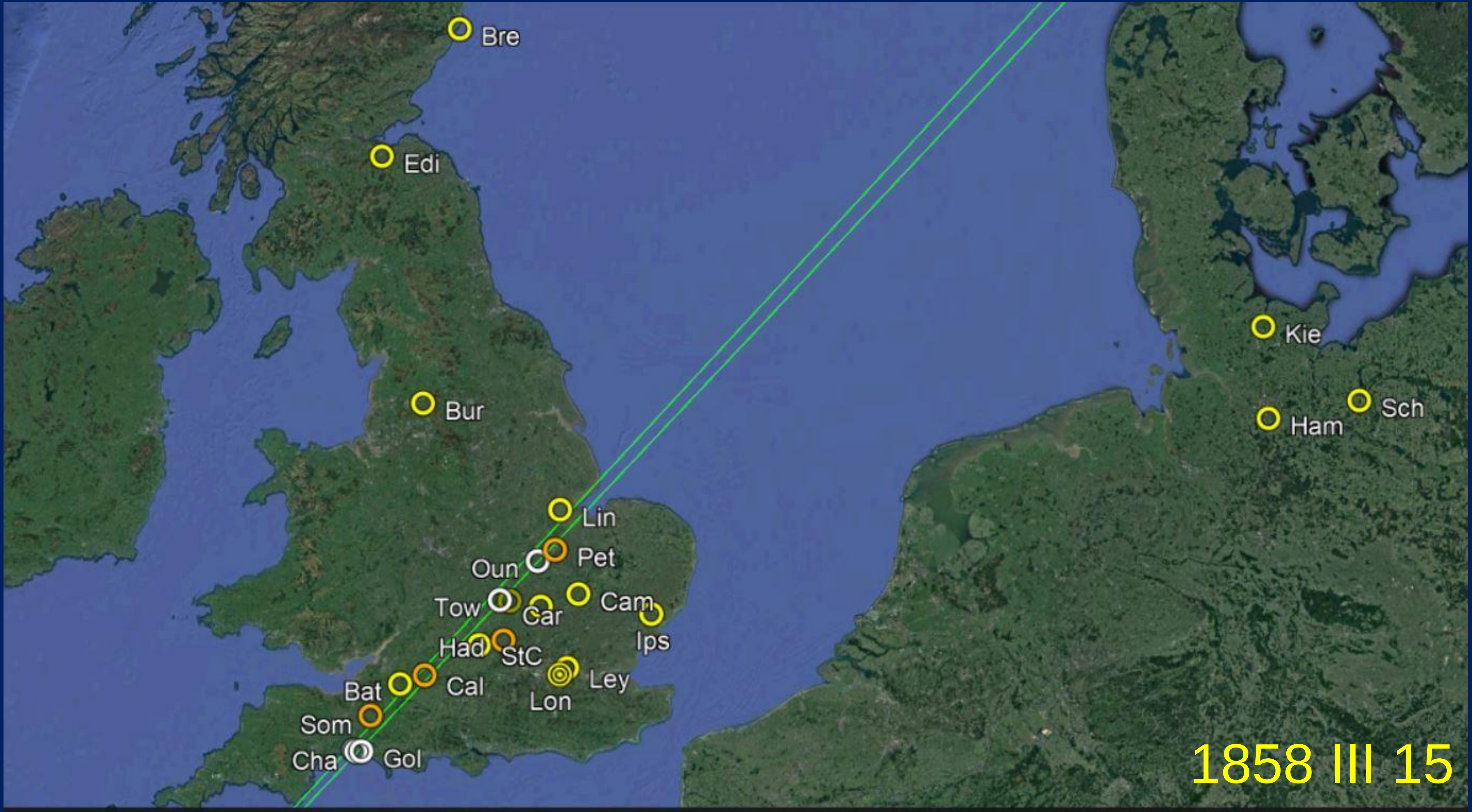
1842 VII 8

1851 VII 28



The first photograph of total eclipse by J.Berkowski

12 seconds of totality at Kiev



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1858 III 15

The orbital motion of the Moon

The basic problems:

- **(a) mean angular velocity**

Even ancient Babylonians precisely knew the mean length of lunation ($\pm$0.3 s/month)!

P.A.Hansen's Lunar Tables (1857) according to his lunar theory.

S.Newcomb was the first who tested his theories using historical observations and gave a better lunar theory (1878). **F.Ginzel** (1884) tried to correct Hansen's theory after analyzes of observations of historical solar eclipses.

E.W. Brown published his improved but fully gravitational theory with many very precise terms explaing perturbations, however ... with a periodical „great empirical term" of about 10"/257 years introduced (1899-1919).

- **(b) secular acceleration, n**

E.Halley discovered this phenomenon which, however, has not been at once included into lunar theories. **S.Newcomb** suggested (correctly) the reason are terrestrial tides and the lunar acceleration also reflects the slowing down Earth’s rotation and the lenghtening of the mean solar day.

The rotation of the Earth and the time scales

UT – universal time, related to the average length of the solar day (19th century-1950)
ET – ephemeris time – around 1950, theoretically constant
TDT, TT – terrestrial (dynamic) time, 1984, related to the atomic time scale (TAI) (around 1984)

How to recognize the rate of **rotation of the Earth in distant epochs**? This cannot be precisely determined theoretically, although it can be done for some of the effects related to the slowing down of the Earth's spin.

It turns out that, first of all, it is necessary to analyse the long-term **dynamic behaviour of the Earth-Moon system**. It follows from the principle of conservation of energy (as angular momentum) that the retardation of the Earth's spin due to dissipation of energy during tides (both lunar and solar) must cause the so-called **secular acceleration of the Moon's orbital motion, n**. This phenomenon, in turn, causes the Moon's distance from Earth to increase. Confirmation of this fact, for obvious reasons, was not possible before the implementation of Earth-Moon distance measurements thanks to the Apollo missions after 1969 (lunar laser ranging, LLR). According to **Christodoulidis *et al.*** (1988) there is a strict relationship between two basic parameters: secular acceleration of the Moon, **n**, and the retardation of the Earth's spin, Ω_{tidal}. Taking the currently found and assumed as constant value **n** = 26.0”cy^{-2} (cy≡century), it is obtained that:

$$\Omega_{tidal} = (-6.20 \pm 0.38) \times 10^{-22} \text{ rad s}^{-2}$$

whence the length of the day should accordingly **increase by 2.3 ms per century**. The corresponding relationship between the UT and TT time scales is as follows [2,3]:

$$TT\text{-}UT = \Delta T_{tidal} = +(42 \pm 2)\ t^2\ [s],$$

where t is given in centuries counted from the year 1825. Newer analyses by Williams and Boggs gave the first factor in the above formula as $+(43.7 \pm 0.2)$.

The first approximation in analyses of historical observations of occulatations and eclipses is to assume such a parabolic relationship and to check how the observational results agree with calculations of known credibly observed phenomena. If this ΔT curve were the only correct one, the observations would agree well with the ephemeris. However, with the current best theory of the motion of the Moon, the parabola adjusted to the observations has a distinctly different course:

$$\Delta T = -10 + (31.4 \pm 0.6)\ t^2\ [s],$$

so, some **non-tidal effects** must play an important role and also tides may change in the course of time.

We can point to a number of factors influencing the rotation of the Earth and causing it to be irregular in time:

a) there are glacial (climate change) periods when the distribution of the mass of ice on the Earth's surface varies;
b) the core and mantle of the Earth is undergoing some changes;
c) air mass changes its structure;
d) solar acivity (especially solar wind) may influence the Earth’s geomagnetic field;
c) sea levels fluctuate periodically to some extent;
d) volcanic activity varies with time;
e) earthquakes occur;

Improved [Brown's] Lunar Ephemeris (ILE) by Eckert *et al*. (1952-1959).

Lunar Ephemeris (LE no.2 and no.3,1964), LE no.4 (1967), final (Seidelmann, 1992, with **n**=25.82″/cy^2 acc. to LLR), Chapront & Chapront-Touzé, (1997, 2002, **n**=25.86″/cy^2).

A set od the dynamic ephemeris of planets and the Moon created by JPL by integration of bodies' motion for the purpose of planetary missions:

DE102 (1981) for the time span from -1410 to +3002

....

DE202 (1987) ---------------------------- +1899 +2050

....

DE403 (1993) ---------------------------- +1599 +2199

....

DE406 (1997) ---------------------------- -3000 +3000

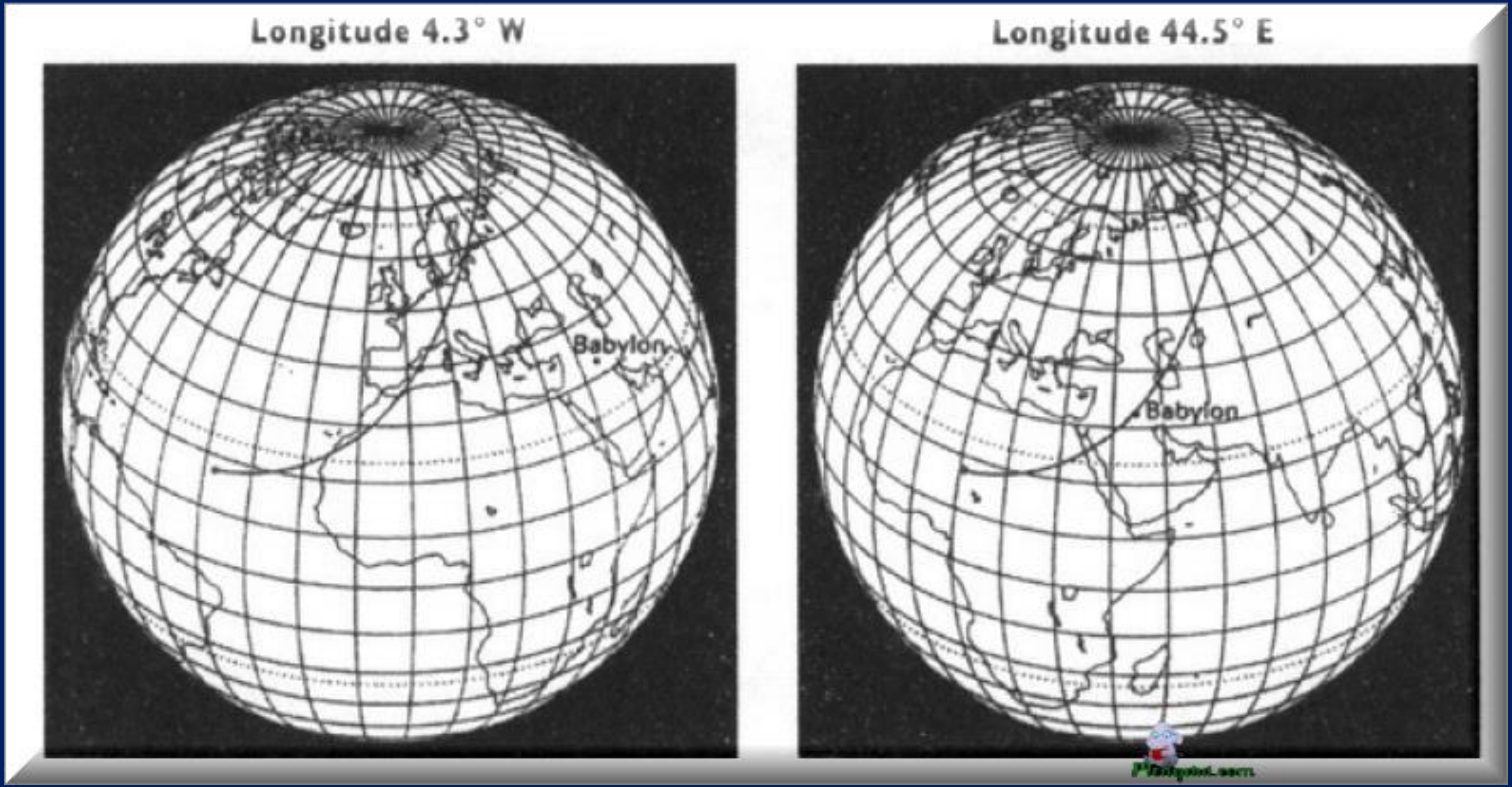
....

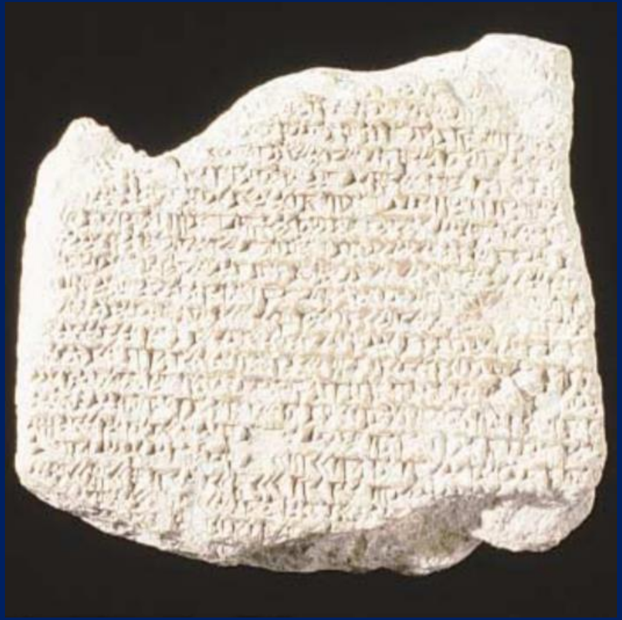
DE431 (2013) ---------------------------- -13200 +17191

....

DE441 (2020) ---------------------------- -13200 +17191

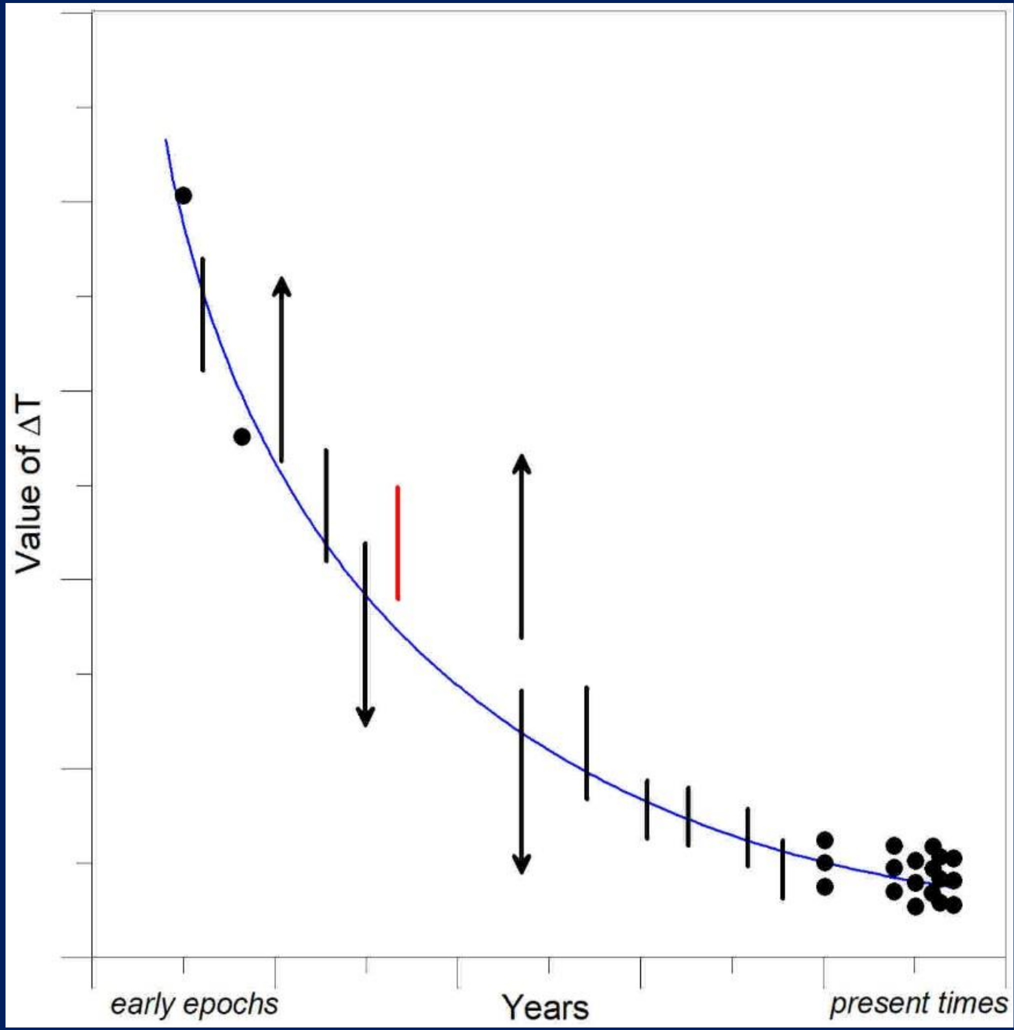
The differences in lunar longitude caused by the error of „**n**" are negligible in the medieval and ancient period compared to the precision of the observations.





The original clay tablet with
the inscription of the eclipse

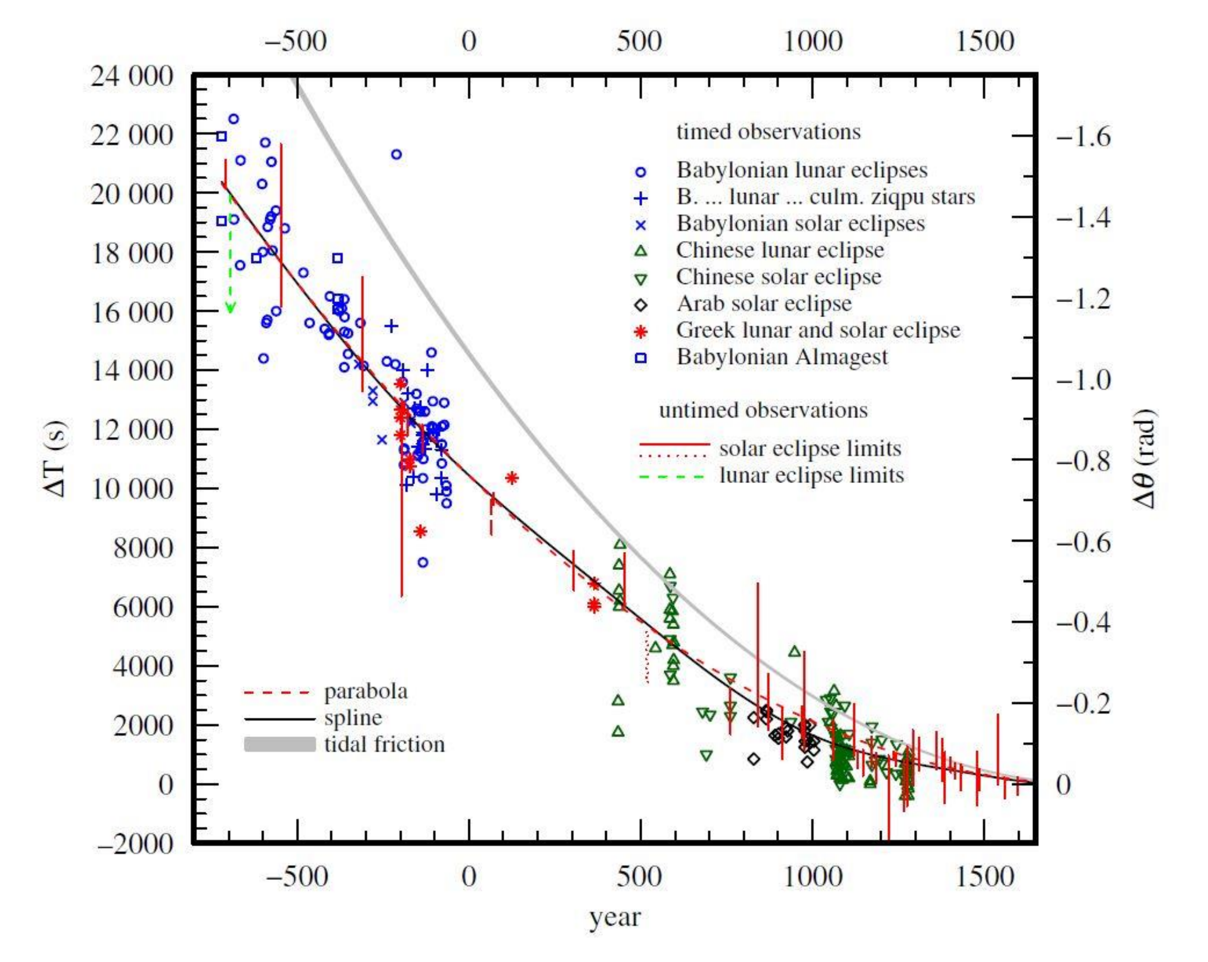
The Babylon eclipse of April 15, 136 BC and the effect of the Earth's rotation slowing.



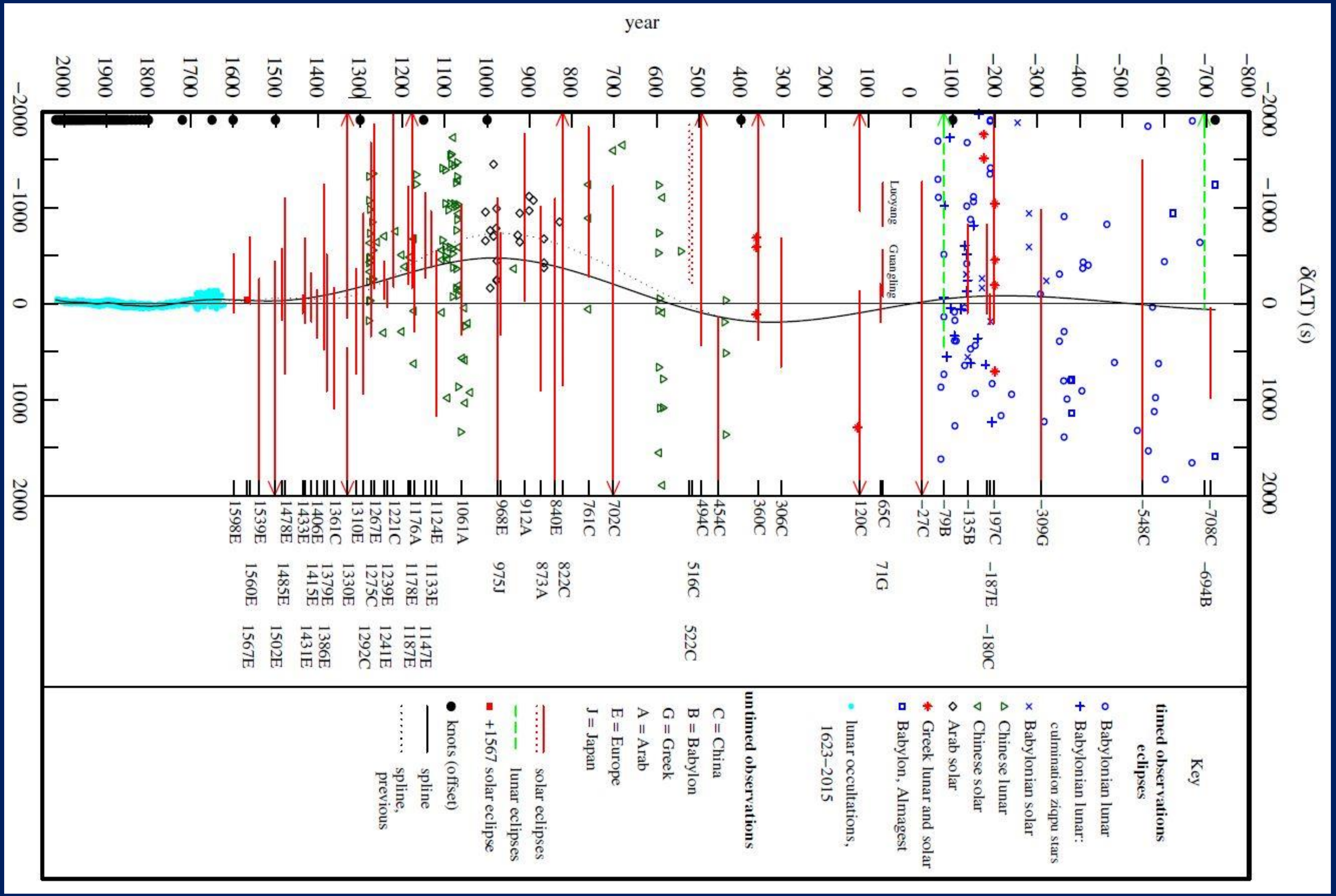
Scheme of fitting ΔT curve based on historical observations. Thick vertical segments represent adequate ranges of ΔT values found for individual phenomena; points represent timed observations. The segment marked in red indicates an error in the original observation record.

For some of the untimed occultations we can at present recalculate the possible “time window”. For instance, Antares was observed as being occulted by the Moon on September 23, 80 BC at ancient Babylon. The phenomenon must be remarkable between the beginning of twilight and the moment with low latitude of the star (of a few degrees) above the local horizon. According to the present calculations, this gives the range of 2.3 to 3.3 hours for ΔT (Gonzales, 2017).

September 23, 80 BC
Babylon

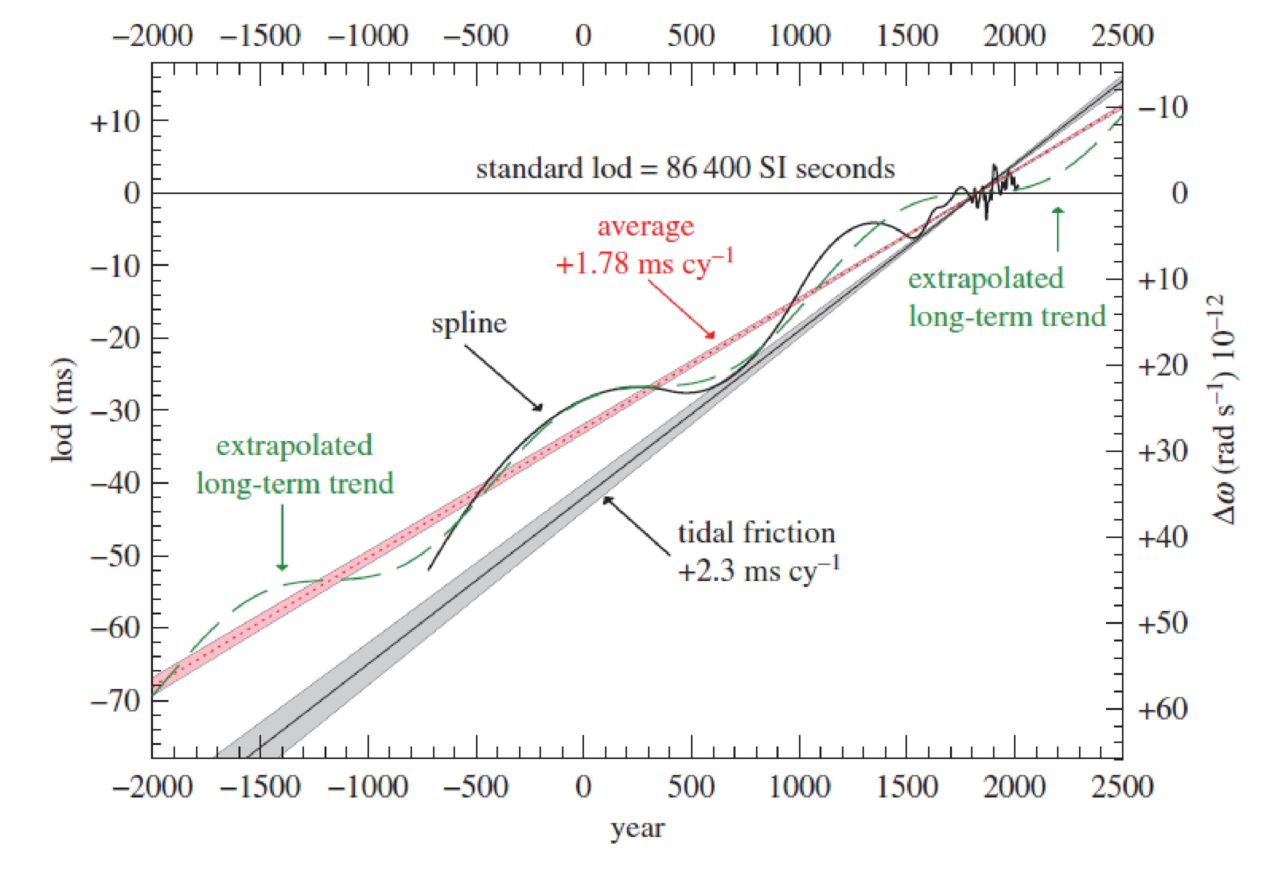


*Results for ΔT for collected timed observations−720 to 1280 and the untimed total solar eclipse of 1567. The dotted red curve is the parabola, and the black curve is the spline curve, both fitted to the observations. The grey curve is the parabola predicted on the basis of tidal friction (according to the complete analyses by **Stephenson et al. , 2016**).*



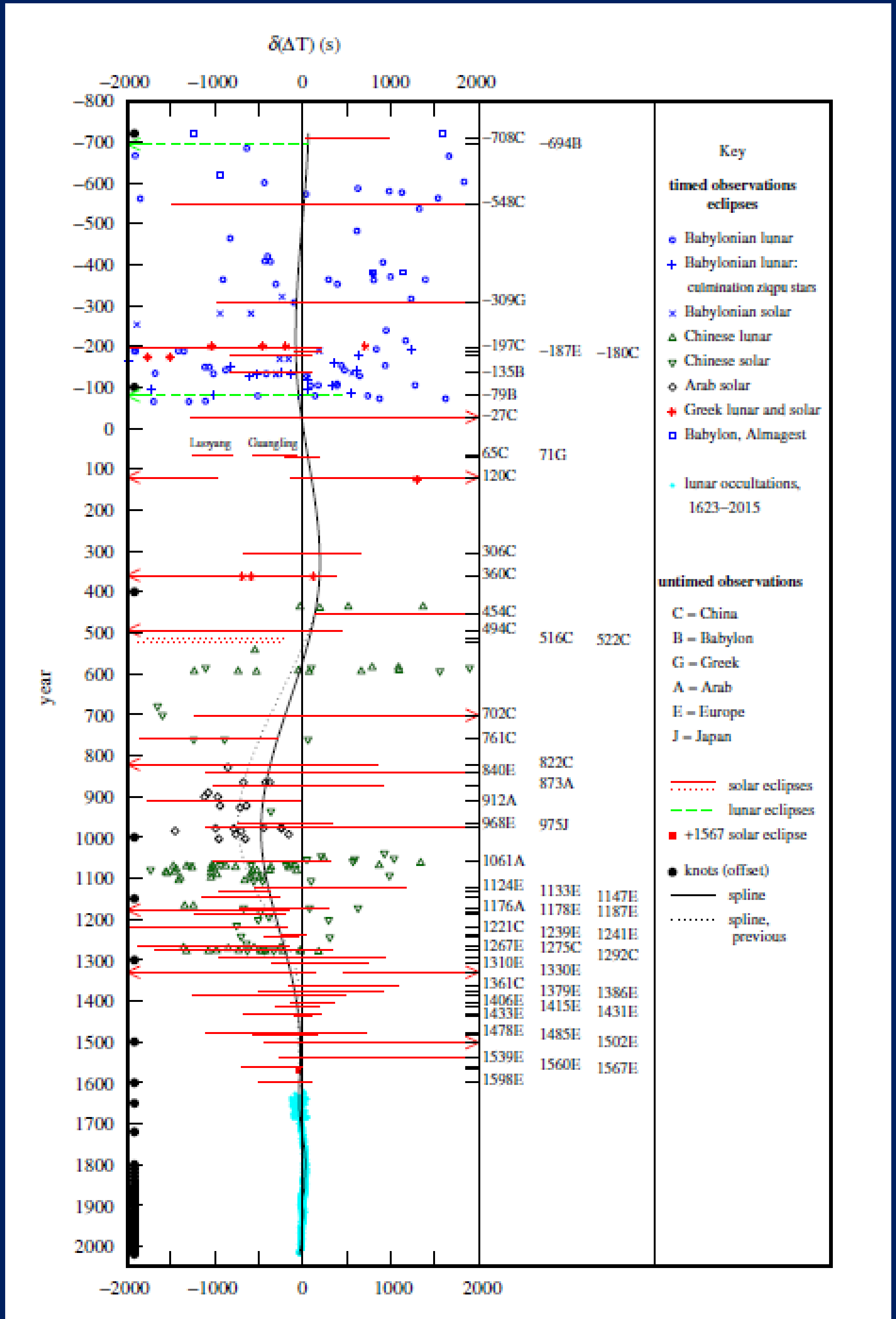
Plot of the differences in ΔT with respect to the parabola, which is represented as a straight line at 0.

The data after+1600 are derived from timings of lunar occultations. The solid black curve is the fitted spline, and the dotted curve for the period+800 to+1000 is the departure of the spline required to accommodate the timed Arabian data in that period. The positions of the knots used in the spline fit are shown as black dots along the time axis (according to the complete analyses by **Stephenson *et al,* 2016**).



Length of the day (lod) −2000 to 2500.

The dotted red line is the average measured rate of change in the lod, +1.78 ± 0.03 ms cy^{-1}, which is equivalent to an acceleration of −4.7 ± 0.1 × 10^{-22} rad s^{-2}. The shaded grey area shows the change expected on the basis of tidal friction, +2.3 ± 0.1 ms cy^{-1}, equivalent to −6.2 ± 0.4 × 10^{-22} rad s^{-2}. The black curve is the slope on the spline fit. The green-dashed curve is the extrapolation of the oscillation.

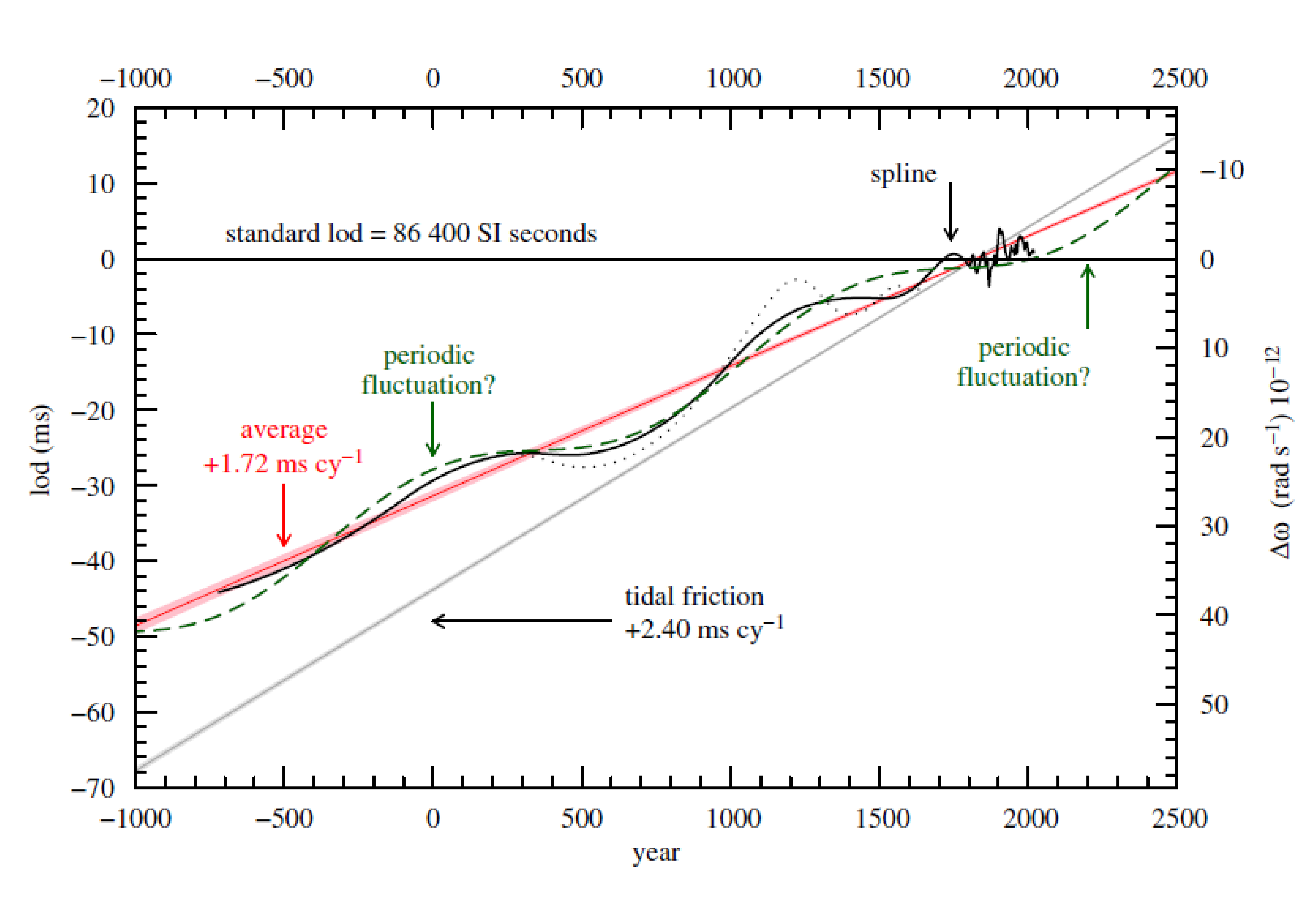


Addendum 2020 to ‘Measurement of the Earth’s rotation: 720 BC to AD 2015’

L. V. Morrison, F. R. Stephenson, C. Y. Hohenkerk and M. Zawilski (2020)

In the years 1988-2020 M.Zawilski was constantly searching for historical observations of solar eclipses and occultations made from Europe and the Middle East. Recently, a progress was made possible by the internet and the increasing amount of scanned sources available.

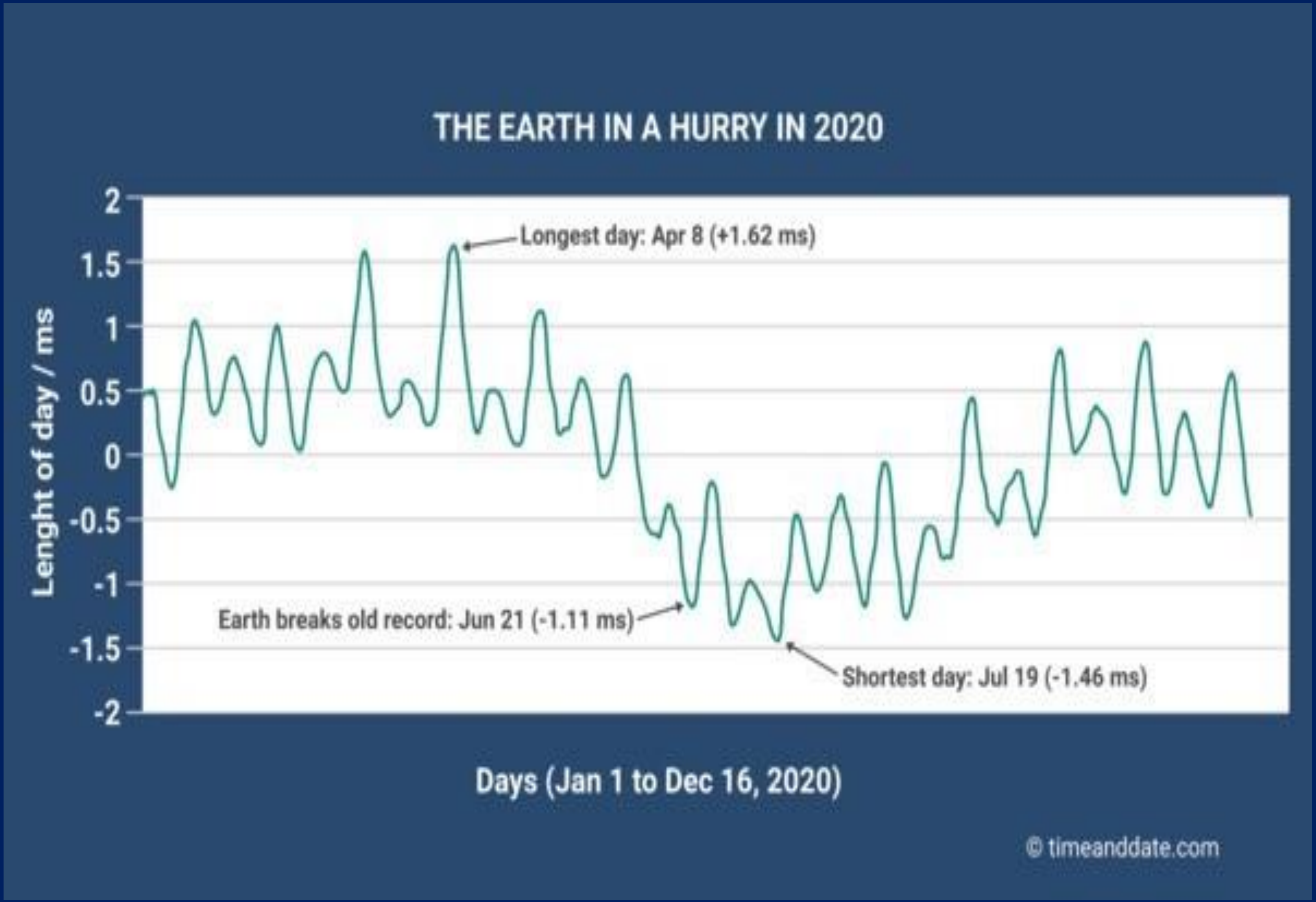
As it turned out, no compelling data can be found for distant epochs, but much remained to be done for the Middle Ages, especially from the 14th century onwards. In summary, 42 of about 100 newer findings have been evaluated in 2020 as credible and became the basis for a next verification of the course of the ΔT curve and some of them turned out to be crucial.



Variations in the **lod** (solid black curve), derived from the first time derivative along the spline. The faint dotted curve between+500 and+1600 is the result of forcing the spline through the Arab timed data. The narrower shaded strip (pink) with uncertainty bandwidth is the observed deceleration, and the grey strip is the deceleration expected on the basis of tidal friction. The dashed curve is the speculative fluctuation with a period of 14 centuries.

Summary of the analyzes (2020)

	lod	SI units
deceleration		
observed	$+1.72 \pm 0.03$ ms cy^{-1}	$-4.59 \pm 0.08 \times 10^{-22}$ rad s^{-2}
tidal	$+2.40 \pm 0.01$ ms cy^{-1}	$-6.39 \pm 0.03 \times 10^{-22}$ rad s^{-2}
deduced acceleration	-0.7 ± 0.1 ms cy^{-1}	$+1.8 \pm 0.1 \times 10^{-22}$ rad s^{-2}
conjectured periodic fluctuation in rate, where $t = (\text{year} - 1750)/1400$	$-3.5 \sin 2\pi t$ ms	$+3.0 \sin 2\pi t \times 10^{-12}$ rad s^{-1}


THE EARTH IN A HURRY IN 2020
Lenght of day / ms
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Longest day: Apr 8 (+1.62 ms)
Earth breaks old record: Jun 21 (-1.11 ms)
Shortest day: Jul 19 (-1.46 ms)
Days (Jan 1 to Dec 16, 2020)
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Thank you for your attention