The upcoming Transit of Mercury of 9 May 2016, placed in a historical context

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At the request of ESA

On 9 May 2016 an intriguing and rare event will occur. Seen from some parts of the Earth, Mercury, the planet nearest to the Sun, will cross the Sun's surface (*fig. 1a & 1b*). Such a phenomenon is better known for the moon, for during such an eclipse it gets dark (or darker), so everyone will notice that something special is going on. But as Mercury is very, very small compared to the Sun, one will never remark such a Mercury-eclipse by oneself.

Fig. 1. Left: Photograph of the Transit of Mercury of 2003. Note that the planet is hardly visible.
Right: Map of visibility of the Transit of Mercury of 9 May 2016

It was the famous astronomer Johannes Kepler (*fig. 2*) who in 1607 realized that transits (or eclipses) of the inner planets Mercury and Venus were possible. In 1607 he even thought he had witnessed such a transit of Mercury, but later he admitted that what he had seen was in fact a Solar spot, instead of the (smaller) image of Mercury. Indeed a transit of Mercury could be observed only when the telescope had been invented. This instrument, so vital for astronomy, emerged in 1608. The first transit predicted after that date occurred in 1631. Unfortunately Kepler died just the year before, so he never witnessed the phenomenon he had predicted.

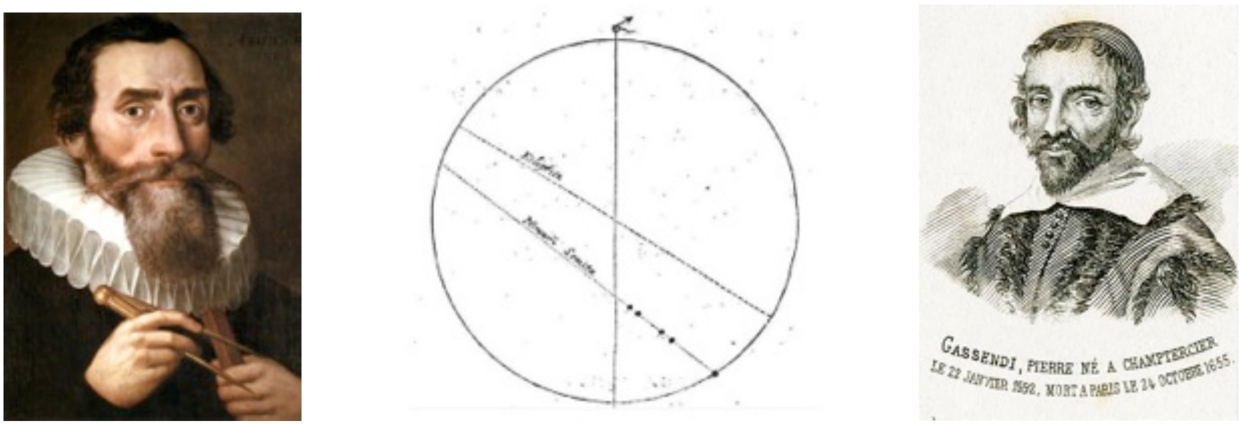


Fig. 2. Left: Johannes Kepler (1571-1630). Middle & Right: The Mercury Transit of 1631, as seen by Pierre Gassendi (1592-1655)

Pierre Gassendi, however, a French astronomer did, and his observation was the first ever to be published (*fig. 2-b*). Gassendi was shocked by the small size of the planet. He wrote: 'I was far from suspecting that Mercury would project such a small shadow. For such was its smallness that its diameter hardly appeared to exceed half of one of the divisions marked'. But others, such as the Dutch astronomer Martinus Hortensius, confirmed that the planet indeed was very small. Until then, knowledge of Mercury and its orbit was rather scarce, because Mercury, as the most inner planet revolving the Sun, can only be seen very close to this very radiant celestial body. So, because the planet was observed more accurate during the transit, the knowledge of the planet's orbit was much improved (*fig. 3*).

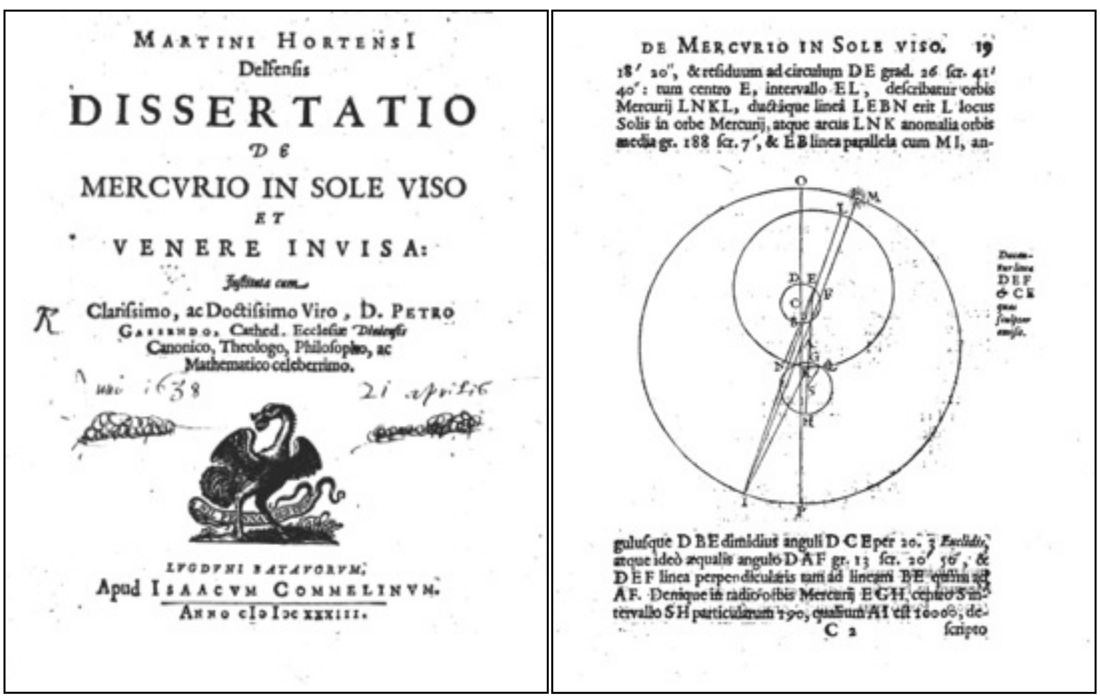


Fig. 3. Hortensius' book with results of the Mercury transit of 1631 (Source: Google Books)

Gassendi and his colleagues used for their observation a method published shortly before, by Christoph Scheiner in 1630. This Jesuit astronomer had studied Solar spots, by using a telescope for the projection of an image of the Sun on a screen (*fig. 4*). In this way he could use a telescope and still protect his eyes from the bright light of the Sun. It was (and still is) a good and easy way to observe a transit.

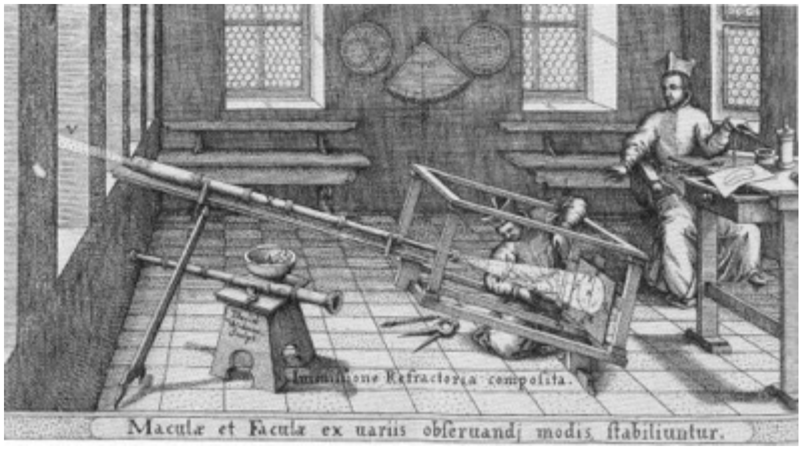


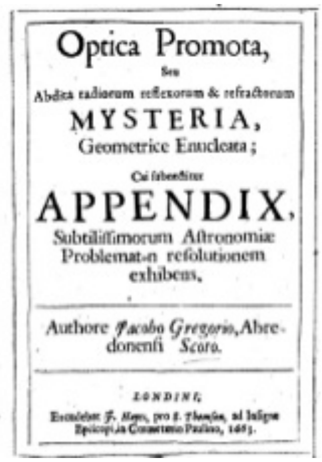
Fig. 4. Scheiner's method of projection from his 'Rosa Ursina' (1630)

The next time a Mercury transit was foreseen was in the year 1651. Unfortunately the transit would not be visible in Europe, but only in Asia. One English astronomer, however, was so keen to witness this rare event that he deliberately travelled to Surat in India, in order to perform this observation. So, this Jeremiah Shakerley is the only person in the world of which we know that he indeed observed this second predicted transit of Mercury.

Transits of Mercury occur about 13 or 14 times per century. Nevertheless, during the third predicted eclipse in May 1661, the transit still was regarded as such a rare and exciting phenomenon, that the Dutch scholar Christiaan Huygens preferred the observation of the transit above the attendance of the simultaneous coronation of the English king Charles II (*fig. 5*). Instead of visiting the ceremony he joined the telescope maker Richard Reeves in his own modest observatory.

Fig. 5. The coronation of the English king Charles II during the Mercury transit of 3 May 1661

Although Huygens was stimulated by the Mercury transit to investigate the phenomenon of the transits mathematically, it was the Scottish mathematician James Gregory who first got the idea that such transits could be more than just a curious rare event. In 1663, in his book *Optica Promota* (fig. 6) Gregory launched the notion that such transits could be used to determine the mean distance between the Earth and the Sun, also called the 'astronomical unit', a parameter at the time mostly called the 'solar parallax'.



Optica Promota,
Seu
Abdita radiorum reflexorum & refractorum
MYSTERIA,
Geometrice Enucleata;
Cui subnectitur
APPENDIX,
Subtilissimorum Astronomiæ Problematum resolutionem exhibens.

Authore *Jacobo Gregorio*, Abredonensi *Scoto*.

LONDINI,
Excudebat *J. Hayes*, pro *S. Thomson*, ad Insigne Episcopi in Cœmeterio Paulino, 1663.

Fig. 6. The Scottish mathematician James Gregory and the title page of his Optica Promota *(1663)*

Gregory, however, left it by the plain concept. It would last a few decades before his idea was mathematically elaborated into a useful method by the English mathematician and Astronomer Royal Edmund Halley. This gifted scholar had witnessed a Mercury transit during his voyage around the world in 1677. But it was only in 1691 that he first published his method to determine the solar parallax from observations made during a transit. He called these transits 'a sight which is by far the noblest astronomy affords'. By then Halley knew that a transit of Venus (which he regarded more useful for this purpose than those of Mercury) would only occur in 1761 and 1769, therefore years after his own death. This 'noble sight' was 'denied to mortals for a whole century, by the strict laws of motion'. But because 'this observation alone' could yield a reliable value for the distance of the Sun from the Earth', Halley called upon his successors, naming them the 'diligent searchers of the Heavens', to bear in mind his injunction and 'to apply themselves actively and with all there might, to making the necessary observations'.

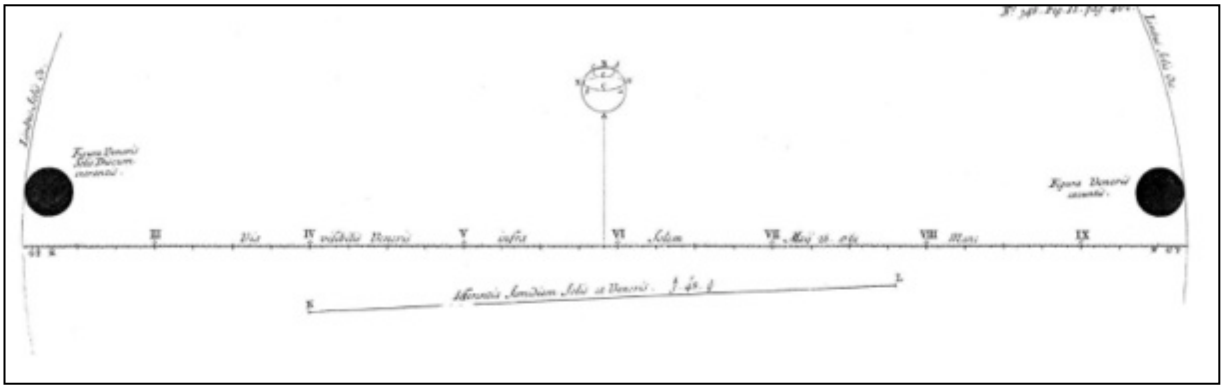
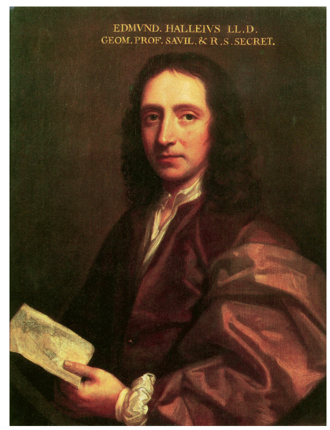


Fig. 7. Figure from Halley's second publication on the method to determine the solar parallax (1716)



This call to his successors in the field of astronomy Halley repeated in 1716, in a more detailed publication on the subject (*fig. 7 & 8*).
He wrote for instance:

> 'I wish them luck and pray above all that they are not robbed of the hoped-for spectacle by the untimely gloom of a cloudy sky; but that at last they may gain undying glory and fame by confining the dimensions of the celestial orbits within narrower limits'.

In the 18th century some 'diligent searchers of the Heavens' indeed would follow Halley's call. Although the transit of Mercury of 1736 only sparked some announcements, for instance from the schoolmaster Symon Panser in the North German city of Emden (*fig. 9*), with the next transit of 1743 things became more serious.

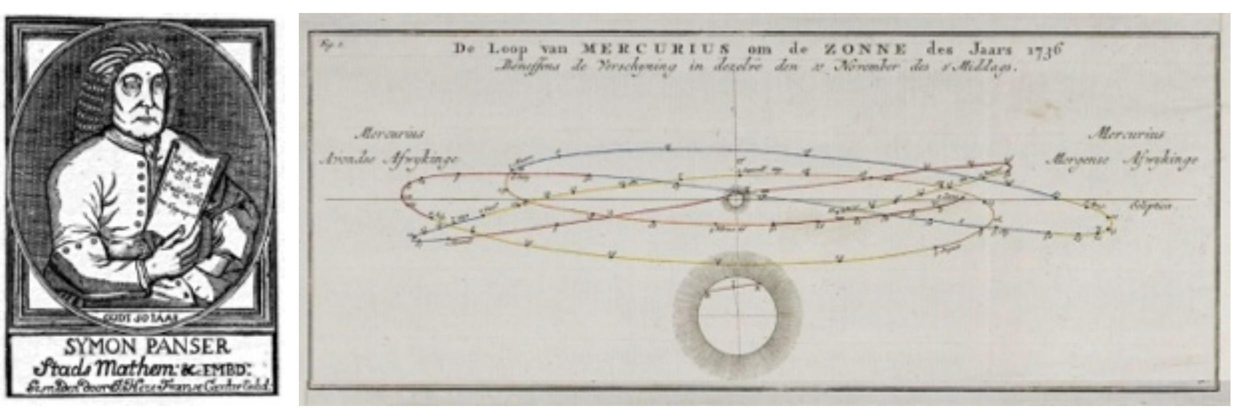
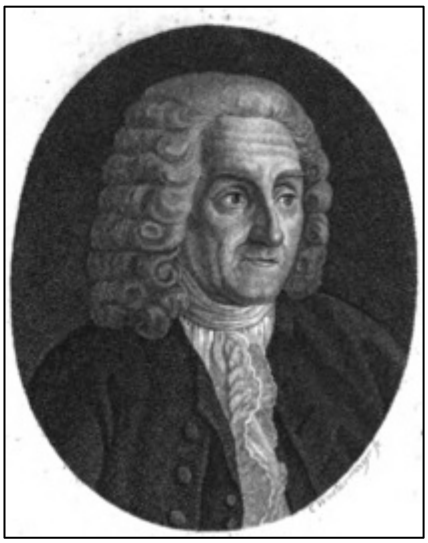


Fig. 9. Prediction of the Mercury transit of 1736 by Symon Panser, city mathematician of Emden

In preparation for the Mercury transit later that year, both the French astronomer Joseph-Nicolas Delisle and the Dutch surveyor and astronomer Dirk Klinkenberg developed methods to use observations of the

Mercury transits of 1743 and 1753 for an attempt to determine the solar parallax, years before the Venus transits of 1761 and 1769 (*fig. 10*). In his younger days, Delisle had observed the 1723 transit of Mercury, being inspired by Halley's latest article on the subject, published in 1716. Since then, Delisle was fascinated by the possibility that the distance between the Sun and the Earth could be determined through an accurate observation of the moments of ingress and egress of one of the inner planets in their passage over the Sun’s disk. During a visit to London in 1724 he called on Halley, who personally gave him a copy of his improved astronomical tables. In the following years Delisle designed an adaptation of Halley’s original method, which made it possible to include also partial observations of a transit.



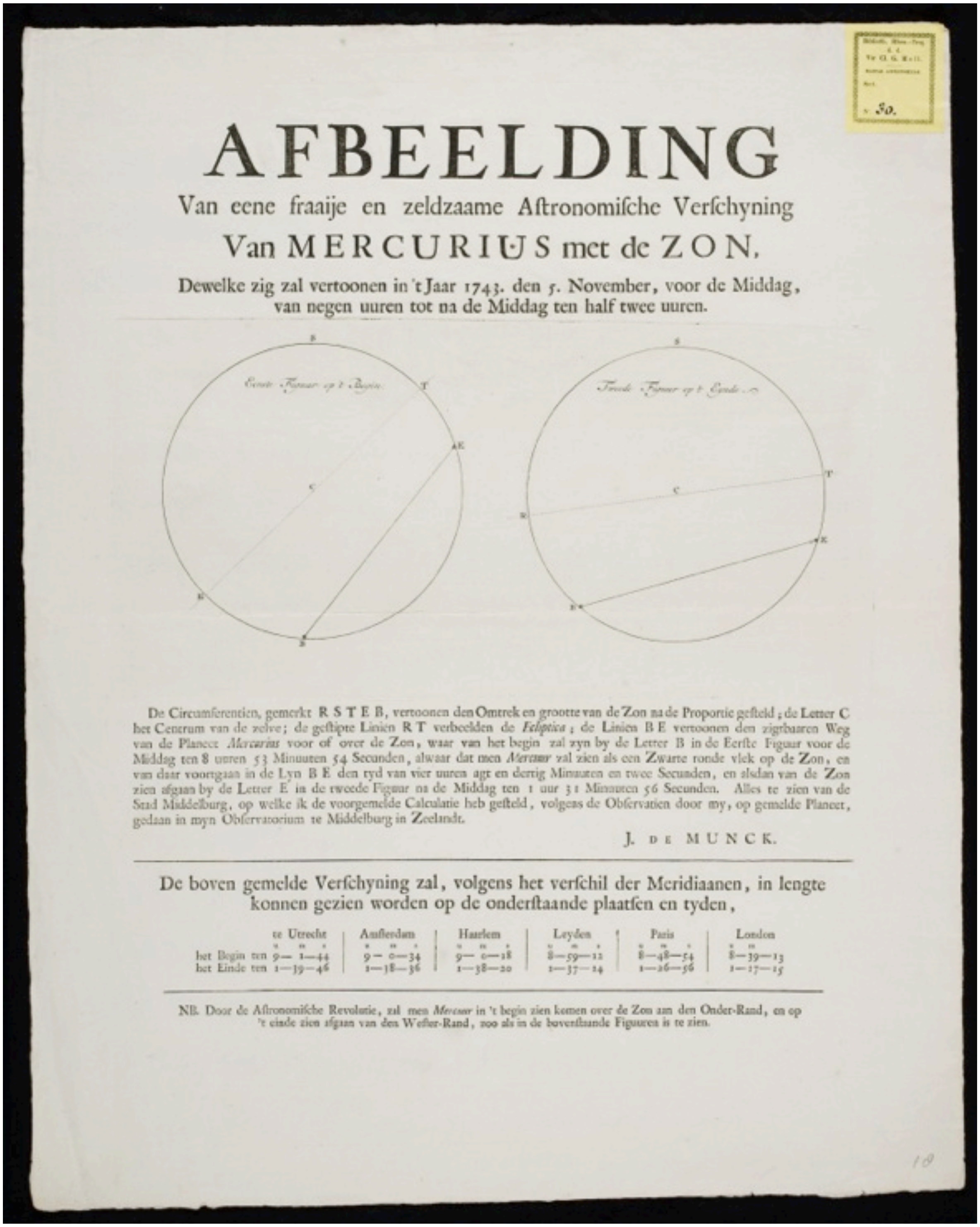
VERHANDELING
Over het vinden van de
PARALLAXIS
DER
ZON;
Zynde eene Beschryving hoe de afstand, tusschen de *Zon* en de *Aarde* kan gevonden worden
Door den schynbaaren weg der PLANETEN
VENUS
EN
MERCURIUS
OVER DE ZON:
Nevens de Afbeeldingen van drie zulke *Verschynsels*, welke voorvallen zullen, het eene in het Jaar 1743, de ander 1753, en de derde in 't Jaar 1761.
Waar agter gevoegd is, oplossing eener Wiskundige
VOORSTELLING:
DOOR
DIRK KLINKENBERG,
Geadmitteert Landmeter te Haerlem.

TE HAERLEM,
By JAN BOSCH, Boek- en Papierverkooper in de Groote Houtstraat, 1743.

Fig. 10. The French astronomer Joseph-Nicolas Delisle and the Dutch surveyor-astronomer Dirk Klinkenberg developed methods to use observations of the Mercury transits of 1743 and 1753 for a determination of the solar parallax

Klinkenberg too had carefully studied Halley's article from 1716. Just as his correspondent Delisle, Klinkenberg wondered why Halley had disregarded the Mercury transits. After all, Halley's method was generally valid, even though measurements during these transits would yield less favourable results than those obtained from a Venus transit. Still every chance of improvement ought to be used. Moreover, what if it was cloudy in 1761 and in 1769? Just that risk would justify every attempt to make measurements during transits of Mercury. Every effort to improve the solar parallax should be attempted. So, the transit of 1743 got a lot of attention. In the Netherlands, for instance, several predictions were published by local mathematicians (*figs. 11-13*).

Fig. 11. Prediction of the Transit of Mercury of 1743, by Symon Panser from Emden. (Source: Utrecht University Library)



AFBEELDING

Van eene fraaije en zeldzaame Aſtronomiſche Verſchyning
Van MERCURIUS met de ZON.

Dewelke zig zal vertoonen in 't Jaar 1743. den 5. November, voor de Middag, van negen uuren tot na de Middag ten half twee uuren.

De Circumferentien, gemerkt R S T E B, vertoonen den Omtrek en grootte van de Zon na de Proportie geſteld; de Letter C het Centrum van de zelve; de geſtipte Linien R T verbeelden de *Ecliptica*; de Linien B E vertoonen den zigtbaaren Weg van de Planeet *Mercurius* voor of over de Zon, waar van het begin zal zyn by de Letter B in de Eerſte Figuur voor de Middag ten 8 uuren 53 Minuuten 54 Secunden, alwaar dat men *Mercuur* zal zien als een Zwarte ronde vlek op de Zon, en van daar voortgaan in de Lyn B E den tyd van vier uuren agt en dertig Minuuten en twee Secunden, en alsdan van de Zon zien afgaan by de Letter E in de tweede Figuur na de Middag ten 1 uur 31 Minuuten 56 Secunden. Alles te zien van de Stad Middelburg, op welke ik de voorgemelde Calculatie heb geſteld, volgens de Obſervatien door my, op gemelde Planeet, gedaan in myn Obſervatorium te Middelburg in Zeelandt.

J. DE MUNCK.

De boven gemelde Verſchyning zal, volgens het verſchil der Meridiaanen, in lengte konnen gezien worden op de onderſtaande plaatſen en tyden,

	te Utrecht	Amſterdam	Haarlem	Leyden	Paris	London
	u m s	u m s	u m s	u m s	u m s	u m
het Begin ten	9— 1—44	9— 0—34	9— 0—18	8—59—12	8—48—54	8—39—13
het Einde ten	1—39—46	1—38—36	1—38—20	1—37—14	1—26—56	1—17—15

NB. Door de Aſtronomiſche Revolutie, zal men *Mercuur* in 't begin zien komen over de Zon aan den Onder-Rand, en op 't einde zien afgaan van den Weſter-Rand, zoo als in de bovenſtaande Figuuren is te zien.

Fig. 12. Prediction of the Transit of Mercury of 1743, by Jan de Munck from Middelburg (Source: Utrecht University Library)

Fig. 13. Prediction of the Transit of Mercury of 1743, by Gerbrand Back from Utrecht (Source: Utrecht University Library)

However, the actual observations of 1743 (*fig. 14*) and 1753 (*fig.15*) revealed that Halley indeed had been correct in disregarding the transits of Mercury as useful for his method. The values obtained for the solar parallax were far too different (10-18 arc seconds) to be reliable. (In retrospect the results could have been better if one had today's knowledge of statistics).

Obſervatie Van Mercurius op de Zon door
de Hr Jan de Munk te middelburg in Zeeland
men heeft door betrokke Lugt niet als de uijtgang
aldaar konnen Waarneemen.
Mercurius begind de zons rand te raken
of te bedekken. te . uur 1 – M: 15 – S: 24
Mercurius Middelpunt op de zons rand 1 – 16 – 14
Mercurius regte Verlaating van de Zon
oft Eynde 1 – 17 – 03
Mercurius Middellijn 15 Secund.

Obſervatie door mijn Broeder Gerrit Spinder
te Krommenie, door een Verrekijker van 8 voeten
vergrootende omtrend 32 maal,
Mercurius Vertoonde als een ſwart Plekje uur M: S:
op de zons rand. . . . . 8 – 49 – 40
Mercurius geheel op de Zon te . . . . 8 – 51 – 00
Mercurius 2 duijm binnen de zons rand
in een duijſtere Kaamer Waargenoomen. 10 – 7 – 10
Diſtantie Minima 3 duijm $3\frac{1}{2}$ Lijn .. 11 – 5 – 30
de Lugt betrok ten . . . . 12 – 18 – 00
men zag Mercurius tuſſen Wolken door
omtrend $1\frac{1}{2}$ van zijn Middellynen
van de zons rand . . . 1 – 15 – 00
Mercurius ſcheen de zon geheel ontweeken 1 – 22 – 00
en de Lugt begon op te klaren,

Fig. 14. Observations of the Transit of Mercury of 1743, collected by A. Spinder from Haarlem (Source: Royal Society London)

WAARNEEMING

VAN

MERCURIUS

OP DE SCHYF DER ZON

den 6 *Mey* 1753.

GEDAAN TE LEYDEN.

DOOR

JOHAN LULOFS.

DE verſchyning van deezen Planeet op de ſchyf der Zon heb ik, neffens andere Sterrekundigen, met veel verlangen te gemoete gezien, dewyl ik een zeer groo-

WAARNEEMINGEN. 373

groote verſcheidenheid beſpeurde in de uitkomſten der berekeningen, die ik een geruimen tyd te vooren gedaan had volgens de Tafels van *Halley*, *Caſſini*, *de la Hire* en *Leadbetter*; en het zoude ten hoogſten wenſchelyk geweeſt zyn, indien men den ingang, zo wel als den uitgang, hadt kunnen waarneemen; nademaal 'er geen eene Sterrekundige is, of geweeſt is, die dit verſchynſel ontrent den daalenden knoop van den Planeets-weg op zodaanig een' wyze heeft kunnen waarneemen, dat men 'er met volle zekerheid de plaats van dien knoop en de helling van den weg op het vlak van den Taankring uit kan opmaaken.

Schoon ik wegens den hevigen wind, en wegens de menigvuldige wolken, die zig niet lang na zes uuren des morgens den 6den *Mey* vertoonden, en de waarneemingen van tyd tot tyd ſtoorden, dit aanmerklyk verſchynſel niet naar myn genoegen heb kunnen zien, en in alle deszelfs deelen met de vereiſchte naauwkeurigheid afmeeten, echter zal ik hier een kort bericht geeven van myne waarneemingen, om welke te doen ik my bediend heb van een

Aa 3 New-

Fig. 15. Observations of the Transit of Mercury of 1753, by Johan Lulofs from Leiden (Source: Google Books)

The transits of Mercury of 1743 and 1753 were the last which were used in an effort to determine the astronomical unit. Although these efforts failed, the observations appeared useful as rehearsal of Halley's and Delisle's methods of observation. They also could be used for correction and improvement of the accuracy of current astronomical tables. The transits of Mercury of 1743 and 1753 also raised awareness for the scientific importance of the next transits of Venus, scheduled for the years 1761 and 1769. In the next years this awareness would give rise to the preparation of numerous scientific expeditions (the first of its kind) towards all parts of the globe. For instance the famous first voyage of captain James Cook to the Pacific was set up especially in view of the upcoming transit of Venus. However, the information collected by Cook and his crew was so enormous that Cook would return to the area for two more discovery tours. In the prelude to these expeditions Delisle's 'Mappemonde', published in 1760, revealing the parts of the Earth where the Venus transit would be visible, helped with figuring out the best locations for observation.

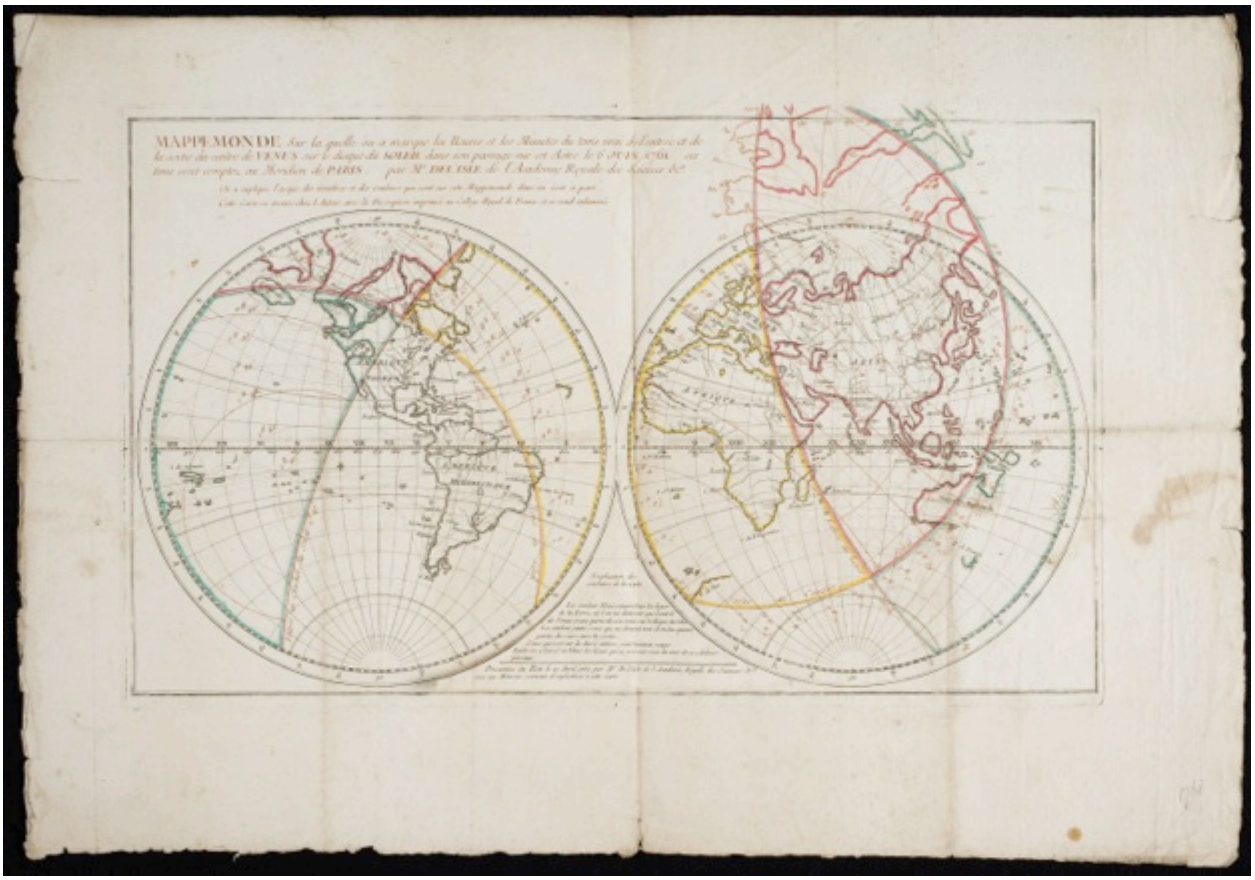


Fig. 16. Delisle Mappemonde for the Transit of Venus of 1761 (Source: Utrecht University Library)

From France expeditions were sent to Pondichery in India and Rodrigues in Madagaskar; from England expeditions went to Bengal and St. Helens; in Russia an expedition was equipped to Siberia; etcetera. At home, in Europe, many other observers also prepared for the observation. However, in Indonesia, at a place already recommended by Halley in his paper of 1716, the colonial Dutch East India Company refused any cooperation. Only thanks to a sailor, a surveyor, and a vicar, an observation was carried out, but only with minor instruments (*compares fig. 17*).

But the result of all these efforts was again in vain. Caused by instrument and human failure, bad weather and unexpected effects such as the 'black drop' (an optical effect just after second contact, and just before third contact) attempts to establish a precise value for the astronomical unit failed.

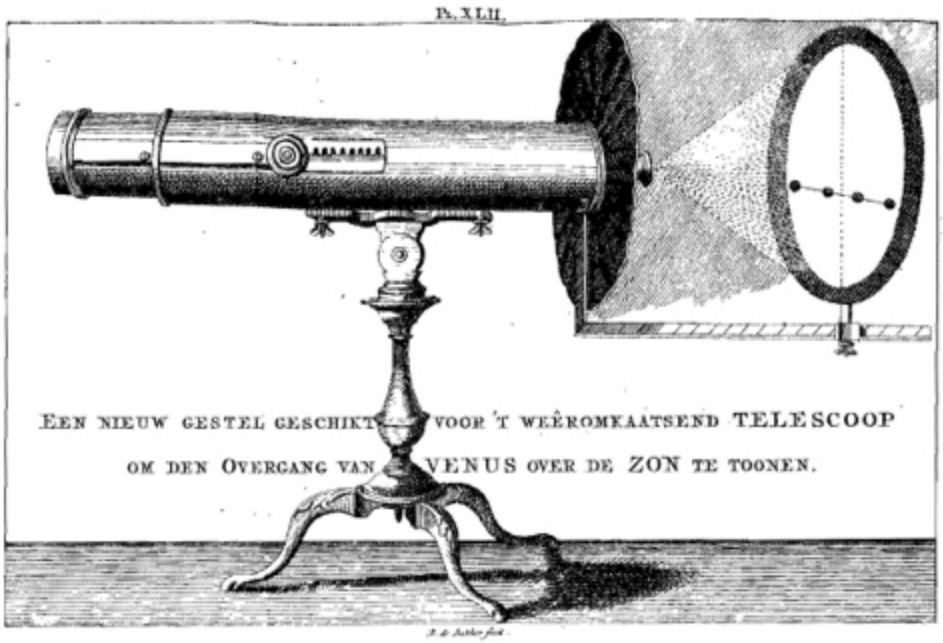


Fig. 17. Projection telescope designed for the Transit of Venus by Benjamin Martin

For the second Venus transit of 1769 new hopes were allocated to the newly available achromatic telescope, patented in 1758. And again many scientific expeditions were equipped and other observational sites were prepared. But in the end the required accuracy of the measurements appeared a bridge too far for 18th century technology. So, in 1770, just after the transits, James Year, a Scottish minister working in the Dutch town of Veere sighed:

> "All hopes of any assistance from the transit of Venus may be laid aside by the present generation, as the next visible passage of that planet through the Sun will not happen before the month of December in the year 1874".

By then, in the late 19th century, other methods for determining the astronomical unit were also available. In the 20th century transit observations were no longer really important for astronomy. But today, in the

21st century, the transit method is very important again. It is the major method for the discovery of exo-planets, revolving around stars far outside our solar system.

Therefore, an observation of the next transit of Mercury on 9 May 2016 will, at the one hand, make you part of a rich history involving many ‘diligent searchers of the Heavens’ from more than four centuries, and, at the other hand, this will bring you in contact with state-of-the-art technology involving exoplanets.

State-of-the-art, too, is the BepiColombo satellite, an ESA mission to explore the planet Mercury in collaboration with the Japanese space agency, JAXA (*fig. 18*). The launch of this spacecraft is scheduled on 17 April 2018, almost two years after the next Mercury transit. The arrival at planet Mercury will be in late 2024. So, the knowledge gathering about our neighbour planet, which started in 1607 with Kepler’s prediction of a Mercury transit and was continued in 1631 with Gassendi’s first observation and consecutive discovery of the small size of the planet, is continued today, but now with means, reaching far beyond the imagination of these early astronomers.

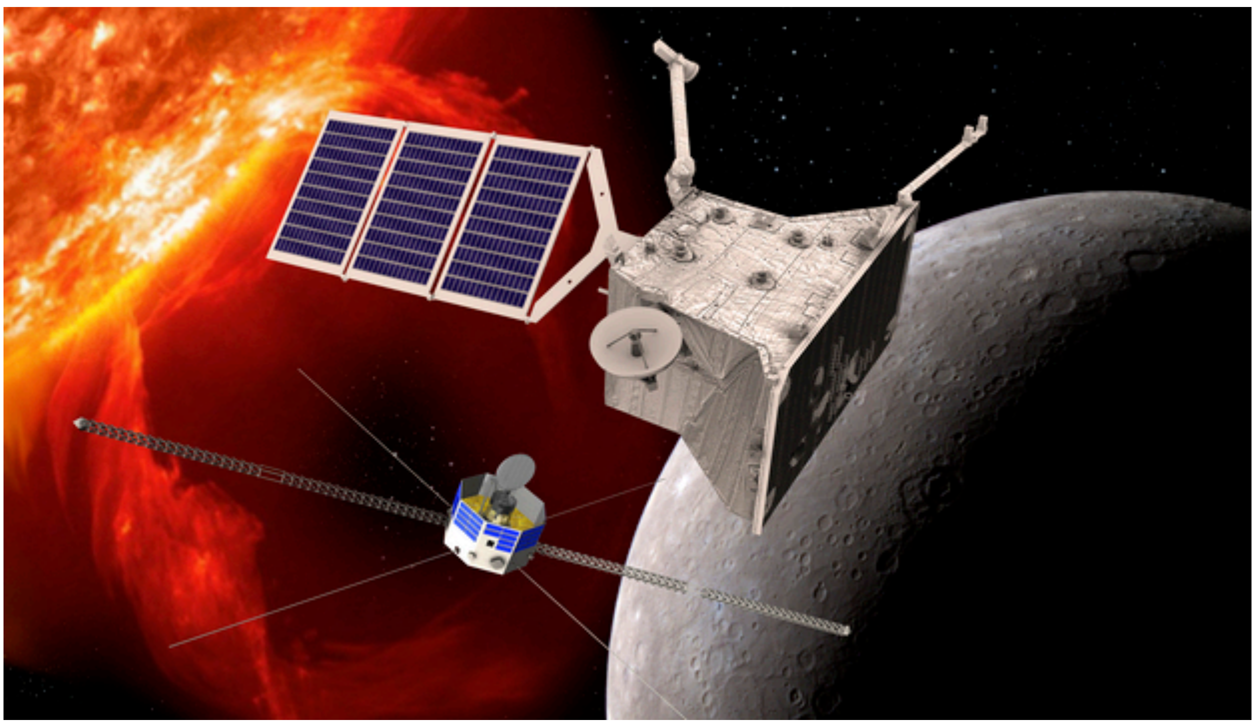


Fig. 18. Artist's impression of the twin satellite BepiColombo, revolving in an orbit around the planet Mercury