MEETING VENUS

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VENUS

A Collection of Papers
presented at the
Venus Transit Conference
Tromsø 2012

Edited by

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Cover illustration: Venus transit 2004. Courtesy David Cortner.

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PREFACE

On 2–3 June 2012, the University of Tromsø hosted a conference about the cultural and scientific history of the transits of Venus.

The conference took place in Tromsø for two very specific reasons. First and foremost, the last transit of Venus of this century lent itself to be observed on the disc of the Midnight Sun in this part of Europe during the night of 5 to 6 June 2012. Second, several Venus transit expeditions in this region were central in the global enterprise of measuring the scale of the solar system in the eighteenth century.

The site of the conference was the *Nordnorsk Vitensenter* (Science Centre of Northern Norway), which is located at the campus of the University of Tromsø. After the conference, participants were invited to either stay in Tromsø until the midnight of 5–6 June, or take part in a Venus transit voyage in Finnmark, during which the historical sites Vardø, Hammerfest, and the North Cape were to be visited. The post-conference program culminated with the participants observing the transit of Venus in or near Tromsø, Vardø and even from a plane near Alta.

These Proceedings contain a selection of the lectures delivered on 2–3 June 2012, and also a narrative description of the transit viewing from Tromsø, Vardø and Alta. The title of the book, *Meeting Venus*, refers to the title of a play by the Hungarian film director, screenwriter and opera director István Szabó (1938–). The autobiographical movie *Meeting Venus* (1991) directed by him is based on his experience directing *Tannhäuser* at the Paris Opera in 1984. The movie brings the story of an imaginary international opera company that encounters a never ending series of difficulties and pitfalls that symbolize the challenges of any multicultural and international endeavor. As is evident from the many papers presented in this book, *Meeting Venus* not only contains the epic tales of the transits of the seventeenth, eighteenth and nineteenth centuries, it also covers the conference participants' encounter with "Venus on the Sun" in historical archives as well as face-to-face at several locations in the Troms and Finnmark counties.

The Editors thank the University of Tromsø – in particular the University Library, the Faculty of Humanities, Social Sciences and Education with the Department of Culture and Literature and the Department of Education – as well as the University of the Arctic for generous funding, the Science Centre of Northern Norway for providing the conference venue, Steinar Thorvaldsen, Marie-Theres Federhofer, Anne Bruvold and Amelie Matt for impeccable scientific and technical organization, Stein Høydalsvik for providing a valuable collection of conference photographs, the Tromsø astronomy club for facilitating observation of the transit in Tromsø, and the organizers of the Venus Transit Event in Vardø, in particular Vardøhus Fortress, *Vardø Videregående Skole*, and the Municipality of Vardø, for their hospitality during an unforgettable day and night in Vardø. We are much indebted to Laszlo Szabados for a deep proofreading of the final manuscript. Last, but not least, we thank the authors of the scientific and narrative articles for their rewarding collaboration.

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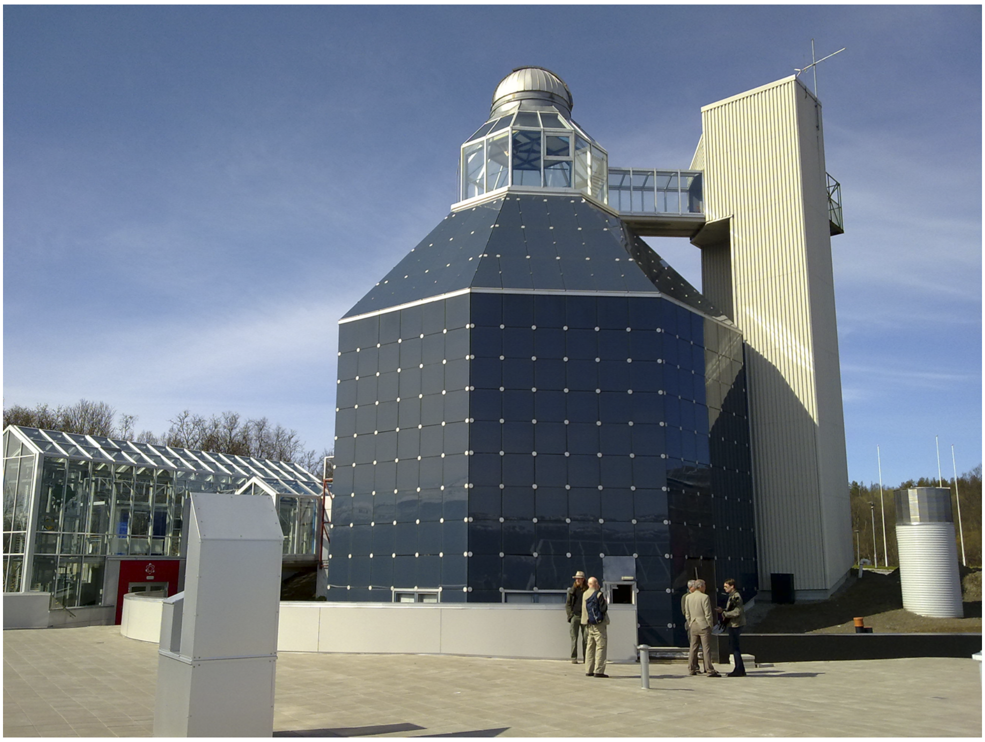
Facing page: conference participants at the Tromsø Planetarium.

Back row, left to right: Torsten Aslaksen, Leonard Doehl, Monique Gros, Marie-Theres Federhofer, Simone Dumont, Eckehard Schmidt, David Dunér, Jean-Pierre Martin, Guy Ratier, Detlev Lutz, Rainer Kruse, Suzanne Débarbat, Hans E. Jørgensen, Christiaan Sterken, Osmo Pekonen, Thomas Posch, Per Pippin Aspaas, Johan Stén, Nils Voje Johansen, Päivi Koivisto, Terje Brundtland, Päivi Maria Pihlaja, Ulrich Dornsiepen, Reinhard Neul.

Front row, left to right: Amelie Matt, Anne Bruvold, Steinar Thorvaldsen, Per Rieffesthal, László Kontler, Gudrun Bucher, Vidar Enebakk.

Conference participants at the Tromsø Planetarium. Photo Stein Høydalsvik.



The Tromsø Planetarium. Photo Detlev Lutz.

Participants at the Tromsø Cable Car Station. Photo Stein Høydalsvik.

DRAMATIS PERSONAE et SITUS

The measure of the sun's distance has always been considered the noblest problem in astronomy.

Sir George Biddell Airy 1857

MEETING VENUS
C. Sterken, P. P. Aspaas (Eds.)
The Journal of Astronomical Data 19, 1, 2013

A Synoptic Overview of Selected Key People and Key Places Involved in Historical Transits of Venus

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Abstract. This paper presents an overview of the *dramatis personae et situs*, or significant characters and places dealt with in this book. Several geographical and political maps, and timelines are provided as an aid to the reader.

1. Introduction

The transits of Venus are landmarks in the history of science, principally because of their use in historical attempts to measure the scale of our solar system. Eight transits of Venus have occurred since the prediction of the first such event by Johannes Kepler in 1629. These transits appeared in four pairs spaced by 8 years, with each pair separated by a time interval of more than one century.[1] The transit pairs alternatively happen in early June and in early December. Figure 1 shows the timeline of occurrence of the events, together with the publication date of four historical works that played a crucial role in the transit of Venus science, viz.,

1. In 1629, Johannes Kepler published in his *De raris mirisq[ue] Anni 1631. Phaenomenis, Veneris putà & Mercurii in Solem incursu*,[2] the very first predictions that a transit of Mercury will occur in November 1631, followed by a transit of Venus one month later. Kepler died a year before the events.

2. Isaac Newton's *Philosophiae naturalis principia mathematica*, that layed down the theoretical basis for Kepler's laws, was published in London in 1687.

3. Edmond Halley's 1716 proposal *Methodus singularis quâ Solis Parallaxis sive distantia à Terra, ope Veneris intra Solem conspiciendæ, tuto determinari poterit*[3] of determining the parallax of the Sun via the multi-site timing of transit ingress and egress times (Halley 1716).

4. Joseph-Nicolas Delisle's method of measuring the solar parallax on the basis of either the ingress or the egress timing of a transit, communicated in various

---

[1] In fact, about 105.5 or 121.5 years.

[2] On the rare and admirable phenomena of the year 1631, namely the incursions of Mercury and Venus on the Sun. For details, see the paper by Thorvaldsen in these Proceedings.

[3] A special method through which the parallax of the Sun, or its distance from the Earth, by means of observations of Venus inside the Sun can be accurately determined.

> letters and pamphlets distributed across Europe and finally in an elaborate memoir read before the *Académie Royale des Sciences* in Paris, 30 April 1760.[4]

The subsequent Sections of this paper present an overview of the *dramatis personae et situs* (scientific as well as political characters and places) together with key maps and timelines for all actors involved in the historical transits of Venus dealt with in these Proceedings. Two types of maps are provided: political maps and geographical maps. The former show national borders at a specific epoch, and are mainly meant for scholars whose field of study is remote from early modern political history. The latter serve to illustrate the geographical extent of the many expeditions that are discussed in this volume. Several of these maps will serve various papers, and complement diagrams and more detailed maps presented in the individual papers in this book. Note that most maps in this paper were made for illustration only, and that positions of the indicated locations are approximate (this is why scales have been omitted).

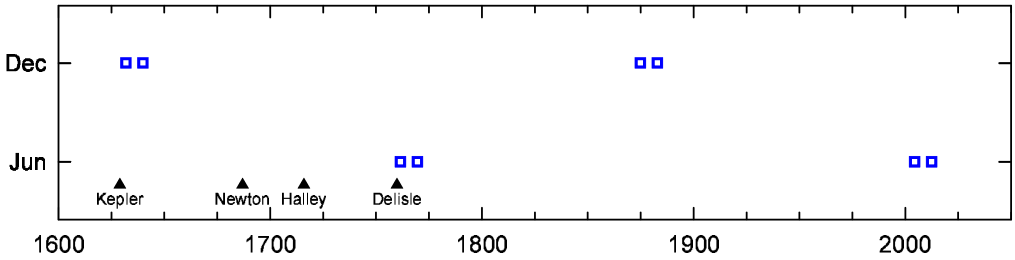

Figure 1. Chronology of all transits of Venus since the prediction of the first such event in 1629. The ▲ symbols represent the publication date of four works that played crucial roles in the celestial mechanics science related to the transits (see text).

2. The 1631–1639 transits

The 1631 transit was predicted by Johannes Kepler, but was not observable for those who knew about the forthcoming event. The 1639 transit was predicted by Jeremiah Horrocks and observed by himself and his friend William Crabtree. Their sites of observation were Much Hoole (Preston) and Broughton (Manchester), respectively. Figure 2 shows the lifespans of Johannes Kepler and the two sole Venus transit observers of the seventeenth century, and Fig. 3 shows a partial map of Britain with the observing locations marked.

---

[4] Delisle's memoir, *Description et usage de la Mappemonde dressée pour le passage de Venus sur le disque du Soleil qui est attendu le 6 Juin 1761* (Description and use of the mappe-monde of the transit of Venus across the disc of the Sun that is expected on 6 June, 1761) is summarized in the article *Du passage de Vénus sur le Soleil annoncé pour l'année 1761* in the Histoire de l'Académie Royale des Sciences, Année 1757 (published 1761), pp. 77–99. For details, see Woolf (1959), pp. 33–35 and the paper by Dumont & Gros in these Proceedings.

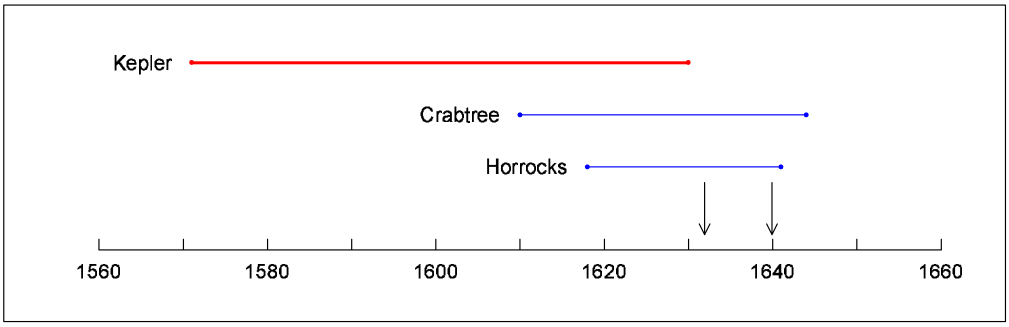

Figure 2. One-century timeline for the 1631–1639 transits. The horizontal bars represent the lifespan of each character. The vertical arrows indicate the times of the transits of Venus.

Figure 3. Observing locations (⊡) for the 1639 transit in the UK. Map based on `GoogleEarth`.

3. The 1761–1769 transits

3.1. The place of birth of Maximilian Hell

Among the many eminent scholars who devoted themselves to the study of the transits of the 1760s, the Jesuit Father Maximilian Hell is of particular relevance for this book. Figure 4 shows a political map of Europe at the moment of Maximilian Hell's birth in 1720. His place of birth, a village just outside Banská Štiavnica (or Schemnicium, Schemnitz, Selmecbánya) in present-day Slovakia is indicated with an encircled symbol *H*. For a discussion on the national and ethnic identity of Maximilian Hell, see the papers by Kontler and by Sterken et al. in these Proceedings.

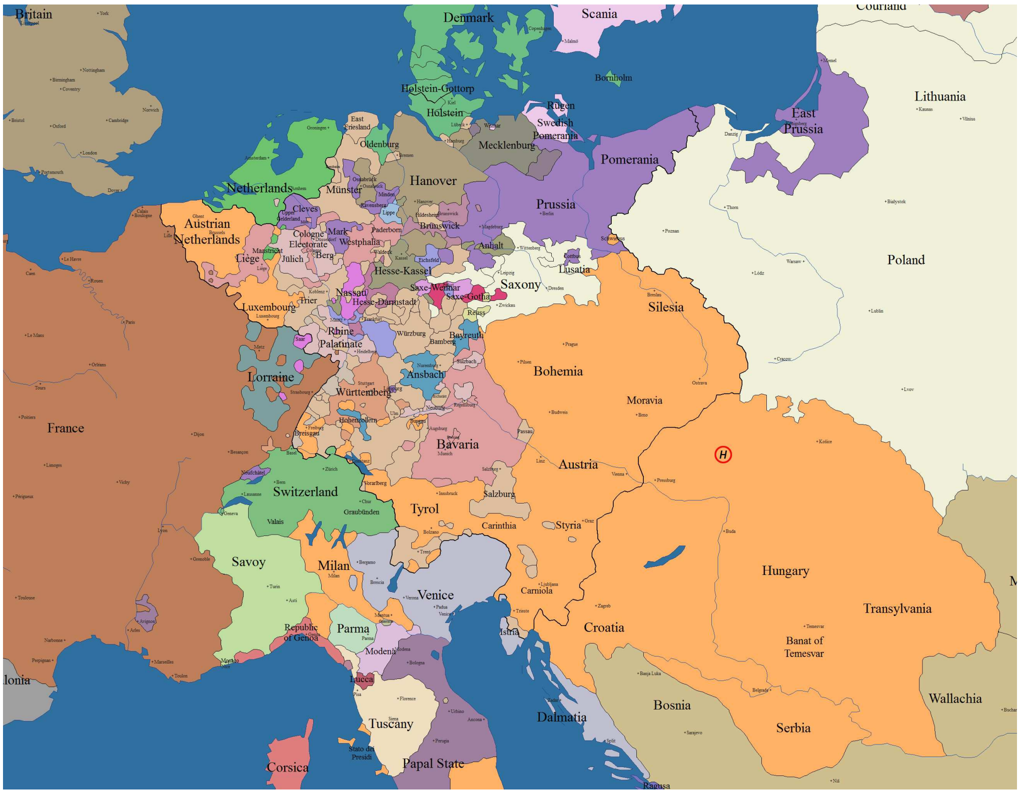

Figure 4. Political map of Europe for 1720 at the time when Maximilian Hell was born. His place of birth, Windschacht (Štiavnické Bane) just outside Schemnicium (Schemnitz, Selmecbánya, Banská Štiavnica), is indicated by the encircled symbol *H*. Map based on `Centennia` mapping software.

3.2. Observatories in the Provincia Austriae of the Society of Jesus

In early modern Central Europe, science was hugely influenced by the Society of Jesus. The role of the Jesuits in the formation of astronomical observatories is illustrated in Figure 5, which shows the location of the five Jesuit Observatories that flourished in the Provincia Austriae of the Society of Jesus during the eighteenth century. For details, see the paper by Posch et al. in these Proceedings.

3.3. Political map of Scandinavia, 1769

In astronomical terms, the far-northern parts of Europe formed a region with very similar advantages as far as the transits of Venus were concerned. Figure 6 shows a political map of northernmost Europe at the time when the eighteenth-century transits took place. The map clearly illustrates the extent of the Kingdom of Denmark–Norway (in green), and the two other far-northern European powers Sweden and Russia (in pink and brown, respectively).

Figure 5. Jesuit Observatories in the Provincia Austriae of the Society of Jesus: Vienna = Vindobona, Wien, Vieden̆, Bécs (1,2); Graz = Graecium (3); Trnava = Tyrnavia, Tyrnau, Nagyszombat (4); and Cluj-Napoca = Claudiopolis, Klausenburg, Kolozsvár (5). Hell's birthplace is again pointed out with the letter *H*.

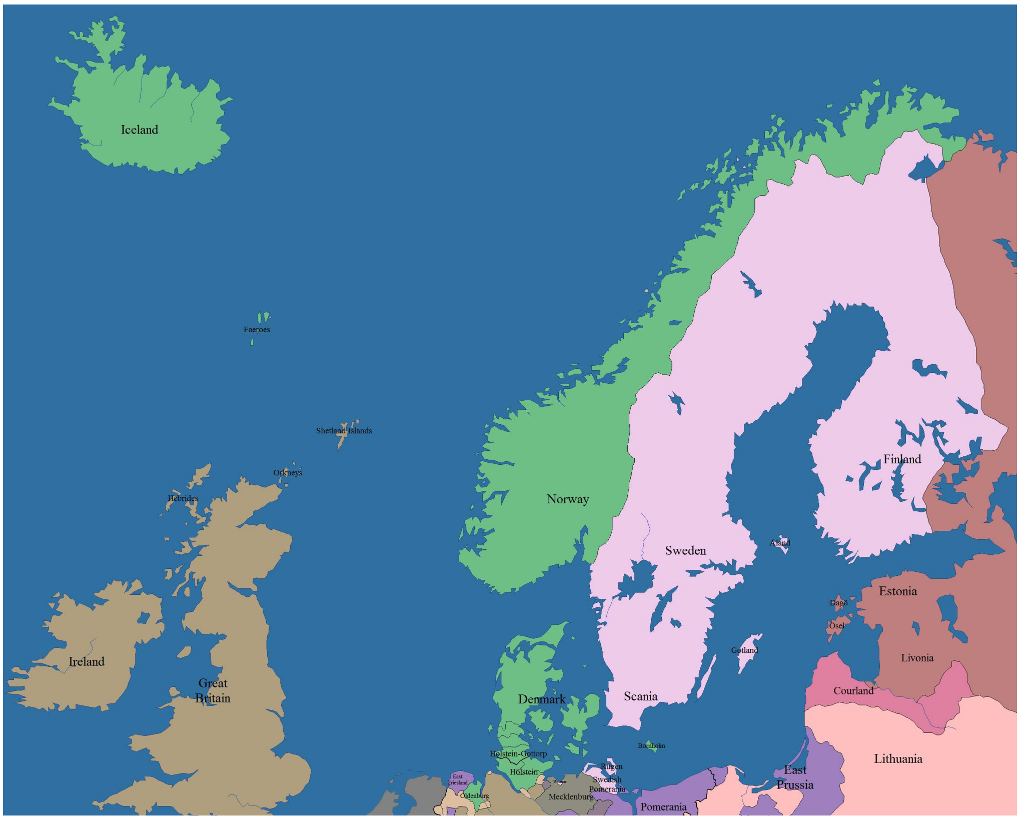

Figure 6. Political map of northern Europe for 1769. Map based on `Centennia` mapping software.

3.4. Geographical map of Russia

Similar to Scandinavia, the geograpical location and extension of the Russian Empire gave it strategic advantages in the efforts to measure the solar parallax on the basis of the eighteenth-century transits of Venus. Figure 7 is a geographical map of Russia, with the principal places of observation of the 1761 and 1769 transits (see the papers by Bucher and by Stén & Aspaas in these Proceedings).

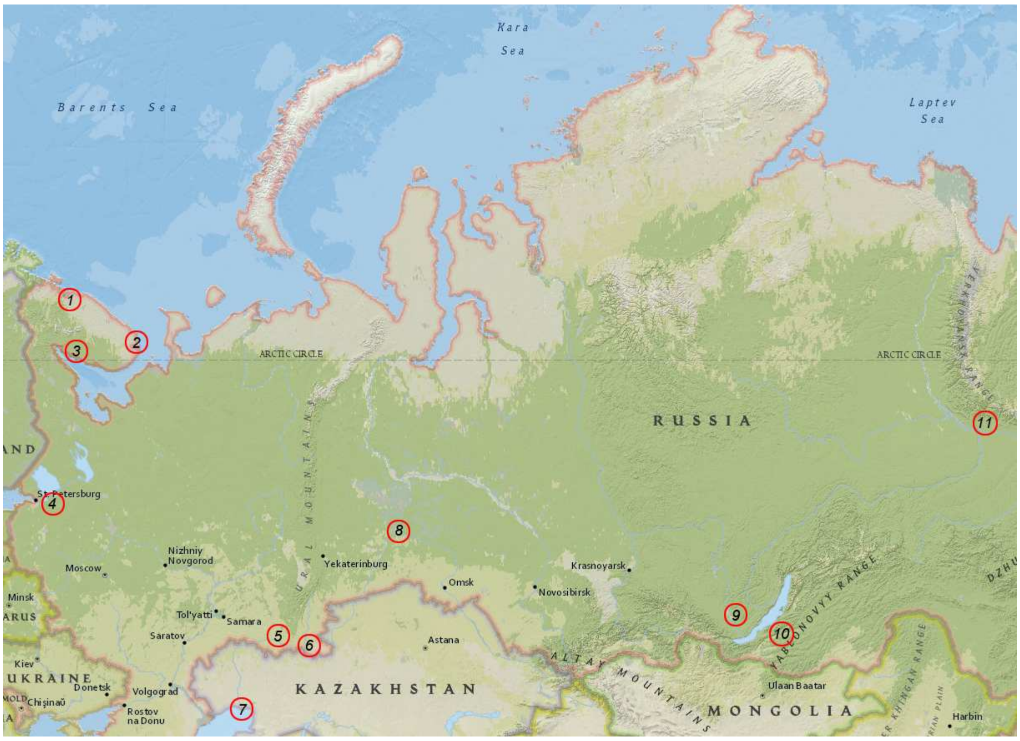

Figure 7. Geographical map of Russia, with the principal places of observation of the 1761 and 1769 transits. The numbers refer to the places listed in Table 3.

3.5. Geographical map of Scandinavia

Figure 8 shows all Scandinavian observing sites listed in Tables 1 and 2. See the papers by Widmalm, Aspaas, Pekonen and Voje Johansen in these Proceedings.

3.6. Historical geographical map of Vardø 1772

Figure 9 shows the historical map of Wardoehuus (Vardø) made by Maximilian Hell, who observed the 1769 transit from this island. The latitude of the observatory is indicated: $70^\circ22'36''$ N; the longitude *"ab Insula Ferri"* is $48^\circ40'45''$ ($3^{\rm h}14^{\rm m}43^{\rm s}$ East of Ferro).[5]

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[5] *Isla de El Hierro*, the smallest of the seven Canarian Islands, and also the prime meridian in common use in those days.

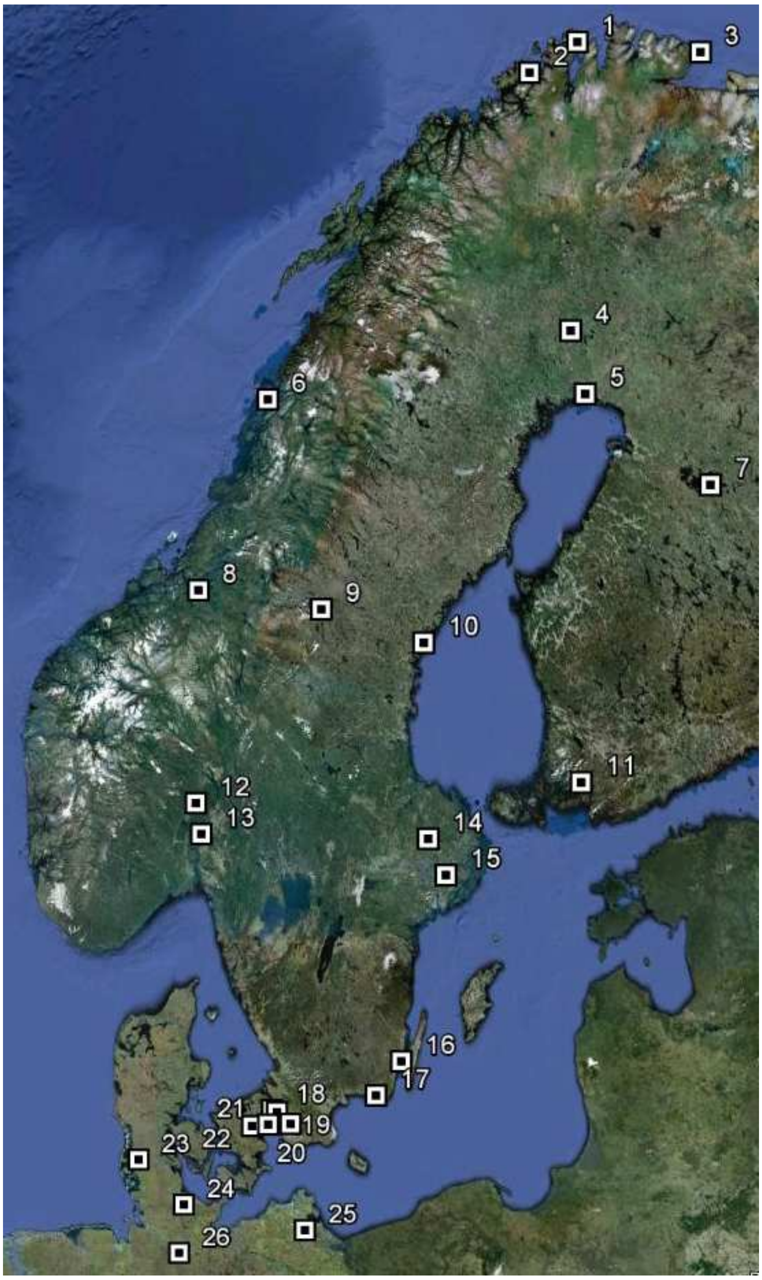

Figure 8. Scandinavian observing sites listed in Tables 1 and 2. Map based on `GoogleEarth`.

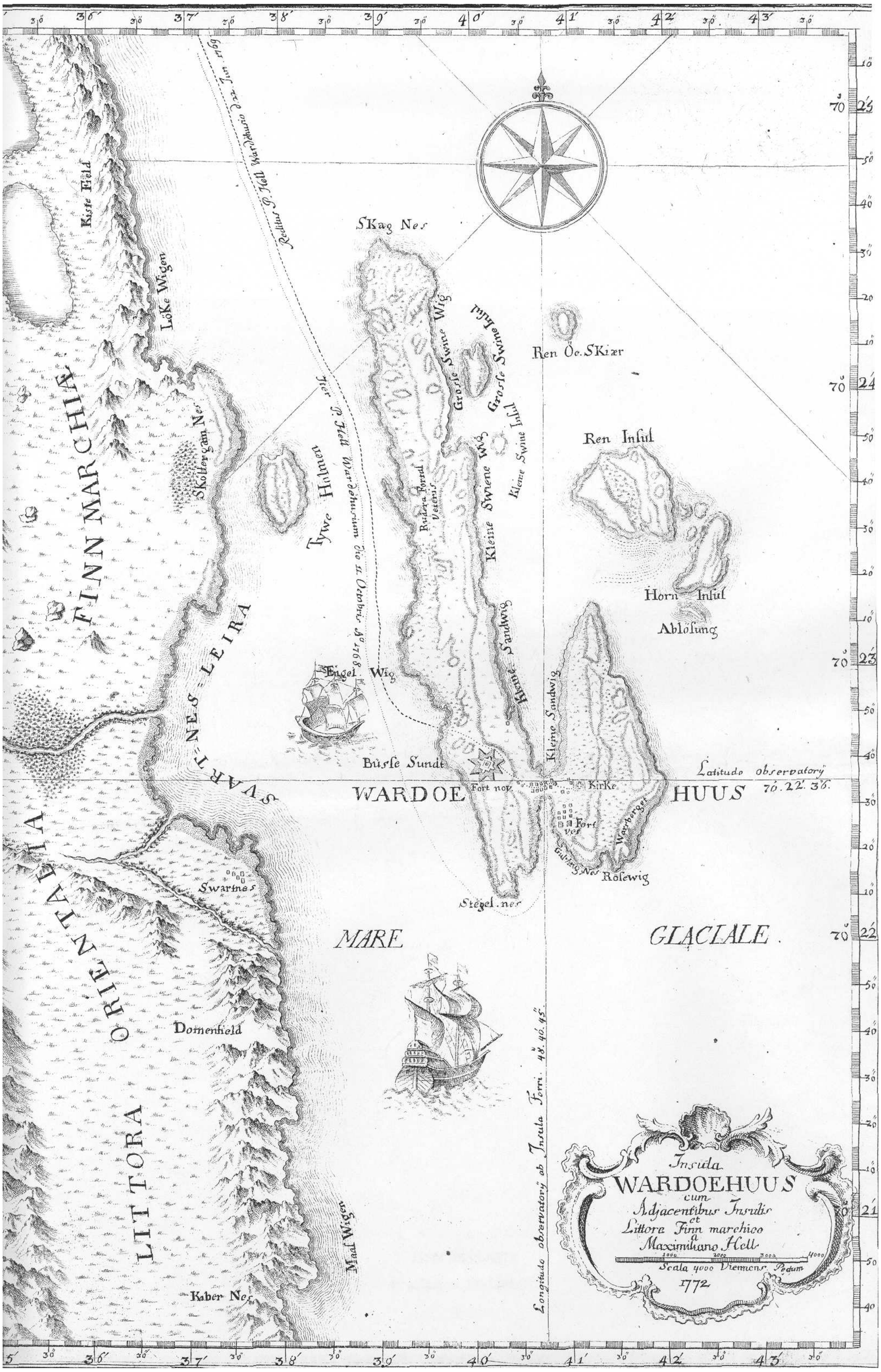

Figure 9. *Insula Wardoehuus cum Adjacentibus Insulis et Littore Finn marchico a Maximiliano Hell* (1772). The scale bar is expressed in Viennese foot, and its total length is about 1194.5 m. Source: *Ephemerides Astronomicae ad Meridianum Vindobonensem Anni 1791* (Vienna, 1790).

3.7. The 1761–69 transits observed from Scandinavian territories

Tables 1 and 2 give an overview of observers and places for the 1761 and 1769 transits from Scandinavian territories. The sources for the 1761 list are Wargentin (1761); Hellant (1761); Hammer (1761); Mayer & Röhl (1762); Planman & Carström (1763); Short (1763); Lalande (1763); Horrebow (1765), supplemented by Lindroth (1967); Aspaas (2011, 2012); Pekonen (2012, these Proceedings) and Widmalm (these Proceedings). The sources for the 1769 transit information are Wargentin (1769); Prosperin (1769); Gadolin (1769); Gissler (1769); Planman (1769); Schenmark (1769a,b); Mallet (1769); Horrebow (1769); Kiøbenhavn Adresse-Contoir (1769); Tronhiems Adresse-Contoir (1769); Nordske Jntelligenz-Sedler (1769); Planman & Widqvist (1770); Hell (1770, 1772, 1790), supplemented by Lindroth (1967); Aspaas (2012); Pekonen (2012, these Proceedings); Widmalm (these Proceedings) and Voje Johansen (these Proceedings). Figure 10 shows the lifespan of the major characters listed in Tables 1 and 2.

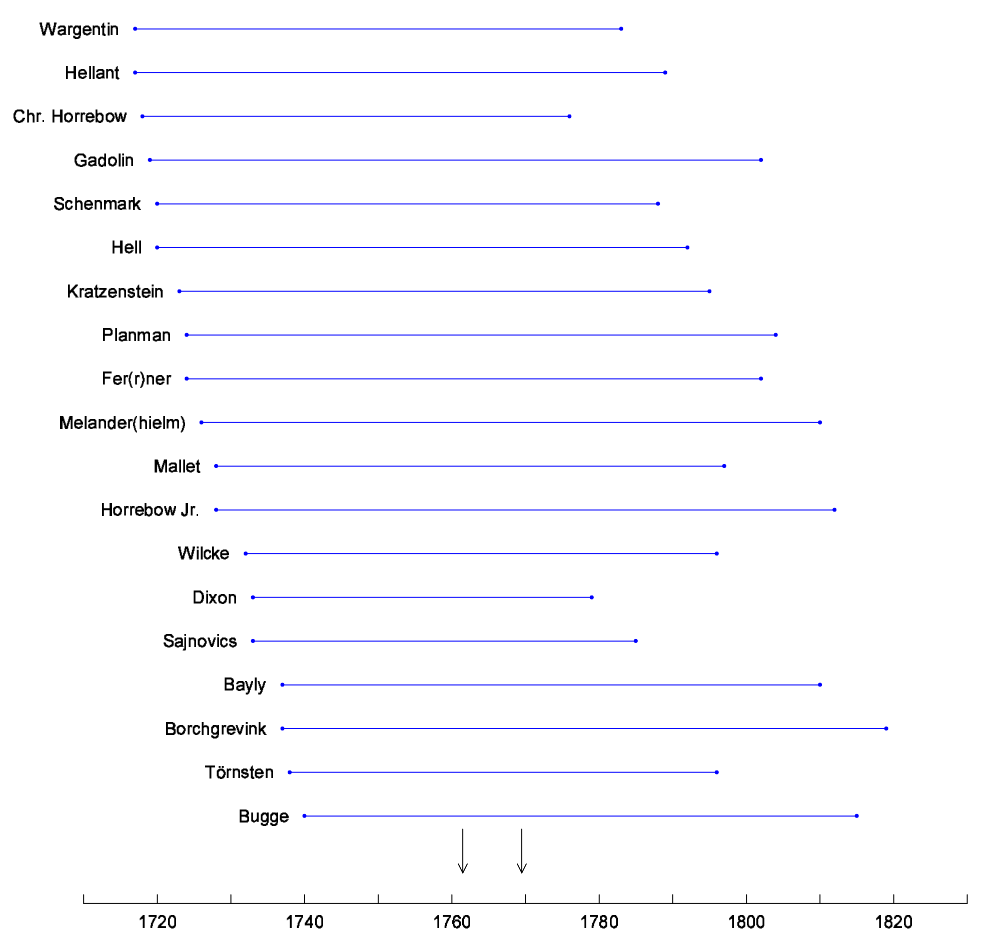

Figure 10. Timeline for the 1761–1769 transits. The horizontal bars represent the lifespan of the major characters listed in Tables 1 and 2. The vertical arrows indicate the times of the transits of Venus.

Table 1. Overview of observations of the 1761 transit from Scandinavian territories. Names in italic refer to observers that are not mentioned elsewhere in this book. The observing sites have been listed north to south.

Observers	Location
Sweden	
Anders Hellant Daniel Lagerbohm Jonas Häggman Abraham Steinholtz	Torneå/Tornio [5]
Anders Planman *Johan Frosterus*	Cajaneborg/Kajaani [7]
Johan Justander *Martin Johan Wallenius*	Åbo/Turku [11]
Pehr Wargentin Johan Carl Wilcke Johan Gabriel von Seth Samuel Klingenstierna	Academy Observatory, Stockholm [15]
Nils Gissler *Ström*	Härnösand [10]
Fredrik Mallet Mårten Strömer Daniel Melander(hielm) Torbern Bergman	University Observatory, Uppsala [14]
Anders Wikström	Kalmar [16]
Carl Gustaf Bergström *Johan Gustaf Zegollström*	Karlskrona [17]
Nils Schenmark *Johan Henric Burmester*	Lund [20]
Fredrik Bremer *Dehn* *Landberg*	Landskrona [19]
Andreas Mayer *Lambert Heinrich Röhl*	Greifswald* [25]
Denmark–Norway	
Thomas Bugge Urban Bruun Aaskow Jørgen Nicolai Holm	Trondheim [8]
Christopher Hammer	Melbustad, Norway** [12]
Christian Horrebow Peder Horrebow Jr	Round Tower, Copenhagen [21]

*Not published in the Transactions of the Royal Academy of Sciences in Stockholm.
**Private undertaking, not mentioned in official Danish-Norwegian publications.

Table 2. Overview of observations of the 1769 transit from Scandinavia.

Observers	Location
Sweden	
Fredrik Mallet	Pello[†] [4]
Anders Hellant	Torneå/Tornio[†] [5]
Anders Planman *Johan Uhlwijk*	Cajaneborg/Kajaani [7]
Johan Törnsten	Frösön, near Östersund[‡] [9]
Jacob Gadolin *Johan Justander*	Wanhallina Berg, near Åbo/Turku [11]
Pehr Wargentin Bengt Fer(r)ner Johan Carl Wilcke *Alexander Michael von Strussenfelt*	Academy Observatory, Stockholm [15]
Fredrik Bremer	Hven/Ven [18]
Nils Gissler *Ström* *Eurenius*	Härnösand [10]
Eric Prosperin Mårten Strömer Daniel Melander(hielm) Torbern Bergman *Johan Gotthard Salenius*	University Observatory, Uppsala [14]
Nils Schenmark *Olof Nenzelius*	Lund [20]
Denmark–Norway	
William Bayly	Honningsvåg [1]
Jeremiah Dixon	Hammerfest [2]
Maximilian Hell János Sajnovics Jens Finne Borchgrevink	Vardø [3]
Peder Horrebow Jr Ole Nicolai Bützow	Dønnes[†] [6]
Christian Gottlieb Kratzenstein	Trondheim[†] [8]
Michael Sundt Døderlein	Christiania[†‡] [13]
Anonymous	"A few miles north of Copenhagen"[‡]
Christian Horrebow	Round Tower, Copenhagen [21]
Christen Hee	Frederiksberg, near Copenhagen
Anonymous	Private observatory, Copenhagen[‡]
Hans Christian Saxtorph	Roskilde[‡] [22]
Peter Lorenzen	Tønder[‡] [23]
Johann Friedrich Ackermann	Kiel[‡] [24]
Gottfried Profe	Altona[‡] [26]

[†] Neither ingress nor egress was observed due to bad weather.

[‡] Private undertaking, not mentioned in official reports.

3.8. The 1761 and 1769 transits observed from outside Scandinavia

Table 3 gives an overview of observers and places for the 1761 and 1769 transits observed from sites outside Scandinavia, and Fig. 11 illustrates the lifespan of the major characters listed in Tables 3.

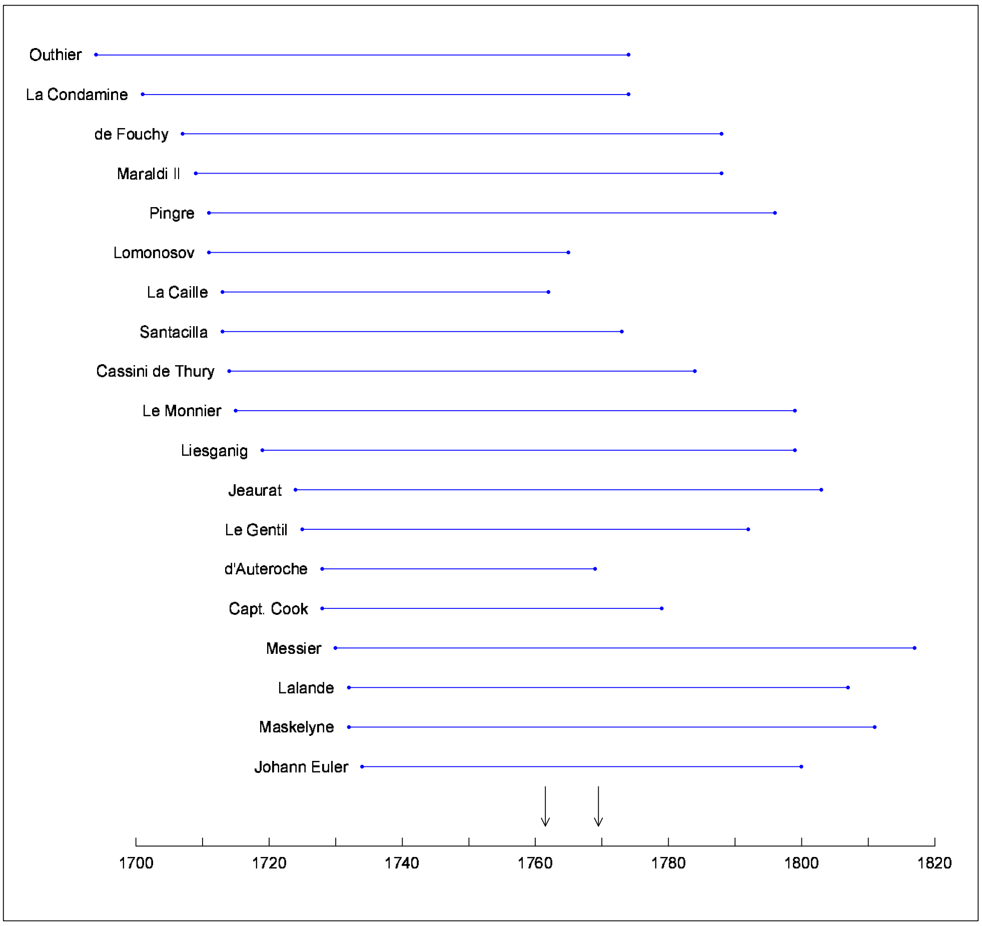

Figure 11. Timeline for the 1761–1769 transits with the major characters listed in Table 3.

Table 3. Overview for the 1761–1769 transit for sites outside Scandinavia. The list is not exhaustive: only sites mentioned in this book are included (names in italic refer to observers that are not mentioned elsewhere). The numbers in brackets refer to the locations shown in Fig. 7.

Observers	Location
1761	
Joseph Liesganig Maximilian Hell César-François Cassini de Thury	Vienna

Table 3. Continued.

Observers	Location
1761	
Ferenc Weiss	Trnava
Christian Mayer	Schwetzingen
Charles Mason Jeremiah Dixon	Cape of Good Hope
Nevil Maskelyne	Saint Helena
Alexandre-Guy Pingré	Rodrigues Island
Guillaume Le Gentil	Pondicherry, India
Joseph-Nicolas Delisle	Paris, France
Jean-Baptiste Chappe d'Auteroche	Tobolsk [8]
Jérôme Lalande	Paris, France
Mikhail Vasil'evich Lomonosov Franz Ulrich Theodosius Aepinus Joseph Adam Braun Andrei Dmitrievich Krasil'nikov Nikolai Gavrilovich Kurganov	Saint Petersburg [4]
Nikita Ivanovich Popov	Irkutsk [9]
Stepan Iakovlevich Rumovskii	Selenginsk [10]
1769	
Nevil Maskelyne	Greenwich
Stepan Iakovlevich Rumovskii	Kola Town [1]
Jacques-André Mallet	Ponoi [2]
Jean-Louis Pictet	Umba [3]
Wolfgang Ludwig Krafft	Orenburg [5]
Christoph Euler	Orsk [6]
Georg Moritz Lowitz	Gur'ev [7]
Istvan Islen'ev	Iakutsk [11]
Christian Mayer Gottfried Stahl Anders Johan Lexell Andrej Dmitrievitsch Krasil'nikov Johann Albrecht Euler	Saint Petersburg [4]
Jean-Baptiste Chappe d'Auteroche	California, Mexico
Guillaume Le Gentil	Pondicherry, India
Alexandre-Guy Pingré	Haiti
James Cook	Tahiti
Jérôme Lalande	Paris, France
Giovanni Domenico Maraldi II	
Edme-Sébastien Jeaurat	
Charles Messier	
Pierre-Charles Le Monnier	
Charles-Marie de La Condamine	
Nicolas-Louis de La Caille	
Jean-Paul Grandjean de Fouchy	
Réginald Outhier	

4. The 1874–1882 transits

The 1874 and the 1882 transits are succinctly discussed in this book. Table 4 gives an overview of observers and places for the transits discussed in these Proceedings, and Fig. 12 illustrates the lifespan of the observers listed in Table 4. Figure 12 shows the baseline San Antonio (Texas) – Santiago de Chile of Jean-Charles Houzeau's 1882 expeditions (see the paper by Sterken in these Proceedings).

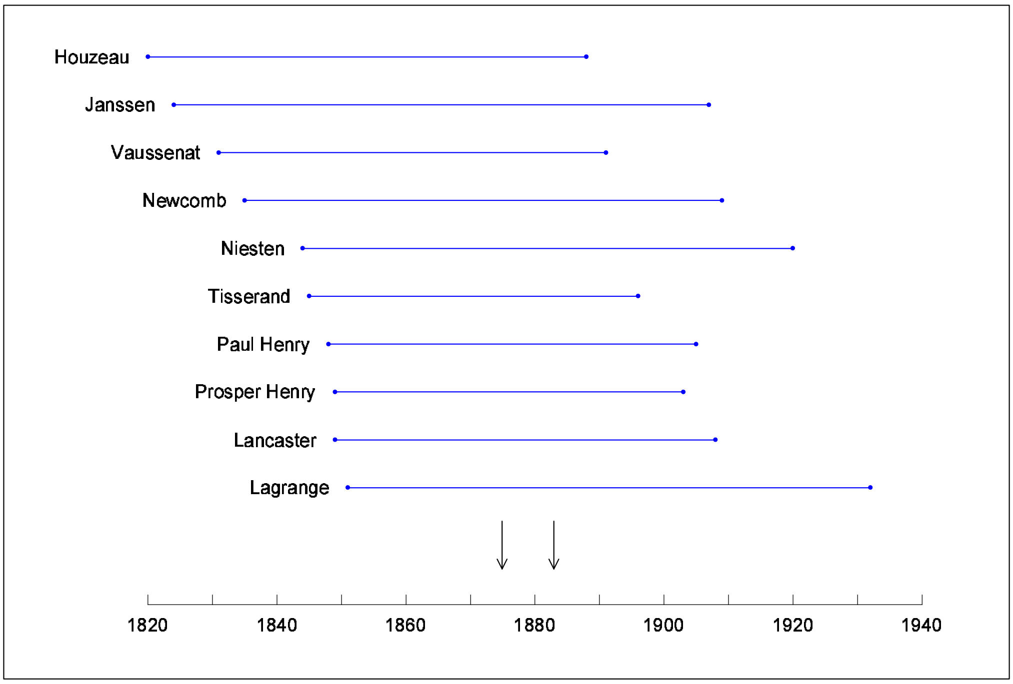

Figure 12. Timeline for the 1874–1882 transits. The horizontal bars represent the lifespan of each personality discussed in this book. The vertical arrows indicate the times of the transits of Venus.

Figure 13. Houzeau's 1882 baseline San Antonio (Texas) – Santiago de Chile. Map based on `GoogleEarth`. North is up.

Table 4. The 1874–1882 transits (persons mentioned in this book only).

Observers	Location
1874	
Paul Henry Prosper Henry Célestin-Xavier Vaussenat	Sencours
Jules Janssen Félix Tisserand	Nagasaki
1882	
Jean-Charles Houzeau Albert Lancaster	San Antonio, Texas
Louis Niesten Charles Lagrange Luis Ladisláo Zegers Joseph Niesten	Santiago de Chile

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VENUS TRANSIT HISTORIES FROM NORTHERN EUROPE, 1761–1769

When such long voyages are undertaken, one must have more than one object, so that in case the essential goal cannot be accomplished, it will be possible in some measure to remedy the damage.

Otherwise, one may be forced to take comfort in having travelled more than a thousand leagues only to gaze at the Sun for six hours and find it eclipsed, not by the planet, but by a cloud.

Cassini de Thury 1762

Translation from Aspaas (2012)

MEETING VENUS
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Science in Transit: Enlightenment Research Policy and Astronomy in Sweden

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Abstract. Swedish participation in the international efforts to measure the transits of Venus in the 1760s was impressive considering the size and the relative youth of the mathematical and astronomical community in the country. In this paper it is argued that the relative success of the Swedish contribution may be seen as the result of an early-modern form of research policy. This policy was promoted by the progressive so-called Hat Party that came into power in the late 1730s, an event that coincided with the creation of the Swedish Royal Academy of Sciences in Stockholm, soon to emerge as an organizational hub of astronomical research in Sweden and to some extent also on the European level. The close connection between the scientific and political elites in Enlightenment Sweden made possible the creation and international integration of a Swedish research community, not least in astronomy under the leadership of the Academy's perpetual secretary and astronomer Pehr Wargentin. The fact that these elites shared a common fate is also illustrated by their simultaneous decline from around 1770.

1. Introduction

Research policy is something we associate with the Second World War and the postwar era. The war brought with it large-scale government investments in research and development all over the western world, and the eastern block and the trend continued during the Cold War. This was true also in a small and neutral country like Sweden, where a system of government-funded research councils was created during the war and then expanded (Pettersson 2012). In the emerging policy community utilitarian and traditional academic values merged in what has been called a social contract for science (Guston & Keniston 1994). As the cost of research escalated, the contract was however renegotiated. More emphasis was placed on innovation, and control systems were implemented in order to steer research towards politically defined goals. As research policy took a technocratic and economistic turn, the period of relative academic autonomy that lasted from the early 1800s to the late 1900s began to look like a historical parenthesis (Rider et al. 2013).

Superficially at least it seems as if a historical circle has been closed. In certain respects current research policy is very similar to early modern research policy from around 250 years ago. This is the framework for my discussion of eighteenth-century astronomy and the transits of Venus in Sweden: the development of early modern astronomy, and the impressive manifestation of organizational and technical skill displayed by Swedish astronomers in connection with the transits in 1761 and 1769, must be understood within a policy framework that had a family likeness to that which we see today.

As Dorinda Outram has pointed out, the Enlightenment has constantly been used during the twentieth century as a point of reference for modernity. It has been seen as a cradle of democracy, secularization, tolerance and of course science (Outram

1999). By suggesting similarities between current and Enlightenment research policy I want to draw attention to the fact that policy has been with modern science since its origin (and that it should therefore not be seen as a twentieth-century invention). I also want to suggest that it is valuable in itself to think about the past using contemporary categories, as long as one avoids the many errors of presentism (judging the past by the standards of the present). By using the Enlightenment as a distant mirror, like Barbara Tuchman (1978) once put it, we are able to distance ourselves from the confusing present and get some sort of perspective on current affairs. Indeed, the fear of presentism should not stop us from applying contemporary concepts when discussing historic phenomena if they can help us to construct bigger pictures of important developments than those offered by micro-historical case studies.

2. The co-founding of science and research policy

An Enlightenment Research Policy was created in Sweden in 1739 through two simultaneous events: the founding of the Royal Swedish Academy of Sciences, and the launching of a party-political parliamentary system with the ascent to power of the so-called Hat Party that had arisen in binary opposition to the old political establishment that was now being identified as the Caps (as in "night caps").

The events surrounding the creation of the Academy were described in 1761 by Carl Linnaeus who drew a useful picture of the political and scientific interests and alliances that lay behind these momentous developments. The description is from a letter to the astronomer Pehr Wargentin whom we will soon encounter again as the main organizational force in Swedish astronomy during the transits of Venus:

> As soon as I returned from my travels in 1738, I was befriended by Herr Captain Triewald who was a really nice man, full of concern for the general good, acquainted with most people, well spoken [...], always promoting the interests of the Fatherland [...].
>
> During our acquaintance we spoke daily about how a science society should be founded in Stockholm, that wrote only about economic and practical matters, and that in the mother tongue [. . .]. He thought I could in particular provide new knowledge in natural history and that we could in each issue [of the Academy's envisaged Transactions] publish something along those lines. He thought he himself could produce mechanical products, and if we engaged a few good country gentlemen everything would fall into place. [—]
>
> Every time we were together, or met in town, we spoke about this project until I finally told him one should commence and talk less. After a few days he told me he had spoken to Baron von Höpken whom I did not know [...]; but Triewald told me about his great talent and how he was the best person to write and regulate statutes and formalities for the society, which was very important (Linné 1908 pp. 243–44).[1]

Linnaeus related how he and Triewald gathered a small group of founding members – the merchant Alströmer and a few landed gentlemen interested in agricultural

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[1] Translated from the Swedish. All translations in this article are by the author.

development – and began regular meetings, the most important object of which was to suggest other fellows for the Academy that they now had founded. According to Linnaeus

> We made a holy promise never to accept any new members on account of friendship or any other reason than that we were convinced that they could provide useful discoveries for the transactions

(Linné 1908, p. 244). The new members were to sign a paper promising to do their best as "honest Swedish men". One person, however, refused to sign this form because he thought the expression honest Swedish men "meant the Hat Party" (Linné 1908, p. 245).

This description captures a number of important features of Enlightenment research policy in Sweden. Most importantly, that the Academy was founded in order to promote *useful* knowledge. Like today, economic utility was central for the ideology of science during much of the eighteenth century, and of course not only in Sweden. In Sweden we tend to describe this period as utilitarian, meaning that focus was always on economic utility.

The idea that science should be economically useful was connected with religious ideas – the usual notions that God has created everything for the use of mankind etc. – as well as economic-political ideology (Frängsmyr 1977). The latter was mercantilistic. The nation was seen as a company and the aim of scientific research and technological development was to help exploit and refine natural resources. The citizens were seen, more or less, as a proletariat that should work at maximum efficiency on as small a salary as possible (Kaiserfeld 2009, Liedman 1986).

The founding members of the Academy represented such an ideology and also the kind of mixture of skills that was needed in order to help realize it. The merchant Alströmer, the engineer Triewald, the physician and naturalist Linnaeus, aristocratic progressive land owners, and not least the young star of the mercantilistic Hat Party Anders Johan von Höpken. All but one supported the Hats and it is not surprising that the Academy as such was seen as a Hat project (Hildebrand 1939, ch. 5–6).

Today policy wonks speak of research meaning innovation and of academic freedom meaning New Public Management auditing. Enlightenment research policy was likewise characterized by a peculiar discourse. In Sweden the term "science" – *wettenskap* – did not differentiate between knowledge production (natural philosophy) and technological development (Hildebrand 1939, pp. 372–373); *wettenskap* was described, in the same breath, as a godly pursuit, a patriotic duty, and an economic necessity (Pihlaja 2012). Such discourses integrate ideals of research with political and economic ambition and forges bonds between scientific practitioners and political and economic elites.

The founders of the Academy attempted to distance themselves from the various interests they represented by emphasizing that only technical qualifications would entitle to membership in the Academy. They somewhat spoiled this impression by then taking turns in nominating their friends. But the principle was of course fundamental in early modern science: credibility depended on the ability to uphold at least the appearance of impartiality; the ideal was meritocratic (Shapin & Schaffer 1985). We could also describe it as proto-professional (Shapin 1994, pp. 409–417).

It would as a matter of fact seem, for a while, that academic science in Enlightenment Sweden was heading towards professionalization some hundred years before the event. Under the guidance of the Hat Party and early parliamentarism a number of institutions were created or modified with the help of scientific expertise of which the Academy functioned as a center, or a kind of umbrella organization (Widmalm

1990, ch. 5). Health care was extended through the system of provincial doctors guided by the *Collegium Medicum*, for many years headed by Linnaeus' close friend Abraham Bäck. Scientifically-founded map making and navigation were improved with the help of astronomical expertise fostered at the new observatories in Uppsala and Stockholm. By and by such expertise was introduced in the national land survey and in the admiralty's chart making. An office for population statistics – possibly the first in the world – was founded in the 1740s under the auspices of the Academy (Johannisson 1988). Chemistry flourished in the government Mining Office that benefited from collaboration with academic chemists (Fors 2003). And of course there was Linnaeus, traversing the land commissioned by Parliament to map exploitable natural resources (Koerner 1999).

By mid-century the Academy functioned as an interface between various semi-professional scientific groups and a science-friendly government. There, poor astronomers like Anders Celsius and Pehr Wargentin (see Fig. 1) mingled with ministers, aristocrats and super rich merchants; the scientists were indeed seen as servants of the state, but government as well as individual patrons could also support endeavors that were only indirectly useful. Blissful harmony seemed to characterize research policy in this period when science surfed on a wave of promises that one hoped would soon be realized through the patronage of an enlightened government.

Figure 1. Pehr Wilhelm Wargentin, director of the Academy Observatory in Stockholm at the time of the Venus transits. Courtesy of the Academy of Sciences in Stockholm.

No wonder scientists thought that they were on the verge of establishing a secure professional status, and this was true not least of the astronomers. Ambitions for

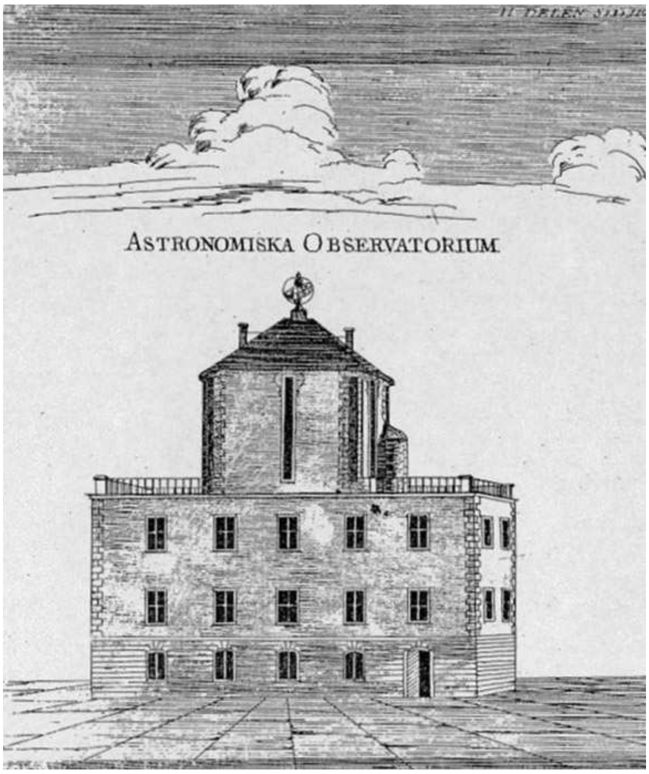

Figure 2. The Uppsala University Observatory. Contemporary engraving, c. 1769. Source: Wikimedia Commons.

Celsius' University Observatory in Uppsala, founded in 1741 (see Fig. 2.), were high. Not only did Celsius promise that observatory staff would produce useful knowledge in areas such as navigation, cartography, ecclesiastical time reckoning, and meteorology. He also devised a research programme that would make Uppsala a central node in the exchange of scientific data between European astronomers, for example mapping the stars of the Zodiac. As Celsius died already in 1744, he was succeeded by a mathematician whereas the research programme was inherited by the incumbent of the newly created position of Astronomer Royal. But this person was not long-lived either and from around 1750 astronomy at Uppsala was in fact dominated by mathematically oriented scientists like Fredrik Mallet and Daniel Melanderhielm (Widmalm 2012).

The national center of practical astronomy moved to Stockholm where the first two perpetual secretaries were both astronomers and where a new Academy Observatory, much grander than the Uppsala institution, opened in 1753 (Fig. 3). It is worth lingering a little on the founding of this observatory as it illustrates the close relationship that had developed between the political and scientific elites in the Hat Party and the Academy, both now nearing zenith of their power.

The inauguration of the observatory in September 1753 took place in the presence of the Royal couple and a host of other dignitaries, and the inauguration speech was delivered by von Höpken, who was by now considered the true founding father of the Academy and who had the year before risen to the highest political office in the land, President of the Chancellery, approximately Prime Minister. Hence, though he was not a scientist himself, he united the highest scientific and political power in one person.

Von Höpken was known as a great orator and on this occasion he proved his worth in this respect, painting a vivid image of scientific developments since Antiquity,

Figure 3. The Stockholm Academy Observatory. Contemporary drawing from the 18th century. Courtesy of the Academy of Sciences in Stockholm.

emphasizing in typical Enlightenment manner that the present was an improvement on the past in most respects and that the future promised even greater things. In the modern period, said von Höpken, "Philosophy discarded semantic quarrels and dressed itself in mathematical garb" (Höpken 1890, p. 181). Mathematical sciences represented not only a useful rationalism but ethical values, as it constituted a disciplining of the mind (Höpken 1890, p. 177). The successes during what we call the scientific revolution, Höpken attributed to a growing appreciation for science among political and military leaders as well as the growing number of scientific practitioners. As for Sweden great things had been accomplished in the past few decades. Von Höpken stressed that all branches of science in Sweden were now – unlike during the so-called Great Power era (1611–1718) – carried out by the Swedes themselves and not by scholars imported from abroad. Addressing himself to the members of the Academy he told them to whom they should be grateful:

> Who has during a shorter space of time enjoyed more grace from the authorities, more favors from Parliament, more consideration from the public, than you have? What have you requested that you have not also received? And how often have you not been granted such a wealth of favors that you have not even dared to wish for them to be so great, and much less demand them (Höpken 1890, pp. 183–4)

And so on. The message was deafeningly clear: the sciences flourished under the Hats, because of the Hats. Von Höpken then pointed out that the observatory was indeed a splendid example of how privileged the sciences were during the present regime. As the scientists had gone about their business without a care for anything but their "calling", he said, a number of benefactors had worked hard in order to realize the project, though modesty and delicacy forbade him to mention their names: benefactors should not be publically praised, they should be honored only through ardent scientific work.

Luckily for us Wargentin – now secretary as well as astronomer at the Academy – printed an appendix to this speech where all the benefactors that helped realize the observatory project are named! Gratefulness demanded, he wrote, that their names were recorded for posterity. The benefactors' contribution was invaluable because astronomy was the most useful and hence the most important science. Without observatories, astronomy would have to be founded on "guesswork" and "a country's felicity, that is founded on economy and commerce, should not be imperiled by guesswork" ([Wargentin] 1753).

So who were these benefactors? First Wargentin's predecessor as secretary of the Academy, Pehr Elvius, an astronomer who like his cousin Anders Celsius had passed away in early middle-age. Then the Baron and architect Carl Hårleman who drew up the plans for the observatory, the Count and leading Hat politician Carl Gustaf Tessin who saw to it that the Stockholm magistrate supported the project, the rich merchant Claes Grill who provided interest-free loans to the Academy. They had one thing in common: they were all prominent representatives of the Hat Party. The Stockholm observatory, where Wargentin would soon move in with an expanding family, was indeed a splendid symbol of the intimate not to say symbiotic relationship between political, economic, and scientific power in Enlightenment Sweden.

3. The transits

In the early 1750s Swedish astronomers participated in an effort organized by the French, in particular Nicolas-Louis de Lacaille, to estimate the parallax of the Sun from measurements of the Moon, Mars and Venus carried out at the Cape of Good Hope and simultaneously in Europe. Observations from Sweden were deemed especially important as they could be made on the same meridian as the Cape. Joseph-Nicolas Delisle, who had been on friendly terms with several Swedish astronomers for a long time, suggested that he should come to Sweden and make the measurements, just like Pierre-Louis Moreau de Maupertuis had done in the 1730s, when an arc of the meridian was measured in northern Sweden (Widmalm 1992).

Wargentin, who was corresponding with Delisle and who had just become secretary of the Academy, however took this opportunity to make a display of national scientific strength by organizing the Swedish measurements himself, in a sense a kind of dress rehearsal for the coming transits of Venus. This would not have been possible if government had not financed the purchase of new instruments, which it gladly did. Observations were carried out during all of 1751 on five different locations by astronomers at Lund, Uppsala, and Åbo/Turku, and by Wargentin in Stockholm as well as by the amateur astronomer Anders Hellant in the far north (Lindroth 1967, pp. 393–399).

Though nothing much of scientific value transpired from these measurements, they served important social goals for the Swedes. The good relations between the scientific community and the Hat government were cemented through this display of scientific magnanimity on part of the Government and of organizational and technical prowess on part of the astronomers. Similarly the Swedes displayed a willingness and a competence to carry out international collaborative work, in effect proving that they had reached a level of maturity where their natural scientific resources could no longer be colonized by the scientific leaders in Paris. As we have seen, the importance of both these moves towards political and international scientific integration were duly noted and praised by von Höpken in his observatory speech.

The Swedish contribution to the much larger international efforts to estimate the solar parallax from measurements of the transits of Venus strengthened this pattern

(Aspaas 2012, pp. 219–227; Lindroth 1967, pp. 399–411). These efforts were, of course, directed towards a worthy and important scientific goal. But they must equally be understood in a policy context, as expressions of a politicized view of science where scientific and political power essentially merged.

This symbiosis was given a powerful symbolic expression during the first transit in June 1761 when observations at the Stockholm observatory were carried out in the presence of leading government representatives as well as the Queen, and the fifteen-year old Crown Prince Gustav who would seize absolute power in a coup eleven years later. His mother had tried to do the same thing five years before the transit event, when the Hat regime ruled almost dictatorially. On that occasion the coup failed and eight conspirators were beheaded after having undergone torture. Prince Gustav, who was to be indoctrinated against all ideas of absolutism, was then given a new tutor, namely the Uppsala mathematician and physicist Samuel Klingenstierna.

General instructions for the education of the prince were written by von Höpken, and they were of a republican and enlightened tendency. The prince should be taught that he was no different from his subjects; luxury should be abolished at court; the prince should travel the land in order to learn about the living conditions of even his poorest subjects so that he would come to realize that "royal personages are not a better kind than other human beings" (Skuncke 1993, p. 183). Unsurprisingly this document was hailed by the French Encyclopaedists. The prince's governor, a leading Hat politician, wrote instructions for Klingenstierna that emphasized the importance of the prince's education in mathematics and physics. In particular mathematics was said to be morally important as it was the foundation for right thinking in a general sense – the same idea that von Höpken had expressed in his observatory speech (Scheffer 1757). Science became part of the moral education of a prince who should be taught republican values. Enlightened science policy therefore ran deep also in the harsh power politics of the period.

Then came the first transit of Venus, and I quote the following from Wargentin's observatory journal:

> On this day, so longed for by astronomers, namely June 6, I successfully observed the rare phenomenon of Venus in the Sun. Present were Her Majesty the Queen, the Crown Prince, a large number of ministers and foreign ambassadors and perhaps a too large group of spectators of both sexes and from all estates. The sky was almost as advantageous as one could wish. [–] The famous mathematician Herr Klingenstierna aided me observing and had his eyes tensely directed towards the Sun through his 10-foot Dollond tube [. . .]. Besides Herr Wilcke, with a 2-foot reflecting telescope, Herr C. Lehnberg with a 9-foot tube and high-born Baron von Seth with a very good 5-foot tube observed. But they, who were standing in another part of the room, could, because of the noise from the spectators, only with difficulty hear the voice of Herr doctor Gadolin who called out minutes and seconds after the time piece. (Nordenmark 1939, p. 177)

Wargentin had put an advert in one of the Stockholm papers announcing the event so he had only himself to blame that it became well attended. At the same time there is certainly something of the spirit of the Hat's educational programme being realized through this event, that gathered leading scientists, politicians, aristocracy and royalty as well as a crowd of citizens of both sexes and from all estates. It should certainly be seen as a manifestation of political unity – of government and court, of political and scientific elites – being put on display for a small but noisy selection of representatives of the people.

A report was quickly published by Wargentin in the *Transactions* (*Handlingar*) of the Academy of Sciences, describing observations of the transit in Uppsala and Stockholm as well as on seven other locations. Wargentin described the event as one where Swedish astronomy would "fulfill its duty" – that is its duty to the international community of astronomy (Wargentin 1761, p. 143). Here interesting effects like the black drop were discussed and spiced with speculations regarding the possibility that Venus has an atmosphere. The main purpose of the report was to display the massive scientific effort by the Swedes; the presence of the royals at the observatory was not even mentioned. The political importance of the event was hinted at through the mentioning of the participation of one important Hat official among the observers.

Apparently the government did not finance observation work in 1761. Only one of the astronomers, Anders Planman, actually traveled a lengthy distance in order to carry them out, the others stayed put and did not need travel money. Instruments were presumably at hand from the parallax work ten years earlier. In 1769 however government support was again called for.

This time observations from the far north were considered especially important for reasons of visibility, and the Academy decided to send the astronomer and mathematician Fredrik Mallet from Uppsala to Pello in the Tornedal Valley, and to do other measurements up north as well. Government was approached and immediately granted a substantial sum of money. The Admiralty sponsored Mallet's work and in return the astronomer was to make observations that were of use for ongoing work on sea charts (Nordenmark 1946, pp. 69–79).

Mallet, who had the mindset of a misanthropic Enlightenment *philosophe*, was eaten alive by mosquitoes and complained bitterly about the lack of female company during his year-and-a-half-long expedition. A further aggravation was that he frequently had to associate with Caps, that is political opponents of the Hats, when socializing with the locals in the horrid northern towns he passed through in the course of the expedition. Judging from letters, his mind during the expedition was constantly occupied with thoughts about politics, economy, sex, and science.

Eventually the expedition was a failure, as Venus was hidden by clouds. "I eat my heart out every time I think about the horrible night that I experienced in Pello between June 3 and 4", Mallet wrote to a friend, asking: "Is it wrong to be a little crazy in one's zeal for one's science" (Heyman 1938, p. 284). Mallet apparently thought so and decided to give up astronomy altogether and instead take up a position as principal at a school in Uppsala: "the good salary and the wicked Venus being my foremost incentives" (Heyman 1938, p. 285). He calculated that the salary for the school job would be three times higher than his salary as astronomer at the Uppsala observatory. Furthermore he would be his own boss at the school, which he clearly was not at the observatory, where the professor of astronomy had higher rank as well as salary.

This was not a complaint that reflected on his personal relationship with the professor of astronomy, Daniel Melanderhielm, who was also participating in the collective effort to observe Venus and analyze data and who, like Mallet, was more of a mathematician than a practical astronomer. The two were close friends and Melanderhielm actually saw to it, using political influence, that Mallet got a professor's salary. So he decided to stay on at the university, eventually becoming professor of mathematics, but never ceasing to complain.

4. A distant mirror

I have talked about research policy in Enlightenment Sweden as being founded on a harmonious relationship between political and scientific elites that was reflected in a mutual determination to develop utilitarian science and in a more general commitment to rationalistic ideals. Astronomy in this period has been described as a success story with two new observatories being built, with successful participation in international project like the transit-of-Venus observations, and with a broader international integration through extensive correspondence, international publication and general scientific prominence. Much of the latter had to do with Wargentin. Pehr Wargentin was an assiduous correspondent with a wide national and international network where he exercised his organizational skill and diplomatic genius concerning a wide spectrum of scientific issues, not least his own specialty, to collect and systematize observations regarding the moons of Jupiter. He was the only Swede to appear in Jean-Baptiste-Joseph Delambre's authoritative History of eighteenth-century astronomy from 1827, a measure of his networking capabilities as much as his scientific importance (Delambre 1827, pp. 543–547).

Wargentin was the foremost astronomical practitioner in Sweden in the generation after Celsius but there were others that were competent enough and who loyally heeded Wargentin's call when he asked them to participate in international collaborations. Virtually all of them helped make Swedish participation in the Venus transit observation project a relative success: Nils Schenmark in Lund; Fredrik Mallet, Mårten Strömer, Samuel Klingenstierna, and Daniel Melanderhielm in Uppsala; Anders Planman in Åbo (Turku). As we have seen, the public show staged at the observatory in Stockholm in connection with the 1761 transit may be seen as a symbolic display of concord between scientific and political elites and a promise of further political support for scientific expansion by the Hat establishment.

Academic science was unusually strong in mid eighteenth-century Sweden. Unlike in countries where the scientific revolution had come earlier, professors constituted the scientific elite at the Stockholm academy. Hence for a while it seemed as if science in Sweden was heading towards professionalization – in the sense we associate with the German research university – already by 1750. Scientific institutions were being built, though on a smaller scale than in the following century, and the Academy constituted a dynamic link between the progressive fraction of the professoriate and the urban political and economic elites of the capital. The Hat government even went so far as to suggest, in 1750, a complete reorganization of the university that would have transformed it into a kind of polytechnic, and they imagined that advanced scientific development could safely be carried out under the auspices of the Stockholm Academy (Segerstedt 1971).

But already by 1761 the power of the Hats had been weakened and during the 1760s it would diminish further; academic science had likewise begun loosing momentum by 1770 (Johannisson 1980). As a matter of fact the academic job market was never particularly secure and scientific specialists tended to leave the university if given a chance. Mårten Strömer, who succeeded Celsius, left for a navigation school; Klingenstierna as well as another Uppsala scientist left for the court in the mid-1750s; Lexell got a position in St Petersburg; Melanderhielm took on a commission to write text books for the military; Wargentin and Mallet married money; a few others were privately wealthy; a couple especially successful professors – Linnaeus and the chemist Torbern Bergman – were enticed to stay on by being offered extra-high salary. When Wargentin's wife died in 1769 after a miscarriage her fortune was gone and Wargentin actually had to borrow money from the Academy in order to pay burial costs. The Academy thereafter raised his salary; he was the one scientist they could not afford to loose (Widmalm 1990, ch. 12).

Enlightenment research policy was co-produced as well as co-destroyed with the Hat regime and with the Swedish parliamentary system, that was overthrown by the autocratic Gustav III in 1772. Mallet wrote to Wargentin in 1781 that they had both consumed all of the money they had gotten through marriage and that his only hope now was to die: "How can one believe, that ruin and despair afflict such valuable and arduous sciences?" (Widmalm 1990, p. 175). A few years earlier Melanderhielm wrote the following to a friend about the awful state of mathematical science in Sweden (Widmalm 1990, p. 175):

> I have now worked 40 years on this science; for this I have been honored abroad whereas for all my work on this science my salary does not even pay for clothes and daily bread. If I hadn't had some money of my own I had already been a great wretch, living in debt and poverty like most of my friends here. [—] I have during my years of service here in Uppsala brought forth and created more mathematicians than have been produced since the foundation of the academy (i.e., the Uppsala University). Some of these are still, at an advanced age, floating like water around rocks. I therefore find that I have not done them a great service by coaxing them [. . .] to stick to this science.

Astronomy and other mathematical sciences were now in decline and would not reach, or rather regain, academic maturity until the second half of the 19th century, with the general adoption of the German university system including academic professionalization and institutionalization. Hence, though an expansive research policy was taking shape and steps towards scientific professionalization were made in Sweden during the Enlightenment, these tendencies would not outlast the political system that sustained them. The successful Swedish contribution to the international efforts to measure the transits of Venus in 1761 and 1769 depended on the ambition and skill of Wargentin and his colleagues as well as on political support. With the political changes around 1770, the Enlightenment social contract for science in Sweden was however broken.

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Transit Observations as Means to Re-establish the Reputation of the Russian Academy of Sciences

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Abstract. This paper explores how Catherine II used the worldwide attention given to observations of the transit of Venus to bring back the Russian Academy of Sciences into international recognition. Starting from the planned observations of the transit of Venus at various locations of the Russian Empire, the expeditions became more complex because naturalists were added to the astronomical expeditions. As the naturalists got separate instructions, their expeditions became more and more independent of the astronomers and eventually became known as the famous Academic Expeditions with a tremendous output of publications. This was the second huge effort made by Russia during the eighteenth century to explore scientifically remote parts of its empire.

As far as individual Venus transit expeditions are concerned, this paper focuses on those that visited places in the southern parts of the Ural Mountains and the northern shores of the Caspian Sea.

1. Russia and the 1761 transit of Venus

When the calculated date of the first transit of Venus of the eighteenth century approached (June 6, 1761), the Russian Imperial Academy of Sciences (Fig. 1) was in a difficult situation. With the beginning of the reign of Elisabeth Petrovna (Tsarina 1741–1761) and her "pro-Russian" policies, open suspicion was cast on foreign scholars as possible clandestine informers of various Western powers, and the decline of the Academy began. Many of the non-Russian scholars left the country and the Academy's scientific achievements and number of publications were poor. Meanwhile, many conflicts between the remaining scholars disturbed the work in the Academy. When Peter I had founded the Academy in 1724, he had entrusted to it an important political and diplomatic role: the Academy should prove to the West that the Russians were not barbarians, were not lacking in appreciation of the intellectual accomplishments of modern Europe, and had contributions of their own to make. This was the reason why the Russian government and academic authorities were alarmed when reports from diplomatic posts began to indicate how widely known was the plight of the Academy in Western Europe (Vucinich 1963, p. 86). This was the case during the last years of the reign of Elisabeth Petrovna when the transit of 1761 approached, and there were no plans to send out major expeditions to observe the transit.

At first there were no special Russian activities at all, but then when France decided to send an observer to Siberia, the Russian Academy promised some support and allowed the foreign astronomer to travel through the country.

The French *Académie des Sciences* decided to send the astronomer Abbé Jean-Baptiste Chappe d'Auteroche to Siberia to observe the transit of Venus. Chappe d'Auteroche had already some experience because he had observed the transit of Mercury in the year 1753 from the observatory in Paris. Tobolsk was at the time the capital of Western Siberia. This place was chosen as location for the observation

Figure 1. The *Kunstkamera* in Saint Petersburg, formerly the main building of the Imperial (Russian) Academy of Sciences (founded 1724), with the observatory tower on top of it. Photo: Per Pippin Aspaas.

because there the duration of the transit would be the shortest observable in 1761. And according to Halley's method of durations, this would be an important location for the observations.[1]

The fact that the French astronomer was on his way to Russia for the transit observation also kindled Russian activities. While waiting for him to arrive in St. Petersburg two Russian observers were sent to different places in Siberia to watch the transit of 1761. These were Nikita Ivanovich Popov (1720–1782) and Stepan Iakovlevich Rumovskii (1734–1812). Popov traveled to Irkutsk and Rumovskii should have gone to Nerchinsk. But he stopped in Selenginsk about 600 to 700 km further west, which is – taking in consideration the vast distances within Siberia – not such a big difference. But a disadvantage of his choice was that it was not very far away from Irkutsk. The results of Popov's observations were not published and it is not quite clear whether they were successful or not. Rumovskii's report was not included in the official *Novi Commentarii* of the Russian Academy until six years after the transit (Aspaas 2012, p. 229).

Chappe d'Auteroche made excellent observations in Tobolsk. He published his results already the next winter when he visited St. Petersburg during his return voyage (Chappe 1762). The oral version was presented on January 8 during the session of the Academy and he sent a copy to Paris where it was read on May 5, 1762. In addition to this publication, his results had been sent already in manuscript form to the Académie des Sciences in Paris, because the mathematicians were eager to get the data as quickly as possible to start their time-consuming and complicated calculations. During the winter 1761/1762 Chappe was offered to stay in St. Petersburg and to take over the position the astronomer and geographer Joseph Nicolas Delisle

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[1] That is why Chappe d'Auteroche was eager to reach this place even though he nearly ran out of time, arriving in Saint Petersburg in February and reaching his destination as the winter roads were melting in late April (Chappe 2004). In Russia, traveling took place either on sledge on the snow or along the rivers in the summer season.

used to have while he was in Russia. But Chappe did not want so stay in Russia and returned to Paris in spring 1762.

In addition to these observations in Siberia, several scholars had observed the transit from their private homes in St. Petersburg or from the observatory of the Academy. The most famed of them was Michail Vasil'evich Lomonosov. Decades later, he became famous for his description and interpretation of the luminous ring around Venus shortly before she entered the Sun entirely. Lomonosov also discussed the phenomenon of the so called black drop (Bucher 2011, pp. 102–104). Other scholars who observed from St. Petersburg were Franz Ulrich Theodosius Aepinus (1724–1802) and Joseph Adam Braun (1812–1768). From the observatory of the Academy, Andrei Dmitrievich Krasil'nikov (1705–1772) and Nikolai Gavrilovich Kurganov (1726–1796) made their observations. The results of Braun, Krasil'nikov and Kurganov found their way into the *Ephemerides Astronomicae* of Hell, through which they became available to the international community of astronomers (Aspaas 2012, p. 230).

As a result one can say that Russia took only a weak part in the observations of 1761 compared to other nations like France, Sweden and Great Britain. This changed considerably for the next transit. In the year 1762 Catherine II became Tsarina and she took the opportunity.

2. Catherine II and the 1769 transit of Venus

The transit of Venus was widely discussed in the famous Academies of the world. It was a point of general interest, not only to scholars but also to the highest statesmen. This situation and the high esteem scholars and statesmen had for the event was used by Catherine II to re-establish the reputation of the Academy of Sciences and of Russia in general. There were many prejudices against Russia and these were promoted once more when Chappe d'Auteroche published his travel journal. After he had returned to Paris he started to write his detailed travel account and published it in the year 1768 during the preparations for the observations of the second transit of Venus. The title was *Voyage en Sibérie fait par ordre du roi en 1761, contenant les moeurs, les usages des russes et l'état actuel de cette puissance; la description géographique et le nivellement de la route de Paris à Tobolsk; l'histoire naturelle de la meme route; des observations astronomiques, et des experiences sur l'électricité naturelle, enrichi de cartes géographiques, de plans, de profiles du terrain, de gravures qui représentent les Russes, leurs moeurs, leurs habillements, les divinités des Calmouks, et plusieurs morceaux d'histoire naturelle.* In this account Chappe writes frankly what he disliked in Russia. He openly criticised the bondage-system in Russia and the backwardness of the country. With some detail he describes the times after the death of Elisabeth Petrovna until the enthronement of Peter III, who was Tsar only briefly in 1761/62. Chappe expressed the opinion that art and science were extremely underdeveloped in Russia, and that only non-Russians did good work in the field of science, but even they got worse in the bleak light of the Russian Academy at the time.

Catherine II understandably did not like this account. She made sure that an extensive answer was published in the year 1770 (anonymously) with the title *Antidote, ou examen du mauvais livre superbement imprimé intitulé, Voyage au Sibérie.*[2]

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[2] According to a widespread hypothesis, Catherine II had actually written the *Antidote* herself (see Michel Mervaud's introduction in Chappe 2004, Vol. I, pp. 86–103).

Possibly the bad picture Chappe's book had created of Russia was responsible for the fact that no French astronomer decided to answer Catherine's invitation to come to Russia in 1769 to observe the transit from there.

In 1769 the visibility of the transit would be quite good in many parts of the huge Russian empire, and there were lengthy discussions where to send the observers. There were several places in Russia from where the entire transit would be visible and these locations could be reached by travelling over land. The use of sledges on snow and ice was considered safer and more reliable than sea voyages. In 1761, some observers using ships had failed to reach their destinations in time. Whatever was seen from the deck of a moving ship was useless for the delicate process of calculating the solar parallax, whereas the coordinates of any site on land could be measured accurately. Thanks to the activities of Catherine II the famous Swiss mathematician Leonhard Euler returned to St. Petersburg and she also managed to contract the naturalist Peter Simon Pallas from Berlin. Catherine II became personally involved in the preparations for the transit observations. In a widely circulated letter dated March 3, 1767, she urged the Academic Conference to point out suitable locations for Venus transit observations and to indicate the resources needed to accomplish successful expeditions. The Academic Conference responded by pointing out four suitable sites. However, the Tsarina was not satisfied and promptly doubled the number of Venus transit expeditions, adding at the same time a programme for naturalist expeditions that were partly to accompany the astronomers on their expeditions, partly operate on their own. As for the Venus transit, four destinations were finally singled out on or near the Kola Peninsula (three of which were reached in the end), along with four sites in eastern and southern parts of Russia. In addition, the transit was to be observed from the Academy Observatory in Saint Petersburg (Aspaas 2012, pp. 230–233). Catherine wanted that the observers would have the best and most modern instruments available for their observations. And Catherine II proposed to instruct officers of the Russian navy how to observe the transit, in case there would not be enough astronomers available to achieve the task.

In addition Catherine II decided to follow up the famous achievements of the Academy from 1733–1743 when the scholars of the Academy took part in the Second Kamchatka Expedition and did intense research all over Siberia in different fields, like geography, geodesy, history, archaeology, mineralogy, botany, zoology, cartography, ethnography, statistics. Peter Simon Pallas was entrusted to write instructions for different scientists who had to travel together with the astronomers – and in some regions independently – to do general research in different parts of Siberia. The output of these natural history expeditions was immense. Many monographs were published while the scientists were still traveling. They had to send their manuscripts back home where they were prepared for publication immediately. In the field of ethnography, linguistics and history (including historical biology and geography) these publications have still today a great value for scientific research and are highly estimated as sources.

These natural history expeditions, which came into being as a result of the Venus transit, turned out to be the most lasting outcome of the Russian Venus transit enterprise of 1769 (Mumenthaler 1997). On the longer term, it was the output of these surveys of the natural history of Russia that fulfilled Catherine's aim and helped improve the international reputation of the Academy. On the shorter term, however, the Russian Venus transit observations and the ensuing calculations of the solar parallax were equally important (see Stén & Aspaas, these Proceedings).

Below, we shall have a look at some of the individuals involved with the Russian-sponsored Venus transit observations in the year 1769.

3. Various Russian-sponsored Venus transit observations in 1769

The Jesuit Christian Mayer (1719–1783), professor of mathematics and experimental physics in Heidelberg and astronomer royal of the elector Karl Theodor in Mannheim followed the invitation to Russia and observed from St. Petersburg. He had observed the transit of 1761 in Schwetzingen in Germany, therefore he was regarded as an experienced observer. He arrived quite late on May 7 in St. Petersburg and had brought his own (that means the elector's) instruments with him. First this had caused irritations because he needed more money than planned for the transport of the instruments, but it turned out that it was a wise decision to have brought own instruments, because the newly ordered instruments had been given to the astronomers going on expedition and the instruments in the observatory in St. Petersburg were in bad shape or entirely broken and therefore could not be used. And he was lucky to have gone to St. Petersburg because the observations in Schwetzingen failed this time due to thick clouds. Mayer observed the transit together with Gottfried Stahl, Anders Johan Lexell, the above-mentioned Krasil'nikov and Johann Albrecht Euler. Shortly afterwards they also documented an eclipse of the Sun; all with fine weather conditions. Catherine II watched the transit herself from her summer residence near Oranienbaum (Moutchnik 2006).

In the southern part of Russia Orenburg and Orsk in the Ural Mountains and Gur'ev at the northern shore of the Caspian Sea were chosen as locations for the transit observations. Wolfgang Ludwig Krafft, Professor of astronomy in St. Petersburg from 1767 traveled together with Christoph Euler (son of Leonhard Euler) to Orenburg. Krafft stayed there whereas Euler continued to Orsk.

Georg Moritz Lowitz (1722–1774) used to be the director of the observatory in Göttingen before he went to Russia. He was appointed professor of astronomy in the Russian Academy in the year 1767. He traveled together with the Russian adjunct P. B. Inochods'ev to Gur'ev. The results of Lowitz's excellent observations were published 1770 in German *Auszug aus den Beobachtungen welche zu Gurjef bey Gelegenheit des Durchgangs der Venus overbey der Sonnenscheibe angestellt worden sind durch Georg Moritz Lowitz, Professor und Mitglied der Kayserlichen Akademie der Wissenschaften zu St. Petersburg.*

At length he describes the problems he faced while preparing for the observation. But he also mentions that he got a lot of help from the officials to protect his observatory. Even the cattle was not allowed on their normal pasture near the observatory the day of the transit to minimize any disturbances of the observations. He also included a comparison he had made with Inochods'ev regarding the pendulum clocks they had brought with them, one was from France, the other one from England.

The southern expeditions are a good example of what happened generally with the transit observations in the eighteenth century. The focus was not only on the transit observations, once an astronomer had reached far off destinations he was asked to do more general examinations. And many of the expeditions had a huge output in natural history, geology, hydrology and ethnography. The transit expeditions largely contributed to the augmentation of general knowledge in the eighteenth century.

4. The outcome: The Russian Academy's reputation re-established

This was the same with the Russian transit observations. Not only that the natural history part – with Peter Simon Pallas as a leading figure – was added to the transit observations of 1769 also the astronomers at various stations got additional tasks. They had to do cartography and they collected data for the geographical department of the Academy in St. Petersburg. In addition, Euler and Inochods'ev were involved in prospection work for the planned channel from the river Don to the river Volga. But some of the scholars had to face severe conditions and got in political trouble. Lowitz was murdered by rebels of the Pugachev uprising. This and other unlucky incidents were the reason for the termination of the Academic Expeditions in the year 1774. But at least five years after the transit observations the scientists were still in the field and at work for the glory of the Academy.

One can conclude that Catherine II was successful in re-establishing the reputation of the Academy using the transit observations as a starting point. Once the focus was on the expeditions, it were the extensions that made them valuable at the time and even today.

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Denmark–Norway, 1761–1769: Two Missed Opportunities?

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Abstract. Despite a promising start in the sixteenth and seventeenth centuries, Denmark–Norway was not a Great Power of Astronomy any longer when the eighteenth-century transits of Venus occurred. Official activity relating to the transit of 1761 was very limited; in this respect, Denmark–Norway was completely overshadowed by Sweden and Russia. In 1769 steps were taken to invite an astronomer of international reputation, the Jesuit Father Maximilianus Hell. He arrived in 1768 and left the country two years later, having published an elaborate report in the name of the King Christian VII. Although Hell's observations from Vardøhus were successful, Denmark–Norway failed to re-establish itself as a country capable of delivering noteworthy contributions to the European community of astronomers. Sweden and Russia displayed a higher level of activity, both quantitatively and qualitatively, making the impression of Denmark–Norway's lagging behind even stronger.

1. Introduction

Throughout the eighteenth century, the northernmost part of Europe was divided between three powers: Denmark–Norway, Sweden, and Russia. They all encompassed territories with very similar advantages as far as the transits of Venus were concerned. However, the history of Venus transit activity in the three countries mentioned is far from uniform. Other contributions to these Proceedings analyze Venus transit activities in Sweden (Widmalm) and Russia (Bucher). There are also case studies on individual astronomers active in these parts (Pekonen, Stén & Aspaas, Voje Johansen, Kontler). This article describes the eighteenth-century Venus transit enterprise of Denmark–Norway as a whole, with side-glances at its neighboring countries.[1]

In the middle of the eighteenth century, the *Runde Tårn* (or Round Tower, *Turris rotunda*) in the center of Copenhagen epitomized Denmark's proud traditions in astronomy (Fig. 1). Inaugurated in 1642, the Round Tower antedated all major observatories of Europe. Even the famous observatories of Paris (functioning since 1671) and Greenwich (1676), not to speak of Saint Petersburg (1727), Uppsala (1741) and Stockholm (1753) were far younger institutions. At an even earlier date, Denmark had been the host of Tycho Brahe, whose observations from the island of Hven (now Ven) had served as foundations for Kepler's Laws. However, for all its glorious past, the reputation of Danish–Norwegian astronomy had dropped considerably by the time of the transits of Venus.

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[1] This paper is in essence a shorter version of materials that have already been presented in my doctoral thesis, which is freely available as a PDF file on the internet. Unless otherwise stated, Aspaas (2012) serves as an implicit reference throughout this article. Reference to primary sources and literature has deliberately been kept to a minimum.

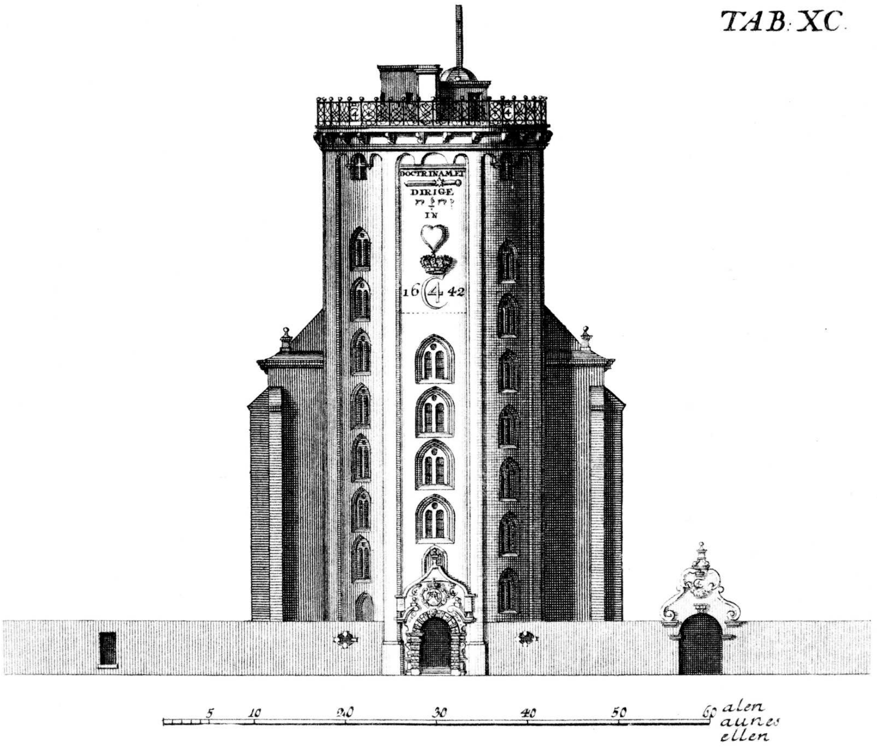

Figure 1. Copenhagen's *Runde Tårn*, erected in the 1640s. Christian Horrebow presided over observations from this tower in 1761 and 1769. From Laurids de Thurah, *Hafnia hodierna* (1748), Wikimedia Commons.

2. The Moltke–Bernstorff–Thott Triumvirate and the Horrebow Clan

During the first half of the eighteenth century, the Kingdom of Denmark and Norway had undergone a gradual "transformation from a personal to a bureaucratic absolutism" (Barton 1986, p. 28). In the run-up to the Venus transit of 1761, all major decision making in Copenhagen involved the head of the German Chancellery (i.e., ministry of foreign affairs) and *de facto* prime minister Baron Johan Hartwig Ernst Bernstorff and the favorite of King Frederik V (ruler 1746–1766), Overhofmarskalk (lord chamberlain) Count Adam Gottlob Moltke. Formally, the minister Count Johan Ludvig Holstein (1694–1763) presided over the entire field of education, science and church affairs in the Kingdom. Among his many offices, Holstein held the Presidency of the Royal Danish Society of Sciences (founded 1742), whose assemblies were held at his residence (Lomholt 1942). By the year 1761, however, Holstein had passed his zenith. Neither he, nor the other high-level decision makers appears to have perceived the importance of the 1761 transit of Venus before too late.

That is not to say that the natural sciences were not cultivated in Denmark at the time. Sumptuous projects including an illustrated inventory of all plants growing in the Danish–Norwegian Kingdom (the *Flora Danica* project) and general land surveys (of Denmark proper, Iceland and the border between Norway and Sweden), were begun under the supervision of Copenhagen's Royal Society in this period. Moreover, in January 1761, a Danish-sponsored team headed by a naturalist (Peter Forsskål), an expert on oriental languages (Frederik Christian von Haven) and a surveyor (Carsten Niebuhr), set out to undertake a grandiose expedition to *Arabia felix* (present-day Yemen and its surroundings). Nearly all participants perished; Niebuhr returned as the sole surviving scientist in 1767. Among the many tasks allotted to the *Arabia felix* expedition were observations of the Venus transit. These failed, however, as the ship was in the middle of the Mediterranean when the transit took place. Another, more modest expedition to Trondheim in Norway will be described below.

By the ascendancy of the young Christian VII in 1766, the responsibility for education, science and church affairs had passed onto the hands of Count Otto Thott (1703–1785), who served as the head of the Danish Chancellery (ministry of the interior) from 1763. The Danish Society of Sciences from now on held its assemblies at Thott's residence. "He was everything but a man of initiative", a biographer of his concludes.[2] All the same, in collaboration with Bernstorff and Moltke, Count Thott did try to use the Venus transit of 1769 as a means to bolster Danish–Norwegian reputation in astronomy. The "Moltke–Bernstorff–Thott Triumvirate" was short-lived, however. King Christian VII soon lapsed into the mentally ill and dysfunctional marionette of influential characters at court. Moltke, Bernstorff and Thott found themselves in a precarious position; by the time the royal physician Johann Friedrich Struensee seized power (from December 1770 to January 1772), they had all been stripped of political power. Whatever increase in astronomical activity that took place in conjunction with the transit of 1769, was put to a halt due to Struensee's coup.

Academic clans are a well known phenomenon in the history of science. Historians of early-modern astronomy will be familiar with the "Cassini clan", consisting of four generations of fathers and sons that led the *Observatoire de Paris* from 1671 to 1793. A less conspicuous example is the "Horrebow clan" in Copenhagen. Peder Horrebow the Elder (1679–1764) served as Astronomer Royal and director of the Round Tower from 1714 to 1753. He then retired to let one of his sons, professor Christian Horrebow (1718–1776) inherit this post. When Christian died, his brother Peder Horrebow the Younger (1728–1812) briefly kept the title until he was forced to retire with a generous pension in 1778. The history of the eighteenth-century transits of Venus in Denmark–Norway is neatly bound up with the Horrebow clan, and with Christian Horrebow in particular.

3. Denmark–Norway, 1761: the observations

Christian Horrebow, along with Peder the Younger, presided over the observations of the 1761 transit from the Round Tower. The weather was good, and the egress (end stage) was distinctly visible from Copenhagen in the morning hours of June 6, 1761. According to the historically oriented astronomer Axel Vilfred Nielsen, who has investigated the official report on the Horrebow brothers' observations, the two did well with the equipment they had (Nielsen 1957). However, eighteenth-century astronomy was about more than actual skills in observing and calculating. Equally important was the ability to position oneself on the map of the European Republic of Letters. Astronomers lived of "corresponding observations", as they were called. They exchanged data sets, they catered for collaboration, they engaged in "networking" on a transnational level (Widmalm 1992). This is where the Horrebows failed.

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[2] "Initiativets Mand var han mindst af alt." (Holm 1903, p. 338).

In the run-up to 1761, the Horrebows' attention seems to have been fixed on the Round Tower alone. Nor were they particularly eager to disseminate knowledge on the phenomenon. Although a member of the Royal Society of Sciences, Christian Horrebow delivered no speech on this long-awaited event. It was Christian Gottlieb Kratzenstein (1723–1795), a German-born professor of medicine and experimental physics that had been recruited to Copenhagen University in 1753, who presented that speech.[3] In the printed version of his lecture, Kratzenstein displays a keen awareness of the global dimensions of the Venus transit (Kratzenstein 1765). Furthermore, perceiving the potential of the Kingdom's northern territories to provide valuable data for the calculation of the solar parallax, he took the initiative to dispatch two students from the university, Thomas Bugge (1740–1815) and Urban Bruun Aaskow (1742–1806), to Trondheim in the middle part of Norway. They arrived in time, but had their observations partly spoiled by bad weather. A summary account of their expedition was published in the *Mémoires* of the *Académie des Sciences* of Paris (Lalande 1763). Despite his young age, Bugge was already a veteran of the survey of Denmark, where he had acquired a keen knowledge of practical astronomy. He was later to emerge as the Astronomer Royal and director of the Round Tower, and proved himself to be a man with good technical as well as networking capabilities. Little is known about further attempts to observe the 1761 transit in Denmark–Norway. A surveyor engaged for the boundary surveying of Sweden and Norway, Jørgen Nicolai Holm (1727–1769) happened to observe the transit from somewhere in Trondheim independently from Bugge and Aaskow. Holm kept a low profile; his observation was only mentioned anonymously as "from a private letter" in an article in the *Philosophical Transactions* of the Royal Society of London (Short 1763). Another surveyor, Christopher Hammer (1720–1804) observed from his private home at Hadeland in southern Norway, seemingly without publishing his report on the observation (Aspaas 2011).

Scientific publications were all-important then as now. However, despite the existence of a periodical with printed Transactions (*Skrifter*) of the Royal Danish Society of Sciences, no effort was made to collect and publish whatever observations were made throughout the Kingdom. As a result, Denmark–Norway came out with a very poor contribution in terms of the number and geographical distribution of its observers. In this sense, it was completely overshadowed by its eastern neighbors Sweden and Russia.

In 1761, Sweden could boast of 25 individual observations from nine sites widely distributed over Sweden (including modern Finland). Two of these sites were located in northern parts of the kingdom, where the entire duration of the transit had been visible. Russia had delivered a handful of observations from Saint Petersburg and organized two expeditions into Siberia, in addition to the French-sponsored expedition of Chappe d'Auteroche. Denmark–Norway's contribution consisted in two dubious reports from Trondheim and one not very impressive observation from the Round Tower. Given Horrebow's non-communicative mode of behavior, his reputation abroad was far lower than his Swedish counterpart Wargentin. Little wonder that the secretary of the *Académie des Sciences* of Paris wrote of the coming transit with barely concealed scepticism (de Fouchy 1762, p. 106):[4]

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[3] Kratzenstein was also the one who had instructed Niebuhr to attempt to observe the transit from "Arabia felix" (see above).

[4] "The King of Denmark, who has likewise demonstrated his sense for the sciences by dispatching astronomers to Norway to observe the transit of 1761, will be in a position to provide us with the same advantage as Russia, if there are, in his Estates, Observers sufficiently experienced, and

> Le roi de Danemarck qui a signalé de même son goût pour les Sciences, en envoyant des Astronomes en Norvège pour le passage de 1761, sera à portée de nous procurer le même avantage que la Russie, s'il se trouve dans ses États des Observateurs assez bien exercés, & munis d'assez bons instrumens pour faire cette grande observation avec une précision suffisante.

4. Denmark–Norway, 1769: the observations

The transit of 1769 was set to take place during the middle of the European night, giving Denmark–Norway, Sweden and Russia obvious advantages because of the Midnight Sun. Early in the year 1767, the scientific academies of Sweden and Russia both positioned themselves by securing funding for expeditions to the High North as well as the East (in Russia's case). Profiled academics from the *Académie des Sciences* in Paris and the Royal Society of London pointed to far-northern Norway as an ideal region for observations. In this situation, Moltke, Bernstorff and Thott took action. First and foremost, they made sure that the Imperial and Royal Astronomer of Vienna, the Jesuit Maximilianus Hell (1720–1792) was invited to undertake an expedition to Vardøhus (now Vardø) in the northeasternmost part of the Kingdom. Secondly, they tried to mobilize various able astronomers to undertake similar expeditions to secure a broader participation than the expedition of Father Hell.

As a result, the above-mentioned Kratzenstein went to Trondheim on a private mission to observe the transit. His attempt failed due to bad weather, however. The same fate befell Peder Horrebow the Younger and his assistant Ole Nicolai Bützow (1742–1794), who traveled northwards from Copenhagen in the winter 1768/1769 with the intention of reaching Tromsø. However, they only made it to Dønnes, where the weather was bad during both ingress and egress. The surveyor Holm planned this time to go to Alta in Finnmark, but died suddenly in April 1769. Further observations were made from several locations in the south of Norway, Denmark (including the Round Tower) and Danish possessions in present-day North Germany, but for unknown reasons these were never published. The lack of interest in communication that characterizes Christian Horrebow's career may have been influential here. Or it may be the case that the chaotic situation in the government hindered attempts at systematizing and publishing Venus transit observations. Be that as it may, in terms of publication Denmark–Norway could boast of no more than one single Venus transit observation from 1769: that of Hell and his assistants at Vardøhus.

Again, the contrast to Sweden and Russia was stark. Sweden's participation remained at the same high level as the previous occasion. 18 individual observations from seven sites were published in the Royal Swedish Academy's Transactions (*Handlingar*) in 1769. In the northern parts of the Realm, where the entire transit would have been visible if it were not for clouds, Sweden had manned three stations. Only one of these far northern stations (Cajaneborg, now Kajaani) had a certain degree of success with the weather. The publicity of all Swedish activity was kept very high, however. It is hardly an exaggeration to say that Sweden set all this activity in

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equipped with instruments of sufficient quality to make this grand observation with adequate precision."

motion – and published the reports promptly both at home and in summaries abroad – thanks to the extraordinary networking capabilities of Pehr Wilhelm Wargentin.

In Russia, Catherine II had taken over the power and persuaded the respected mathematician Leonhard Euler to return to the Imperial Academy of Sciences. His oldest son, Johann Albrecht Euler became the secretary of the Academy. Along with other prominent members of this institution they developed an impressive programme for observations of the transit throughout the Russian Empire. The Kola Peninsula was considered particularly important. Of the four expeditions to this area not far from Vardøhus, only three reached their intended destination. At one of the sites (Kola town) a team of Russian astronomers actually managed to record the entire transit, but only through a layer of cloud. Like in Sweden, the publicity surrounding the Russian expeditions was kept very high; reports were printed and distributed throughout the Republic of Letters as soon as the data sets reached the capital. Nonetheless, Denmark–Norway managed to keep the astronomical community in suspense: rumors had it that the weather in Vardø had been good and that Father Hell had made excellent observations. But where were these data?

5. A Jesuit in the service of a Lutheran Court

It is a paradox that a Lutheran Kingdom recruited a Catholic to undertake this prestigious expedition on His Majesty's behalf, especially since the laws of the Monarchy forbade the presence of Jesuits.[5] Maximilianus Hell had other assets, however. Denmark–Norway needed to recruit an astronomer of international reputation from abroad, but not just from any nation. A French or a British astronomer would all too easily be reckoned as a representative of those Great Powers. That might put the already dubious reputation of Danish–Norwegian astronomy at risk. A Jesuit would be more likely to remain loyal to his sponsor. And as for international reputation, Father Hell was the editor of the widely distributed *Ephemerides Astronomicae ad Meridianum Vindobonensem* – an almanac/journal with articles on astronomy and related topics. In 1761, he had coordinated observations from the Habsburg territories and produced a lengthy report summarizing observations from all over Europe, a strong manifestation of how well connected he was.

Maximilianus Hell was presented with the invitation from the Danish ambassador to Vienna in September 1767. He immediately said yes. As soon as the necessary permissions had been granted by the Viennese rulers as well as the General of the Society of Jesus, all was set for an ambitious expedition. Maximilianus Hell prepared himself for an encyclopedic programme, where a whole range of scientific questions pertaining to the High North were to be placed under scrutiny. Among these were a new method to determine the shape of the Earth by means of barometers; the ebb and flow of the tides; the refraction of the atmosphere in the High North; the declination of the magnetic needle from true north; the cause and nature of the Aurora Borealis; the language and customs of the Samis (see Kontler, these Proceedings; Lynne Hansen & Aspaas 2005; Aspaas 2008).

Father Hell set forth from Vienna in April 1768. At Travemünde in Holstein he met Bernstorff and had an audience with King Christian VII, who was then about to embark on a "tour of Europe". Most of June was spent in Copenhagen, where Moltke was his principal host. Hell also met the notable natural scientists of the capital, such as Niebuhr and Christian Horrebow. The journey continued overland

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[5] Not until 1956 was this paragraph removed from the Constitution of Norway.

via southwestern Sweden and southern Norway to Trondheim, where they arrived in late July. In this city there flourished a young Society of Sciences centered around the Bishop Johann Ernst Gunnerus. Although no astronomer lived in the city, other forms of collaboration with the expedition were initiated. Notably, Hell got the Bishop's *amanuensis*, Jens Finne Borchgrevink (1737–1819), a former student of Carl von Linné (Linnaeus), attached to the company (Voje Johansen 2004). Along with Borchgrevink and Joannes Sajnovics, who had accompanied him all the way from Vienna, Hell sailed north to Vardøhus in the autumn, reaching his destination after seven weeks at sea, in October 1768. Then began the construction of the first state-funded observatory on Norwegian soil (Fig. 2). It was ready by Christmas, and the ambitious programme of research began. If Father Hell had missed the transit because of bad weather, as so many other crews in the High North of Europe did, he would still have had ample materials to build a reputation as an expert on virtually everything pertaining to this region. But Hell also succeeded to observe the transit of Venus. He returned from Vardøhus with heaps of scientific data, the most prominent of which being the timing of the moments of contact of Venus with the limb of the Sun by the three observers Hell, Sajnovics and Borchgrevink. The return voyage brought them to Copenhagen in October 1769. They now stayed there the entire winter, leaving the country in May 1770.

Little trace of the political problems of contemporary Copenhagen is detectable in the diary and letters written by Hell and Sajnovics during their stay. They paid numerous visits to Thott and presented lectures at the Royal Society of Sciences. Everything suggests that they were met with a collegial, collaborative spirit despite their Jesuit background. Thott is praised throughout. Even Horrebow did what he could to make them feel comfortable. One point proved problematic, however. The publication of Hell's report was delayed. Not until February 1770 it was circulated throughout Europe. This led to suspicions of fraud, an accusation Hell was not freed from until the next transits of Venus had taken place in the nineteenth century.

In an article on Danish scientific expeditions during the eighteenth century, Allan Sortkær points to the importance of the printed book as a symbolic manifestation of

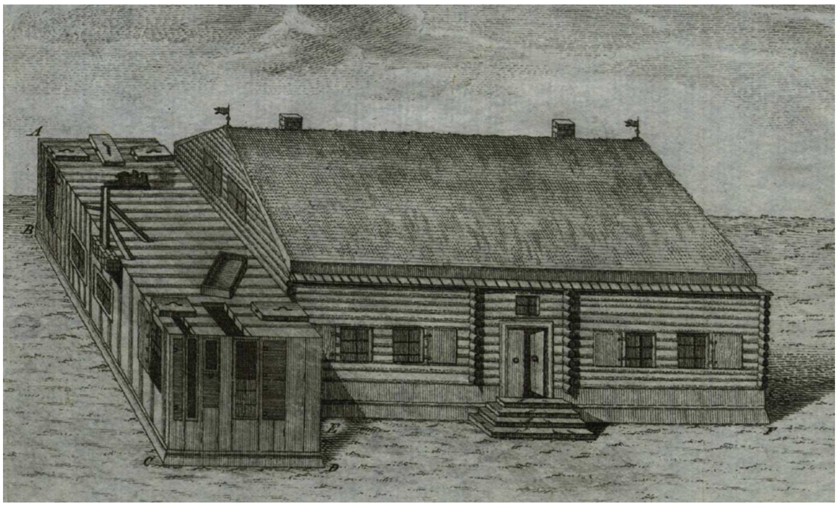
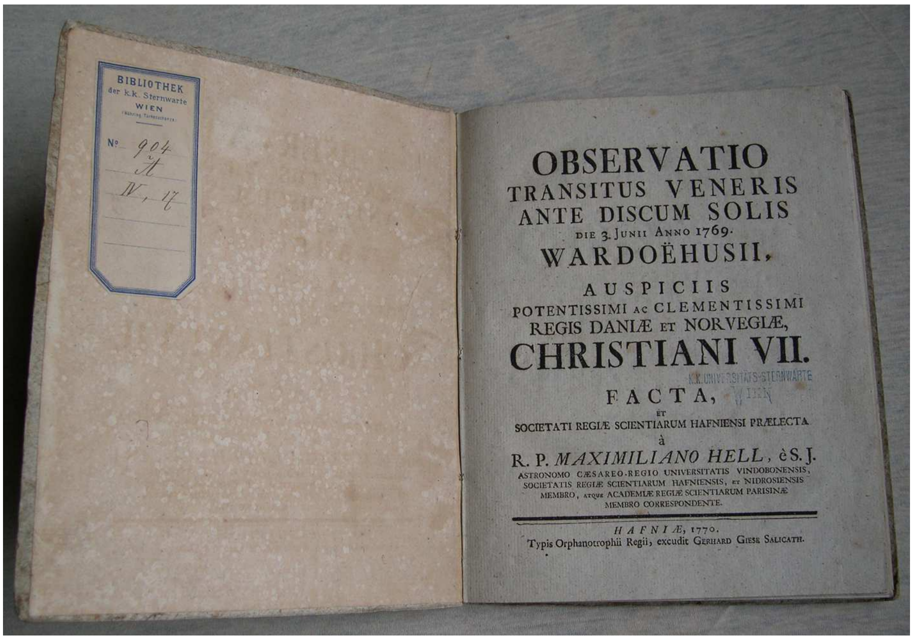


Figure 2. The first state-funded observatory on Norwegian soil was constructed by Maximilianus Hell at Vardøhus. It was built as an annex to the house Hell disposed during his stay on Vardø Island in 1768/69. From Hell's *Ephemerides Astronomicae ad Meridianum Vindobonensem 1791* (1790).

Royal power in the field of science. In a certain sense, a de luxe edition could serve as a replacement for the physical presence of the King. "Without the written word in the book, no event", he concludes.[6] In early modern Europe, royal sponsorship and scientific prestige went hand in hand, with the printed publication as its primary medium.



BIBLIOTHEK
der k.k. Sternwarte
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A
IV, 17

OBSERVATIO
TRANSITUS VENERIS
ANTE DISCUM SOLIS
DIE 3. Junii Anno 1769.
WARDOËHUSII,
AUSPICIIS
POTENTISSIMI ac CLEMENTISSIMI
REGIS DANIÆ et NORVEGIÆ,
CHRISTIANI VII.
FACTA,
ET
SOCIETATI REGIÆ SCIENTIARUM HAFNIENSI PRÆLECTA
à
R. P. *MAXIMILIANO HELL*, è S. J.
ASTRONOMO CÆSAREO-REGIO UNIVERSITATIS VINDOBONENSIS,
SOCIETATIS REGIÆ SCIENTIARUM HAFNIENSIS, et NIDROSIENSIS
MEMBRO, atque ACADEMIÆ REGIÆ SCIENTIARUM PARISINÆ
MEMBRO CORRESPONDENTE.

HAFNIÆ, 1770.
Typis Orphanotrophii Regii, excudit Gerhard Giese Salicath.

K.K. UNIVERSITÄTS-STERNWARTE
WIEN

Figure 3. Title page of Hell's Venus transit report from Vardøhus. The most conspicuous information on the entire page is the name of the King, Christian VII. Photo Per Pippin Aspaas.

The first publication from the Vardøhus expedition was an 80-page report in *grand quarto*, with an impressive title page whose most conspicuous element is the name Christian VII (Fig. 3). The original Latin edition was also translated into Danish and included in the Transactions of the Royal Danish Society of Sciences later in the year 1770. The same volume of the Transactions included a treatise arguing for the existence of a linguistic link between Hungarian and Sami by Hell's assistant Sajnovics (first published separately in Latin) and a series of latitude determinations made by Hell during his journey between Copenhagen and Vardøhus. Noteworthy as well is the call for subscriptions for an even larger work, the three-volume, richly illustrated *Expeditio litteraria ad Polum arcticum*. Although that work would be published in Vienna, not Copenhagen, it would still strongly emphasize the sponsorship of Christian VII – if it had ever been finished. The Society of Jesus was dissolved by the Pope in the summer of 1773, bringing Hell's working pace in disarray. Parts of the *Expeditio litteraria* were, however, published in the *Ephemerides Astronomicae ad Meridianum Vindobonensem* in the years that followed. Most prominent of these are determinations of the solar parallax based on all observations made in the year 1769, and a treatise on the Aurora Borealis (Lynne Hansen & Aspaas 2005).

To trace the rest of the career of Maximilianus Hell up to his death in 1792 would be to exceed the limits of this paper. Suffice it to say that although he found himself

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[6] "Uden det skrevne ord i bogen ingen begivenhed." (Sortkær 2008: 7).

under heavy attack, both scientifically and spiritually after his return to Vienna, he always defended the honor of Denmark–Norway. When confronted with the fact that it took eight months from the Venus transit observation was made until the report was published, he claimed that it was his duty to deliver a printed copy to His Majesty before anyone else was allowed to see his data. As an ex-Jesuit, he remained a staunch defender of conservative Catholicism for the rest of his days, but never changed his opinion about his Lutheran hosts in the north. In this sense, one may conclude that he remained in the service of Denmark–Norway for the rest of his life.

6. Conclusion: two missed opportunities?

The transits of Venus were highlights of eighteenth-century science, attracting attention and funding from all "nations of science". Nor did they pass unnoticed in Denmark–Norway. However, whereas the Swedish Academy of Sciences managed to muster activity in all parts of the country and gain recognition worldwide, Denmark–Norway was left in the backwaters in 1761. Further east, the Russian Academy of Sciences was riddled by internal conflicts in 1761, but still managed to dispatch two expeditions into Siberia to compete with the attention aroused by the French expedition led by Chappe d'Auteroche. By 1769, a major change had taken place in Russia, with a new Tsarina in place and a set of influential academics imported from abroad. The Petersburg Academy now considered the northwestern part of the country especially important, sending four Venus transit expeditions to the Kola Peninsula. Sweden again delivered a strong contribution, with three astronomers stationed in the far north. In this situation, Denmark–Norway invited the court astronomer Maximilianus Hell to observe the transit from the scientifically and strategically important site of Vardøhus. The government was clearly convinced that only by importing an astronomer of international reputation would it be possible to deliver a noteworthy contribution to the quest to determine the solar parallax.

Sven Widmalm argues elsewhere in these Proceedings that mid-eighteenth century Sweden was marked by a development towards professionalisation in the field of science. One may add that alongside this professionalisation there came a useful alliance with persons outside academia, the so-called *dilettanti*. When Wargentin organized the Swedish observations, he welcomed observations by gymnasium teachers, surveyors, military officials and noblemen. These were included in the Transactions (*Handlingar*) alongside the observations from university professors and observatory directors like Wargentin himself. No such alliance is detectable in Denmark–Norway. In 1761, the Astronomer Royal Horrebow did his duty at the Round Tower, but failed to include non-professional observers in the project. Professor Kratzenstein was behind two other attempts to observe the transit – the surveyor Niebuhr's from "Arabia felix" and the students Bugge and Aaskow from Trondheim. The 1769 effort with Maximilianus Hell was again marked by a strong element of elitism. It is not unlikely that the observations of the professors Peder Horrebow the Younger (Dønnes) and Kratzenstein (Trondheim) would have been published, if not bad weather had spoiled their attempts. However, primary sources demonstrate that the egress of the transit was recorded from several places further south, but this data was never presented to the international community of astronomers.[7] Similarly, the ban against sharing the data sets from Vardø until the King had seen them was also in breach with

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[7] For a complete list of known observations of the 1761 and 1769 transits in the Scandinavian countries, see the synoptic paper by Sterken & Aspaas, these Proceedings.

practices followed elsewhere in Europe. As a result, Denmark–Norway was regarded as a country lacking in able astronomers and Maximilianus Hell was suspected of fraud.

In retrospect, Denmark–Norway may indeed be considered to have missed two golden opportunities to rebuild its reputation in astronomy.

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MEETING VENUS
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The Journal of Astronomical Data 19, 1, 2013

The Amateur Astronomer Anders Hellant and the Plight of his Observations of the Transits of Venus in Tornio, 1761 and 1769

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Abstract. Anders Hellant was a versatile Swedish amateur scientist whose figure dominated eighteenth century intellectual life in Tornio, his little home town of some 500 inhabitants at the mouth of the Tornio river.

My study is mainly based on the biographies published in Finnish (Boström 1918) and in Swedish (Tobé 1991) but I have also consulted some original sources in Paris and in Stockholm. Hellant incarnated almost all by himself the inquiring scientific spirit of the Age of Enlightenment in Swedish Lapland. There is much to be said about his life and works, but here I focus on his observations of the Venus passages in 1761 and 1769.

1. A biographical sketch

Anders Hellant (1717–1789) was born on November 30, 1717. His family was in exile from its native Tornio[1] at the Korteniemi manor in Pello, not far from the Arctic Circle, fleeing the atrocities committed by Russian troops that occupied Finland since 1713 during the Great Northern War 1700–1721. His father was the merchant Anders Hellant Sr (1687–1746); his mother Britta Hermansdotter Kempe (1686–1739) who was cousin to Mickel Henriksson Korteniemi, the owner of the famous Korteniemi manor, often qualified as the northernmost guesthouse of the Swedish realm (Fig. 2). Hellant spent most of his life in Tornio, the northernmost town of the kingdom, founded in 1621. Tornio was important as a commercial gateway to Lapland, and also Russian merchants regularly attended its ancient market held in the island of Suensaari. The Hellant family belonged to the Swedish-speaking elite whereas the common people's language was Finnish. Divine services were held in both languages in the two parishes of Tornio.

Hellant received his early education in the school of Tornio, established in 1630. His teacher was Johan Wegelius the Younger (1693–1764), a well-known Pietist leader and at the end of his career the vicar of Oulu. In 1733–1739 Hellant was enrolled as a student of law, economy and mathematics at the University of Uppsala. Among his teachers were the mathematician Samuel Klingenstierna (1698–1765) and the astronomer Anders Celsius (1701–1744); he also interacted somewhat with Carl von Linné (1707–1778) who had made his famous trip to the Tornio river valley in 1732. Hellant was introduced to a wide spectrum of natural sciences but the topic of his bilingual thesis – the first one ever published in economy in both Swedish and

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[1] Tornio is known in Swedish as Torneå, the Tornio river as Torne. We use the Finnish name forms because the town of Tornio (Fig. 1) nowadays is in Finland. Since 1809, the Tornio river forms the boundary between Sweden and Finland but this was not the case in Hellant's lifetime when Finland belonged to the kingdom of Sweden. Culturally and administratively, Tornio was not a part of Lapland, and not even of Finland, before 1809. Rather, it used to belong to the province of Västerbotten. Few Lapps have lived in the area in historical times.

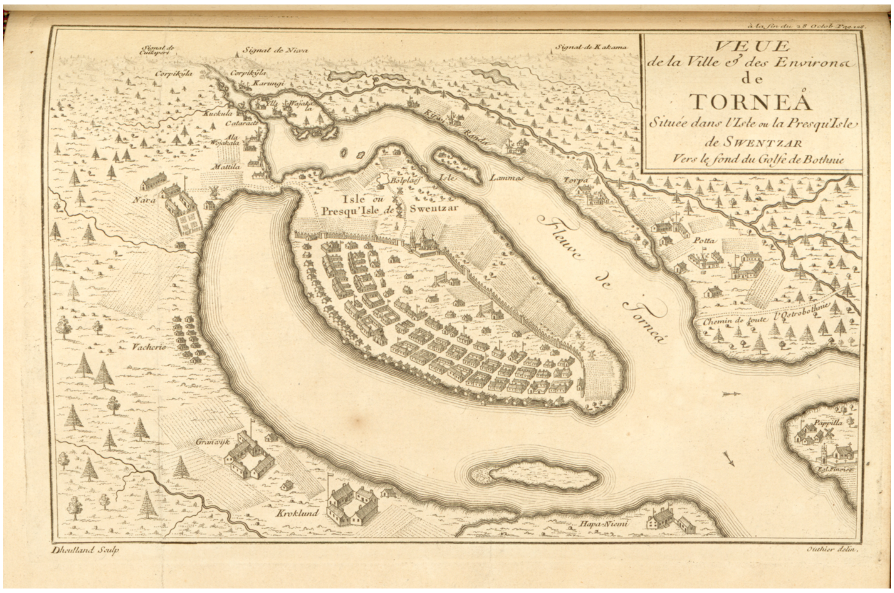

Figure 1. Hellant's home town Tornio as drawn by abbé Réginald Outhier in his *Journal d'un voyage au Nord* (1744).

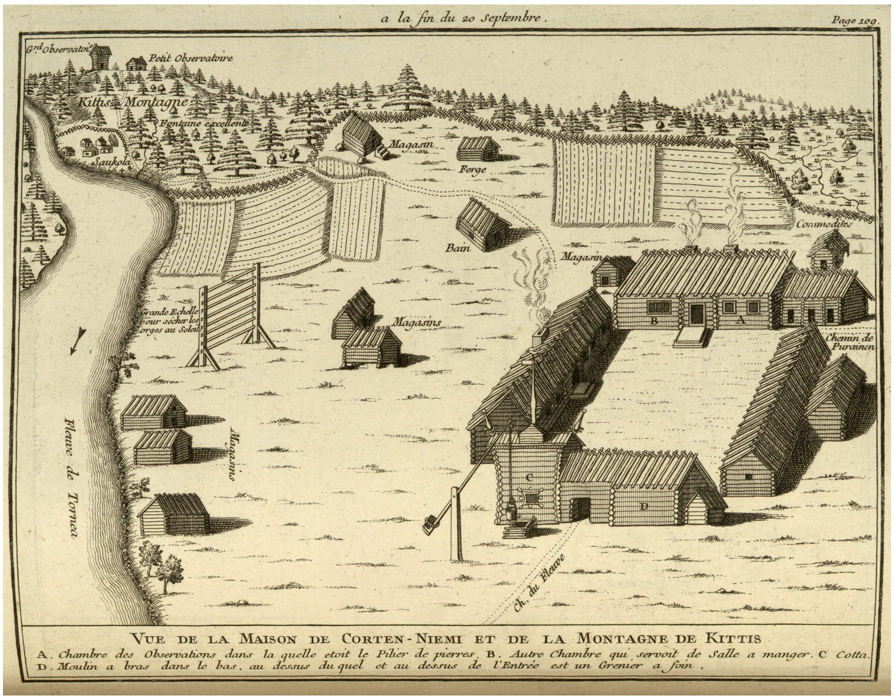

Figure 2. The historical Korteniemi manor, the northernmost inn of Sweden not far from the Arctic Circle, served as a basis of several scientific expeditions to Lapland, including those of Maupertuis in 1736–1737 and of Mallet in 1769. Unfortunately, the buildings were destroyed by the German army in 1944. Drawing by abbé Réginald Outhier in his *Journal d'un voyage au Nord* (1744).

in Latin – was typical of the utilitarian concerns of his epoch: *Et nyt sätt at fiska i the norländska elfwer / De novo in fluviis Norlandiarum piscandi modo.*[2] Hellant had written his thesis himself, which was not the general rule in the eighteenth century. During his student years Hellant also worked as a scribe in the chancellery of Västerbotten province in Umeå.

The determining experience of Hellant's life was his association as a young man in 1736–1737 in the work of the geodetic expedition of Pierre Louis Moreau de Maupertuis (1698–1759) which was dispatched to the Tornio river valley by the *Académie Royale des Sciences* to measure the shape of the Earth. Under Maupertuis' leadership, the expedition included the French academicians Charles Étienne Louis Camus (1699–1768), Alexis Claude Clairaut (1713–1765), Pierre-Charles Le Monnier (1715–1799), abbé Réginald Outhier (1694–1774) and, as a representative of Swedish science, Anders Celsius who had joined the expedition already in France. Hellant spoke some French and served as interpreter and local guide. He also took part in the practical art of land surveying between Tornio and Pello and developed remarkable skills as an amateur scientist. Maupertuis' expedition established its place in the history of science by demonstrating that our globe is slightly flattened around its poles due to its rotational movement, precisely as Newton had predicted (Terrall 2002, Pekonen 2010). Hellant promptly translated Maupertuis' research report into Swedish (Maupertuis 1738).

2. An enlightened economist

Later, for almost half a century, Hellant was one of the most influential persons not only in his native Tornio river valley, but in all of Swedish Lapland. He was nominated as *Oeconomie Directeur* of Lapland, and he had many initiatives to develop Lapland's economic life. However, his attempt to create an industry to extract glue from reindeer horns proved a failure. He also served as district judge of Lapland, and he often traveled for months inspecting the poorly charted Northern possessions of His Majesty the King of Sweden. In 1748–1766, he took part in the work of the Swedish–Danish border commission to establish the frontier between the two kingdoms in Lapland. In this quality, he made several journeys until the Arctic Ocean proceeding until Tana fjord and to the Vardø fortress (Vardøhus). He dreamed of visiting the North Cape but never did so. His visit to Vardø can be qualified as a spying operation because he closely inspected the new fortress achieved in 1738 and deposited a detailed report on its structure to military authorities in Stockholm.

Despite his industrial enterprises and administrative duties, Hellant found leisure to pursue his scientific interests as well. His observations range from astronomy to meteorology, from geomagnetism to *Aurora Borealis*. Field work was a way of life for Hellant. Wherever he traveled in Lapland, he made diligent observations of various natural phenomena. Only a fraction of the data that he collected was ever published.

He understood the relationship of intense Northern lights to deviations of magnetic declination. He also tried to measure by triangulation the height of aurora borealis. A precious set of cryophenological data that Hellant managed to compile is an unbroken sequence of the dates of ice break-up in the river Tornio since 1693 – a unique time series from an arctic river in the world which may serve to demonstrate

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[2] "A new way of fishing in the rivers of Norrland", 1738.

the reality of climate change (Kajander 1993). Hellant also was among the first scientists to measure the slow land uplift of the Western shores of the Gulf of Bothnia. (As a matter of fact, the land uplift also affects the dates of ice break-up.) Lapland at large was the subject of considerable scientific interest in the eighteenth century, especially in France (Pihlaja 2009).

Hellant collected an important private library featuring works of Cassini, Delisle, Euler, Fontenelle, Linné, MacLaurin, Maupertuis, Newton, Voltaire, Wolff, etc. (Tamelander 1941, pp. 166–171). He was musically gifted, playing the flute. He left behind a variety of musical instruments and a large collection of notes.

In 1751 Hellant was elected member of the Royal Swedish Academy of Sciences. He contributed no less than 18 papers for the Transactions (*Handlingar*) of the Academy between 1745 and 1786, and he was in extensive correspondence with Pehr Wilhelm Wargentin (1717–1783), the long-time secretary of the Academy (Fig. 3). Since 1784, he also was a corresponding member of *Musée de Paris*, an esoteric society founded by the mystic Antoine Court de Gébelin (ca.1719–1784).

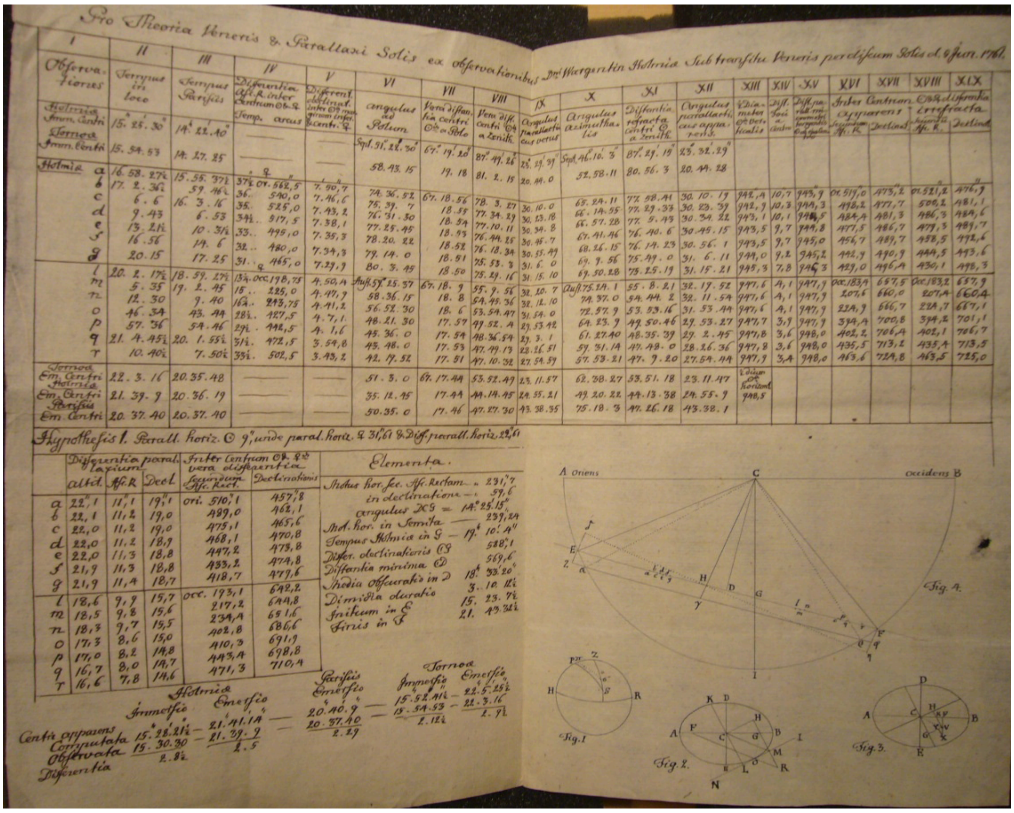

Figure 3. Wargentin's compilation of Swedish Venus observations made in 1761 includes Hellant's data from Tornio. Source: Archives of the Royal Swedish Academy of Sciences, Stockholm. Photo by Johan Stén.

Hellant never married but he had a female house keeper Brigitta Widte who also served as an assistant for his scientific observations. Critical visitors, like the caustic Uppsala-based astronomer Fredrik Mallet (Fig. 4), perceived him as a libertine, a free-thinker and moreover a charlatan in astronomy (Nordenmark 1946, p. 75).

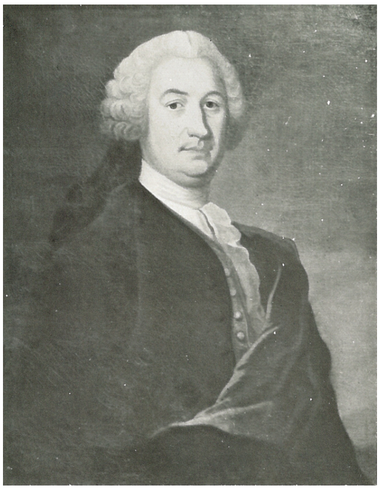

Figure 4. Fredrik Mallet (1728–1797). Oil painting by Arenius (?) in the Observatory of Uppsala.

3. Creation of an observatory

The departing Maupertuis expedition had left Hellant with one of its telescopes, a seven-foot tube. This was the semen of the northernmost permanent observatory of the world, *Observatorium Tornense*, which Hellant established in Tornio (Fig. 5). The Royal Swedish Academy of Sciences appreciated Hellant's activities and supplied additional equipment.

Hellant perceived Observatorium Tornense as a crucial pinnacle of a global observational network in emergence. In 1751, he participated in an international campaign of observations to determine the Moon's parallax from simultaneous observations roughly along the meridian of the Cape of Good Hope where abbé Nicolas Louis de La Caille (Lacaille, 1713–1762) had installed an observatory; as a matter of fact Tornio is six degrees off that meridian. In a letter (dated November 20, 1758) to Count Anders Johan von Höpken (1712–1789), president of the Royal Chancellery, Hellant pleaded, among other concerns, for the creation of similar permanent observatories in the Cape of Good Hope, in South America, and in North America – a dream that has become reality only in modern times.

The first version of Observatorium Tornense was destroyed in the great fire that devastated Tornio in 1762. Hellant rebuilt the observatory in the form of an octagon whose sides measured more than 3 meters.

Hellant edited and printed twice (for the leap years 1744 and 1748) an almanac according to the horizon of Tornio (see Fig. 6). His almanacs did not indicate the Moon's Metonic cycle of 19 years as Hellant did not believe anymore in the Moon's influence on weather.

4. Observations of the Venus passages

The passage of Venus early in the morning of June 6, 1761 was observed in Tornio with four telescopes. Hellant used his own 20-foot telescope whose objective had been prepared by Samuel Klingenstierna and the ocular ground by Carl Lehnberg. Captain Lagerbohm who was reputed to have sharp eyes operated a 32-foot telescope of the Royal Academy that had been constructed by Lehnberg. Bailiff Häggman had an $8\frac{1}{2}$ foot telescope endowed with a micrometer. These three telescopes had a red-brown glass for eye protection. The 7-foot telescope that Maupertuis' expedition had

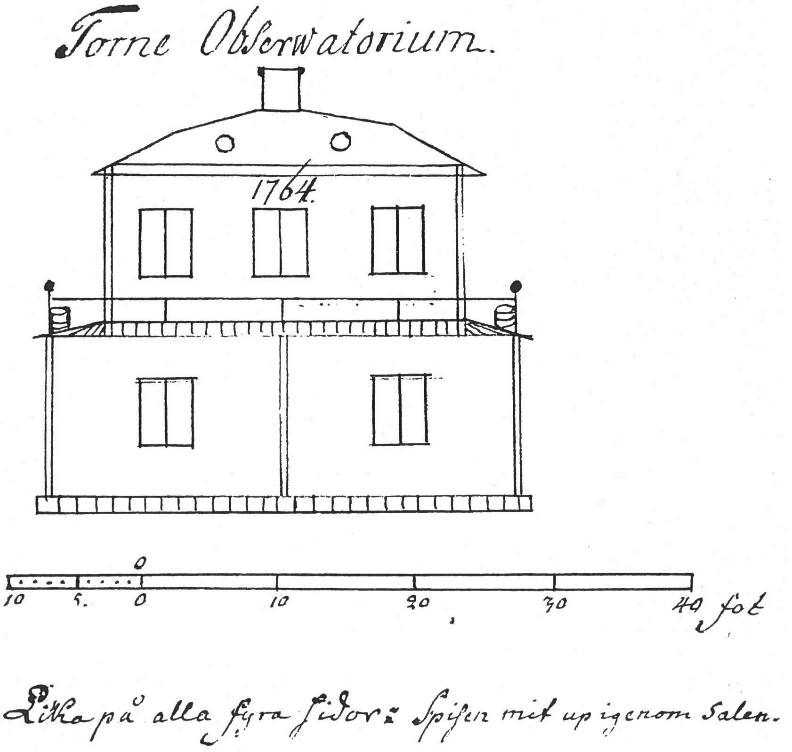

Figure 5. Observatorium Tornense, the world's northernmost permanent observatory in its day, as drawn by Hellant in a letter to Wargentin in 1764. Source: Archives of the Royal Swedish Academy of Sciences, Stockholm.

left to Hellant was operated by merchant Burström and by mine-owner Steinholtz and arranged as a helioscope in a dark room where the transit of Venus could be observed on a white board by the general public. Hellant reports to have invited all the "nymphs" of the town. The seconds were counted with two pendulum clocks which had been calibrated to even temperature of 15 to 16 centigrade.

The amateur team delivered a lot of data to Stockholm, but the figures were approximative and contradictory. The weather was all fine, except for a single cloud that stubbornly followed the Sun. The first contact (external ingress) was missed altogether. As for the second contact (internal ingress), Hellant obtained the time as something between 04:03:54 and 04:03:59 a.m. whereas Lagerbohm got 04:04:01. The third contact (internal egress) took place between 09:54:06 and 09:54:08 according to Hellant but rather at 09:54:18 according to Häggman and 09:54:22 according to both Lagerbohm and those in the camera obscura. The timing of the fourth contact (external egress) scattered even more: 10:11:58 according to both Häggman and camera obscura; 10:12:14 according to Lagerbohm; 10:12:22 according to Hellant. Despite Hellant's enthusiasm and self-confidence, his observations proved unreliable and virtually useless from a retrospective point of view. Nonetheless, Wargentin communicated them to Paris where Hellant's data was presented to the *Académie Royale des Sciences* on May 8, 1762.

In 1769, the Venus passage took place during the night between June 3 and 4 and was fully observable only in the northernmost part of Scandinavia against the backdrop of the Midnight Sun. The Royal Academy of Sweden realized the value of Venus observations obtainable from Lapland and didn't want to entrust

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ALMANACH
För Skott-Åhret, efter Chriſti Födelſe,
1748.
Til TORNE Horizont,
Belägen 65. gr. 51. m. Norr om Æquatorn,
och $6\frac{1}{2}$ gr. eller 26. m. i tid öſter om Upſal Obſ.
Hwarjemte bifogas
Slutet af Underrättelſen för de Siöfarande uti Bot-
niſka Wiken;
Samt
Anmärkning. öfwer tiden af Js-gången uti Torne-Elf.

Soli inocciduo Sol obvius alter.
Medaille öfwer Kon. CARL XI.
åſkådande af Midnat-Solen.

Af
ANDERS HELLANT.

STOCKHOLM, tryckt hos LOR. LUD. GREFING.

Figure 6. Front page of Hellant's 1748 almanac. The medallion commemorates the visit of King Charles XI of Sweden to Tornio to observe the Midnight Sun in 1694.

the work to amateurs anymore. Fredrik Mallet (1728–1797), the *Observator Regius* of the Uppsala observatory, was dispatched to the Arctic Circle. Together with an assistant, Daniel Hallencreutz, he started his journey from Uppsala already on August 15, 1768. On their way, the two men also contributed to general land surveying of the coasts of the Gulf of Bothnia. Mallet met with Hellant in Tornio at the end of April 1769. Wargentin had recommended Hellant as an assistant but Mallet's perception of Hellant, as we have seen, was entirely negative. Checking the three meridians traced by Hellant, he found deviations up to $27\frac{1}{2}$ arc seconds. According to Mallet, Hellant was "somewhat stubborn and full of ideas" but lazy in bringing them to reality (Nordenmark 1946, p. 75).

Hellant advised Mallet to continue to Pello, beyond the Arctic Circle, and house in the Korteniemi inn where Mallet arrived on May 12. *"May God allow Venus to be observed in Pello as well as in Stockholm"*, Mallet wrote to Wargentin. These prayers were not heard, however. The observations both in Pello and in Tornio during the night of 3 to 4 June 1769 failed because of cloudy weather. Mallet caught a glimpse of Venus at 09:45 p.m. (local time) and another one during four minutes at 02:00 a.m., but he missed the moments of ingress and egress. Hellant, on the other hand, caught a glimpse of Venus at about 03:00 a.m. but that was all. *"I am angry with Venus for ever; and I wish I could take revenge on her"*, Mallet wrote to Johan

Henrik Lidén, a friend in London, in a letter dated in Åbo, Finland, on September 9, 1769.

Wargentin had expressed doubts about the authenticity of Maximilian Hell's observations when they were communicated in 1770. Astronomers wondered why Hell had waited so long before releasing his data. Anders Planman (1724–1803), a docent of Uppsala who had obtained observations from Kajaani in Finland both in 1761 and in 1769, openly suspected Father Hell of having fiddled with his figures.

As late as on December 8, 1772 Wargentin writes to Planman telling him that Hellant had been asked to *"spy how the Jesuits had behaved in Vardøhus"*. Indeed, Hellant traveled every year to northernmost Lapland and had a good number of local informants. Even so, it appears extraordinary that more than three years after the events he was asked to find out what the weather had been like in Vardø when the Jesuits made their observations of Venus. Hellant indeed had interviewed a merchant named Wadell whom he had met at Utsjoki and who could confirm that the weather in Vardø had been fine.

Among other things Hellant also observed the oscillating variable star Mira in the constellation Cetus and the transits of Mercury at least in 1753 and 1786.

5. Conclusion

Anders Hellant in 1761 and 1769, and Fredrik Mallet in 1769, were the northernmost observers of the transit of Venus in Sweden. Hellant enthusiastically communicated his amateur observations to Wargentin, the secretary of the Swedish Academy of sciences, who shared his data with colleagues in Paris. It seems, however, that no significant use was made of Hellant's data of 1761 which was printed in Stockholm but only survives as a manuscript in Paris. This must be due to the highly scattering and scientifically mediocre quality of the figures obtained by Hellant's team. In 1769, on the other hand, the observations of both Hellant and the more professional Mallet failed altogether. The truly significant Venus observations in Sweden were made by Anders Planman in Kajaani both in 1761 and in 1769. Planman's results immediately entered international literature, whereas Hellant's contribution is rarely mentioned.

Hellant is an interesting figure for many other reasons as arguably the foremost exponent of the spirit of Enlightenment in eighteenth-century Swedish Lapland. His rightful place in the history of science is due, first of all, to his participation as a young man in the expedition of Maupertuis to measure the shape of the Earth.

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MEETING VENUS
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The Expeditions of William Bayly and Jeremiah Dixon to Honningsvåg and Hammerfest, 1769

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Abstract. In 1769 the Royal Society in London sent the astronomers William Bayly and Jeremiah Dixon to northernmost Norway to observe the transit of Venus taking place the night between 3 and 4 June. The astronomers should set up two prefabricated observatories and were brought to Norway by HMS *Emerald*, a ship provided by the Admiralty and commanded by Captain Charles Douglas. This paper describes the expedition as well as some results including Captain Douglas' attempt to measure the temperature of sea water at great depth.

1. From 1761 to 1769

After the transit of Venus in front of the Sun in 1761, it became clear that the observations had not provided a reliable value of the solar parallax – it was only enclosed between 8.5 and 10.25 arcseconds. A new opportunity would however soon present itself: in 1769 another transit of Venus could be observed, and then one could build upon the experiences from 1761. The transit in 1769 would take place during night-time in Europe, more specifically the night between 3 and 4 June. The scientific communities in Europe therefore wanted to send observers to different locations around the globe. The most obvious would be to go west where one could observe the transit while the Sun was high in the sky. Another possibility was to send observers to the far north – inside the Arctic Circle. There they could take advantage of the Midnight Sun, and the transit could be seen even though it was night. Before the transit, Britain launched an ambitious program with several overseas expeditions, one to northernmost Norway, one to Hudson Bay in Canada and one to Tahiti in the Pacific. These expeditions involved maritime navigation, and the opportunity for exploration and a host of themes of interest to the scientific community. We will here focus on the expedition to Norway. The expedition has of course been discussed earlier by others, for instance Woolf (1959) and Aspaas (2012).

2. Preparations by the Royal Society

In 1763 James Ferguson wrote an article in the *Philosophical Transactions of the Royal Society* where he suggested that one should send observers to Vardøhus [Vardø] in Norway or "any other place near the north cape" (Ferguson 1763, p. 30). In 1765 Thomas Hornsby followed up with an article on the forthcoming transit and suggested that "Wardhus [Vardø], and in the neighborhood of the North Cape" would be locations where the transit could be very advantageously observed (Hornsby 1766), see Fig. 1.

As pointed out by Woolf (1959) it lasted however until 1767 before the Royal Society formed a Committee to look into what should be done to observe the transit.

Figure 1. Map of Northern Norway showing Vardø, Honningsvåg [near North Cape] and Hammerfest where Maximilian Hell, William Bayly and Jeremiah Dixon put up their observatories.

This Committee consisted of eight persons, John Bevis, John Campbell, Charles Cavendish, James Ferguson, Nevil Maskelyne, Patrick Murdoch, Matthew Raper and James Short. As it happened, the scientific work was done by Maskelyne, Bevis, Short and Ferguson who also worked out the proposal that was presented to the Council on November 19, 1767. One of their recommendations was to send observers to Vardø and to the North Cape "unless it was learned that Swedish or Danish astronomers were planning to make use of these stations" (Woolf 1959). In any case the Admiralty should be consulted on the use of the annual ship sent out to those regions. On January 5, 1768, Maskelyne wrote a letter to the Swedish astronomer Pehr Wargentin asking Sweden to send observers to Vardø and to the North Cape. Such a letter was not sent to astronomers in Denmark–Norway, probably because Maskelyne "had such low faith in the quality of the Danish astronomers that he found it futile to encourage them" (Aspaas 2012, p. 247). Apparently the Royal Astronomer was not aware of the fact that the eminent astronomer Maximilian Hell of Vienna had accepted an offer by the Danish-Norwegian King to go to Vardø to observe the transit in 1769. However, by the end of January 1768 Nevil Maskelyne had abandoned Vardø as a possible station. Maybe he by then had learned of Hell's forthcoming expedition? In a letter to Doctor James Lind (1736–1812) of Edinburgh, who had asked to join the expedition at his own expense, Maskelyne wrote:

> It is proposed to send 2 observers, one to be landed at the North Cape, on the Island of Maggeroe, in Latitude $71^\circ\frac{1}{2}$, & the other at Cherry Island, Latitude $74^\circ 40'$ lying between the N. Cape & Spitzbergen, about 70 leagner North of the former. A wooden observatory with a movable roof, fit for one observer, together with a wooden dwelling house 12 foot square is provided for each place. (Maskelyne 1769a)

Cherry Island is today known by the name Bear Island (Bjørnøya), a small island without any permanent settlement. Maskelyne intended to send his assistant William Bayly to Cherry Island. Another observer should go to the North Cape together with the captain and the chaplain of HMS *Emerald*, the ship provided by the Admiralty. Maskelyne offered Lind, who was skilled in botany and natural history, to join Bayly on Cherry Island. All Maskelyne could tell about the island was that "scurvy-grass grows there, and there is plenty of wild fowl. What animals there are there, if any, I don't know, but rather believe there are none, not even bears". But Lind was also interested in astronomy and he had a good $2\frac{1}{2}$ foot telescope made by Dollond. In addition to this Maskelyne asked him to bring a good watch and also a tent since the observatory only had space for one telescope.

In another letter dated 14 February 1769 Maskelyne informed Lind that the expedition to Cherry Island would not take place, probably because the Admiralty refused to call at the island due to lack of harbors. Instead Maskelyne hoped the Admiralty would agree to carry one observer "to Spitzbergen where there are noble harbors" (Maskelyne 1769b). Whether Lind still wanted to join was of course up to him, but Maskelyne told him that he had understood from friends of the captain that he would be incommoded by the addition of another gentleman. This might be the reason why Lind ended up observing the transit from Hawkhill outside of Edinburgh (Lind 1769). The captain on board the HMS *Emerald* was Charles Douglas.

In February 1768 the Royal Society sent a memo to the King presenting their ideas and asking for 4000 pounds to support their plans. In the letter they explained that

> The Memorialists are humbly of opinion, that Spitzbergen, or the North Cape, in the higher northern latitudes; Fort Churchill, in Hudson's Bay; and any place not exceeding 30 degrees of Southern latitude, and between the 140th and 180th degrees of longitude, West, from your Majesty's Royal Observatory in Greenwich Park, would be proper stations for observing the ensuring transit, to each of which places two observers ought to be sent.

The King instructed that the sum of 4000 pounds should be paid to the Royal Society, enabling the preparation for the three expeditions to continue. In May 1768 Samuel Wallis returned from his voyage of exploration around the globe and reported that King George's Island (today Tahiti) would be a perfect location in the Pacific. In November 1767 the Committee had suggested names of possible observers, among them Charles Mason and Jeremiah Dixon. They had both observed the transit in 1761, and in 1768 they were asked to go to Norway. Only Dixon expressed a willingness, and by December 1768 it was decided that William Bayly and Jeremiah Dixon should go north (Woolf 1959).

3. The observers and their instruments

Charles Douglas was born in Carr in Scotland in 1727 and joined the Royal Navy at the age of twelve. He was appointed captain of the HMS *Emerald* in 1767, a position he held until 1770. Charles Douglas was known as a mechanical genius, but today he is remembered for his part in the American War of Independence. Charles Douglas died in Edinburgh, Scotland, in 1789 (Valin 2009).

Jeremiah Dixon was born in 1733 near Durham in England as the son of a Quaker coalmine owner. During his education he became interested in astronomy and mathematics and got to know the instrument maker John Bird. In 1761 Dixon observed the transit of Venus from the Cape of Good Hope together with Charles Mason. From 1763 to 1767 the two worked together surveying what is today known as *The Mason–Dixon Line*, a demarcation line forming part of the borders of Pennsylvania, Maryland, Delaware and West Virginia in the U.S. After his visit to Norway in 1769 Dixon resumed his work as a surveyor in Durham, where he died ten years later, in 1779 (Danson 2002).

William Bayly was born in 1737 as the son of a farmer. His interest in mathematics was discovered and local gentlemen helped him to some education. He became an usher at a local school, and when Nevil Maskelyne heard of his talents he engaged him in 1766 as an assistant at the Royal Observatory (Croarken 2003). Bayly held this position until 1771. In 1772 and 1776 he sailed as one of the astronomers on James Cook's second and third voyages of discovery (Fig. 2). In 1785 he was made headmaster of the Royal Academy at Portsmouth, an office he held until 1807 when he retired. Bayly died in 1810.

Figure 2. William Bayly observing with a quadrant set up on a cask in Anamooka during James Cook's third voyage. This is the only known picture showing Bayly and it is taken from an engraving titled *A view of Anamooka* made by John Weber.

We do not know exactly which instruments William Bayly and Jeremiah Dixon used on their expedition to Norway, but from the papers they published we may put together the following list of William Bayly's instruments:

1. an astronomical quadrant of 1 foot radius, by [John] Bird,
2. a 2-foot reflector telescope, by [Peter] Dollond,
3. a transit instrument of 4 foot by John Bird, with achromatic object glass by [Peter] Dollond,
4. an astronomical clock with gridiron pendulum, by [John] Shelton,
5. a journeyman clock, by [John] Shelton,
6. an alarm clock, by [John] Shelton,
7. a variation compass, by [Gowin] Knight,
8. a dipping needle (belonging to the Royal Observatory) by [George] Graham,
9. a barometer by [Jesse] Ramsden, and
10. two thermometers by [John] Bird.

According to Bayly's information Jeremiah Dixon had similar instruments except for the dipping needle.

4. Instructions given to the observers

In the beginning of March 1769 the Danish-Norwegian King assured the Royal Society of full cooperation in connection with their expedition to the North Cape. As a result local authorities in Norway were instructed to help the astronomers in all possible ways. But the local authorities where also told to report whatever they learned about the British astronomers' arrival (Thott 1769). The information from Denmark reached the Royal Society on April 6 (Woolf 1959). Around the same time Maskelyne gave the two observers their instructions (Maskelyne 1769c), in which they were informed that they should go to the North Cape and to "some other place at some distance, to be fixed by Captain Douglas". It was up to the observers to settle which of them should observe at one place, and which at the other. We do not know why Spitzbergen was abandoned but the reason maybe that it was considered too risky to set up an observatory so far north during springtime – or maybe the Admiralty refused to go there. On their voyages to and from Norway the astronomers should make observations of the latitude of the ship's position with a sextant or a quadrant, determine the longitude of the ship by measuring the distance of the Moon from the Sun and fixed stars, and observe the variation by the azimuth compasses of the ship.

On Monday 24 April HMS *Emerald* arrived at Magerøy and Captain Douglas wrote in his logbook: "Working into Magero Sund. 2pm Sailed into Honnings Bay" (Douglas 1769a). According to their instructions (Maskelyne 1769c) they should as soon as possible put up the observatory and the dwelling house, and then fix up the clock firmly and calibrate it to determine the difference of gravity between that place and Greenwich. From this they would find the length the pendulum should have to assure that the clock would keep near sidereal time at the North Cape.

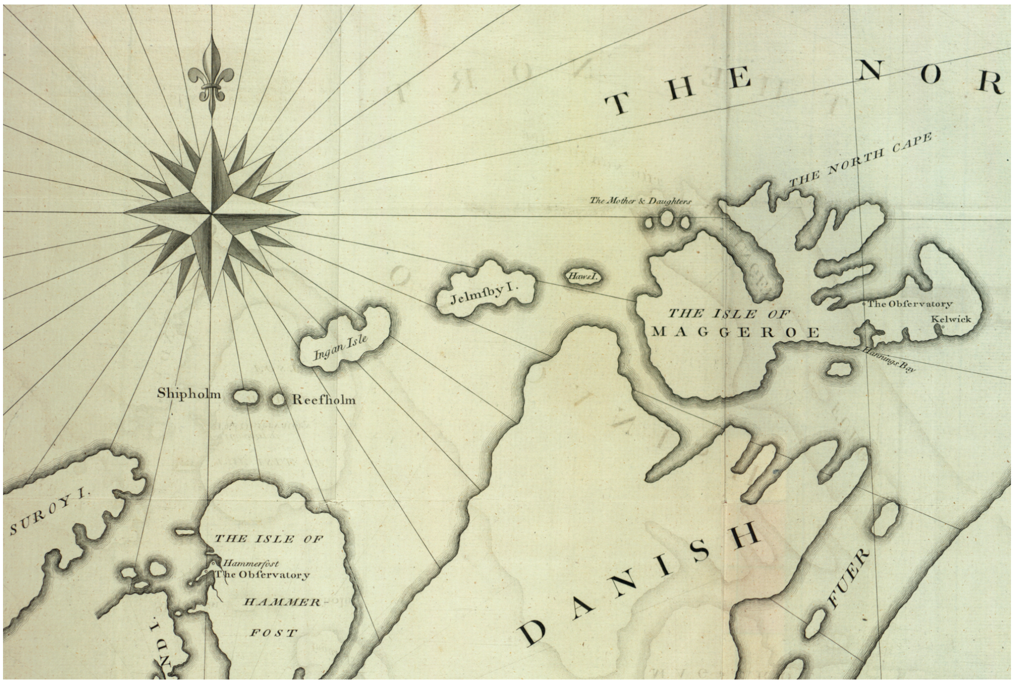

Figure 3. Map of the area around North Cape and Hammerfest drawn by Bayly (1769) and Dixon (1769) showing the locations of their observatories.

They should then observe several corresponding altitudes of the Sun every day in order to test the accuracy of the clock and to draw a meridian line. From this they could align the observatory to the true north so the transit instrument could move through the meridian. They should also erect a meridian mark at a convenient distance from the observatory.

To determine the latitude of the place, they should observe meridian altitudes of the Sun, both to the north and to the south, and also of the fixed stars as well as the planet Venus. In order to ascertain the astronomical refractions they should measure a series of altitudes of the Sun and Venus from the horizon and note the time of the rising and setting of Venus and of the bright fixed stars. From this it seems as if Maskelyne was not aware (or had forgotten) that fixed stars would not be in sight from late April to the middle of August because the bright sky due to the Midnight Sun.

To determine the longitude of the place they should as often as possible observe the transits of the Sun and Moon and of the principal fixed stars of the first and second magnitude lying between the tropical circles. These celestial objects were also observed at the Royal Observatory at Greenwich. In addition they should, particularly with a view to this purpose, attend to the eclipse of the Sun, which would happen soon after the transit of Venus.

Throughout this time they should note the height of the barometer and thermometer. In addition to all this they should determine the elevation of the observatory above the sea and use the quadrant to observe the depression of the horizon of the sea.

Most important of all was of course the observation of the transit of Venus. Here they should especially take care to observe the internal contacts, whether by the coincidence of the limbs of the Sun and Venus, or by the breaking in of the Sun's light behind the hinder limb of Venus, at the first internal contact; or by the disappearance of the light between the limbs at the second internal contact. They should also look out for any thin, faint ring to be seen surrounding the circumference of Venus, or any other signs of an atmosphere. Toward the middle of the transit, they should take several measures of the nearest distance of the limbs of the Sun and Venus, in order to ascertain the nearest approach of Venus to the Sun's center.

5. The North Cape and Hammerfest

On April 26 Bayly's observatory and instruments were taken ashore in Honningsvåg and between April 28 and May 5 the observatory and dwelling house were built and the instruments put in place. On May 6 the observations started. This would give plenty of time for Bayly to determine the accuracy of the clock, put up a meridian mark and find the coordinates of the observatory, Fig. 3.

The day before, on May 5, Captain Douglas had taken the ship out of Magero Sund and he and Dixon started to look for a suitable place for the other observatory. They sailed past Kelwick [Kjelvik], the North Cape, the Mother and Daughter-Islands [Storstappen, Kjerkestappen and Bukkstappen], Suroy [Sørøy], (see Fig. 3) and at 10 am on May 7 entered into Hammerfest harbor (Douglas 1769a). After some research Dixon managed to find a place for the Observatory at *Rypeklubben* just outside Hammerfest (Hagerup 1769). On May 9 the observatory was landed, and three days later the instruments were taken ashore. On May 14 Dixon put up the quadrant on the stand provided for it. To give it a firm foundation it was put on "a large cask filled with water [...] and the box in the bottom of the stand filled

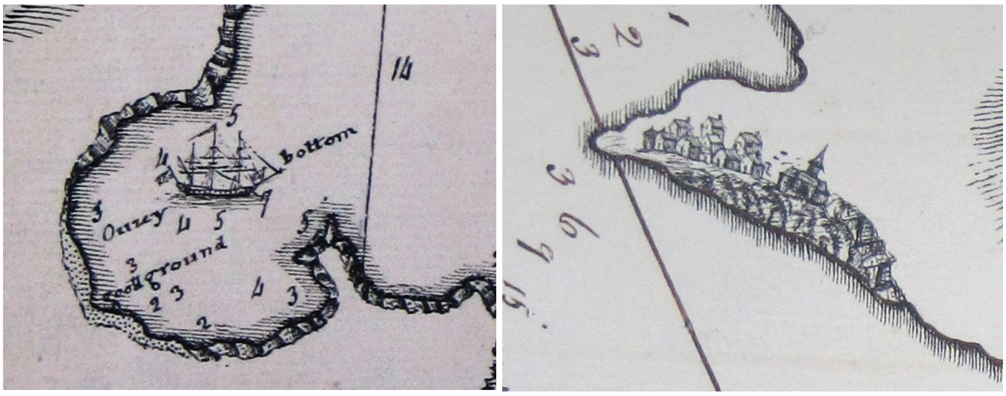

Figure 4. *Left*: HMS *Emerald* in a little bay in Honnings Voe [Honningsvåg] as shown on a manuscript chart probably made by Charles Douglas (1769b). *Right*: Dixon put up his observatory near the town of Hammerfest. Here the town is shown on a manuscript chart probably made by Charles Douglas (1769b). Photos: Jonathan Peacock.

with stones" (Dixon 1769), see Fig. 2. Due to cloudy weather Dixon had to wait until May 20 before he could perform any observations. On 25 May three of his Danish Majesty's Ships came in to Hammerfest, and the day after HMS *Emerald* was visited by Eiler Hagerup, county prefect of Finnmark (Douglas 1769a), Fig. 4.

By June 3 Bayly and Dixon were well prepared to observe the transit. But the weather turned out to be cloudy with gales (Douglas 1769a). Bayly reported that "the Sun came out from under a cloud, with Venus on it, about $\frac{1}{4}$ of her diameter". At 9h 14^{m} 1^{s} local time Venus' outer limb was apparently joined to the Sun's limb by a black ligament, which gradually diminished in breadth until the Sun's light broke through 55 seconds later. The conditions were however poor and Bayly (1769) reported that (Fig. 5)

> Venus seemed very ill defined when on the Sun [...] a better idea will be formed of the bad appearance of Venus at the internal contact, owing to the very hazy state of the air, from the representation.

The observation of the transit had failed, and in Hammerfest the situation was more or less the same. In Maskelyne's instructions it was stated that if they missed the transit due to bad weather they should depart the place immediately, only first observing carefully the eclipse of the Sun, which happened a few hours after the transit. So they did, and on June 6 Dixon's observatory was taken on board HMS *Emerald* and on June 25 Bayly's observatory was taken on board. Ten days later they left Honningsvåg and started on their voyage back to Britain. Today it is not possible to locate the exact position of the observatories as nothing seems to be left.

6. Bonus results from the expedition

Bayly and Dixon published their results in the *Transactions of the Royal Society* even though they had failed to observe the transit satisfactorily. They reported what they had seen of the transit of Venus, as well as results from the corresponding altitudes of the Sun, transits over the meridian, the eclipse of the Sun and also

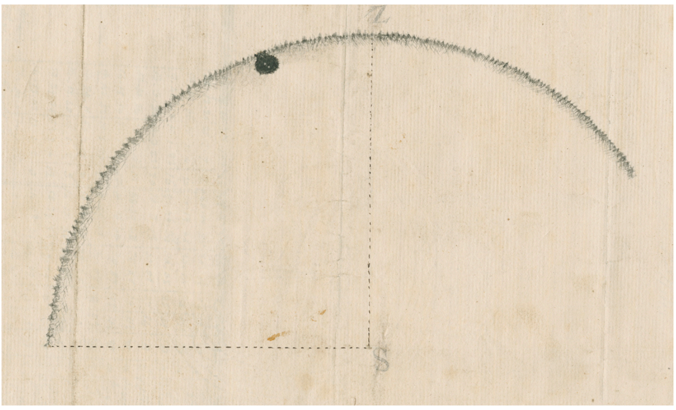

Figure 5. Venus internal contact during the transit. Source: Bayly (1769).

some meteorological observations (Bayly 1769, Dixon 1769). The positions of the observatories were given as:

	Latitude	Longitude
Bayly's observatory	71° 00′ 47″ N	26° 01′ 30″ E
Dixon's observatory	70° 38′ 23″ N	23° 43′ 45″ E.

Along with their observations they published a chart showing the sea coast and the islands near the North Cape including three silhouettes of coastal approach.

While Bayly and Dixon were ashore, Captain Charles Douglas was busy doing observations on board the HMS *Emerald*. Like all naval ships he kept what may be described as a spying log (Douglas 1769b). It was a collection of reports on defenses, commercial information, marks for anchoring, descriptions for sailing in and out of ports with soundings and marks for particular rocks etc. He also added supply possibilities ("watering and wooding") for any territory they were visiting. These are the headings of columns in a pre-printed reporting volume. For the areas around Honningsvåg and Hammerfest the log was supported by charts of the coast. We do not know whether these charts were made by Douglas or by anyone else – maybe Dixon and Bayly contributed?

In addition to this Professor of Astronomy at Glasgow University, Alexander Wilson, had asked Douglas to measure the temperature of sea water at great depth. Twenty years earlier Wilson had used kites to measure air temperature at various levels in the atmosphere, the first recorded use of kites in meteorology (Wilson 1829). In 1769 Wilson had constructed a special device to be used by Douglas. A thermometer staying upright was placed in a watertight tin cylinder without touching the walls of the cylinder. This cylinder was sunk to great depth by using sounding-lead and should hang free near the bottom for half an hour. It was then hauled up as fast as possible and the thermometer was inspected. After trying this several times Douglas changed the design by making two small holes, one at each end of the cylinder. This would let in water – hopefully most of it at great depths. It sunk 260 fathoms (475 meters) in $3\frac{1}{2}$ minutes and was hauled up in $13\frac{1}{2}$ minutes. Douglas recorded at the same time the temperature in the air and the water temperature at the surface. As far as I have been able to discover this is among the first [maybe the first?] attempts to measure the temperature of deep water, Fig. 6. The results were published in the *Transactions of the Royal Society* (Douglas 1770).

Before going to Norway, Captain Douglas had read Erik Pontoppidan's book *The Natural History of Norway* published in Copenhagen in 1752/53 and in an English

Figure 6. Approximate positions (red bullets) with corresponding values for temperature (°C) and water depths (meters) according to the information given by Charles Douglas (1770).

version in London in 1755. During the stay in Finnmark Douglas tried to investigate some of the stories told by Pontoppidan in his *Natural History*. Among these are the stories of the huge aquatic animal called Kraken, the information about Sea Worms and the story of the Whirlpool or Maelstrom laying between the islands of Lofoten. This Maelstrom was well known to sailors and regarded dangerous for ships.

Douglas' judgments of the stories were based on what information he could collect from Norwegian seamen. Regarding the Maelstrom he was told that by high water it was perfectly smooth, but in ebb or flood it became agitated and dangerous. According to Douglas this was probably due to the unevenness of the rocky bottom over which the current rolled with vast rapidity, since the water was confined in a narrow passage. A Norwegian had even told him that at very low water it was possible to see sharp pointed rocks at the bottom, which would account for the loss of open boats. Douglas hoped that his report would unravel the mystery of the Norwegian Maelstrom.

Talking about the big animals in the sea it was quite obvious for Douglas that the huge Kraken did not exist – none of his informants had ever seen it. In relation to the Sea Worm it was quite another story. Douglas had met with a master of a Norwegian vessel that had seen three Sea Worms outside Bergen just six years earlier. One of them he judged to be 25 fathoms long and about one fathom in thickness. It looks as if Douglas himself trusted the man, but he left to the Royal Society to judge whether these animals existed or not.

Charles Douglas' paper in the *Philosophical Transactions* earned him a membership in the Royal Society in London probably due to what is referred to as his "series of curious experiments to determine the different degrees of cold at different depths in the Sea" (Royal Society 1770).

7. Conclusion

The expeditions of Bayly and Dixon are not very well known today. The main reason is of course that they failed to observe the important stages of the transit of Venus due to bad weather. In addition they where told only to do observations that were necessary to support their main goal, i.e., to observe the transit of Venus. In Maskelyne's instruction it is stated that they should leave as soon as possible if they failed to see the transit. This means that there is nothing spectacular or epic from other parts of the expedition that may catch our interest. Despite this the story may broaden our knowledge on how such expeditions were organized and planned 250 years ago. It seems for instance that the Royal Society had to cooperate with the Admiralty and the captain of the assigned vessel when determining where to go. And the Admiralty used the opportunity to get information about the places they visited.

Acknowledgments

I wish to express my gratitude to Jonathan Peacock, Durham, who went out of his way to look up the two manuscript charts in The National Archives at Kew (ADM 346/8/25). He has supplied me with photos of the charts and has also provided many useful comments on an earlier version of this article. I would also like to thank archivist Joanna Corden, the Royal Society of London, who has supplied me with photos of and a transcription of Nevil Maskelyne's instruction for William Bayly and Jeremiah Dixon (CMO/6/14).

In addition, Rebekah Higgitt, Royal Museums Greenwich, told me that William Bayly could be identified in the engraving entitled *A view of Anamooka*.

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Anders Johan Lexell's Role in the Determination of the Solar Parallax

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Abstract. Anders Johan Lexell (1740–1784) was a mathematician who gained considerable recognition for his scientific achievements during the century of Enlightenment. Born and educated in Åbo/Turku in the Finnish part of the Swedish Realm, he was invited as an assistant and collaborator of Leonhard Euler at the Imperial Academy of Sciences in Saint Petersburg in 1768. After Euler's death in 1783 he inherited his mentor's chair and became professor of mathematics at the Petersburg Academy of Sciences, but survived only a year in this office. One of Lexell's first tasks in Saint Petersburg was to assist in the calculations involved in the Venus transit project of 1769. Under Euler's supervision, Lexell formulated a system of modeling equations involving the whole bulk of observation data obtained from all over the world. Thus, by searching (manually) the best estimate of the parallax with respect to all available measurements made of the Venus transit simultaneously, he anticipated later statistical modeling methods. The usual method at the time consisted of juxtaposing a pair of measurements at a time and taking a mean value of all the parallax values obtained in this way. What had started as an innocent, purely academic attempt to establish the solar parallax, soon escalated into a heated controversy of international dimensions. The roles played by Jérôme de Lalande in Paris and Maximilian Hell in Vienna in this controversy are well known; Lexell's role less so. Our analysis has two aims. First, we elucidate Lexell's place in the international solar parallax controversy by making use of his published works as well as surviving parts of his correspondence. Second, we present the method used by Lexell and analyze his way of calculating the solar parallax.

1. Introduction

Anders Johan Lexell (1740–1784) is best known as a mathematical astronomer with two major achievements: he calculated that the "star" found by Herschel in 1781 moved in a nearly circular orbit around the Sun, thereby concluding that it must be a planet (i.e. Uranus), and he elucidated the very special motion of the Comet D/1770 L1, also known as the "Comet Lexell" (Grigorian & Youshkevich 1970–1980; Lehti & Markkanen 2010). His real vocation, however, was mathematics (*Encyklopädie der Matematischen Wissenschaften, 1907*, Grigorian & Youshkevich 1970–1980, Lysenko 1980). As far as the Venus transits are concerned, he did take part together with Johann Albrecht Euler and the Jesuit Fathers Christian Mayer and Gottfried Stahl in the observations of the transit of 3–4 June 1769 in the observatory of the Petersburg

Academy of Sciences (Moutchnik 2006)[1], but as a newcomer in practical astronomy he put no great weight on the accuracy of his own observations, nor expected others to do so. His engagement in the Venus transit project of 1769 was more theoretical and mathematical than practical and observational. Lexell's mission was nothing less than to determine, with the highest possible degree of accuracy, the solar parallax on the basis of all observations assembled world-wide in the year 1769.

2. Lexell's role in the Venus transit project

Lexell arrived in Saint Petersburg from Åbo, Finland, in the end of October 1768. The Secretary of the Imperial Academy of Sciences, Leonhard Euler's oldest son Johann Albrecht, played a key role in integrating Lexell in the scientific life of the Academy. As an Editor of the Academy's official organ, *Novi Commentarii Academiae Scientiarum Imperialis Petropolitanae*, J. A. Euler provided room to a number of lengthy and theoretically ambitious works written by Lexell in the fifteen years to come. Christian Mayer, who was engaged in Saint Petersburg from May 1769 to June 1770, taught Lexell the art of observing using astronomical instruments (Moutchnik 2006). The Secretary of the Royal Academy of Sciences of Stockholm, Pehr Wilhelm Wargentin, was another unfailing supporter and confidant of Lexell, as is evident from their largely preserved correspondence as well as from the number of Lexell's articles published in the Transactions of the Royal Academy of Sciences of Stockholm, *Kongliga Vetenskapsacademiens Handlingar*, even before Lexell was a member (in 1773).[2]

The Petersburg Academy of Sciences invested considerable resources and prestige in the Venus transit project of 1769 (cf. e.g., Bucher's contribution to these Proceedings). The individual observation reports from the various Russian-sponsored expeditions were churned out from the press and distributed across Europe with aplomb as soon as the Academy received them. Furthermore, all reports were edited in Latin in the *Novi Commentarii* as well as in a separate volume entitled *Collectio omnium observationum quae occasione transitus Veneris per Solem a. MDCCLXIX. iussu Augustae per Imperium Russicum institutae fuerunt una cum theoria indeque deductis conclusionibus* (1770)[3]. For these official reports, as well as for several subsequent publications, Lexell appears to have made the lion's share of the calculations pertaining to the solar parallax. In a letter dated 18 August 1769 (Centre for history of science at the Royal Swedish Academy of Sciences, Stockholm), Lexell reports to Wargentin that all the observation journals made in Russia of the transit of Venus had already reached the Academy at that time, except the one from Iakutsk, and that five of the respective reports had already been printed, namely those from Saint Petersburg, Kola (Stepan Rumovski), Ponoi (Jacques-André Mallet: Candaux et al.

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[1] Independent observations were made at the Academy Observatory in Saint Petersburg by Christian Mayer SJ, his assistant Gottfried Stahl SJ, Johann Albrecht Euler, and Lexell. Both the beginning and the end of the transit could theoretically be observed in Saint Petersburg (where the Sun set just after ingress), but only the two lasts contacts were actually perceived distinctively (after sunrise the next day). For details, see (*Collectio omnium observationum quae occasione transitus Veneris per Solem,* 1769).

[2] For a comprehensive list of Lexell's works, see Johan C.-E. Stén's biography of Lexell (forthcoming on Birkhäuser Verlag).

[3] "Collection of all the observations that were made in the Russian Empire upon orders from Her Majesty on the occasion of the Venus transit in front of the disk of the Sun in the year 1769, with a theory and conclusions resulting thereof".

2005), Umba (Jean-Louis Pictet: Candaux et al. 2005) and Orenburg (Wolfgang Ludwig Krafft). One year after the transit of Venus, Lexell wrote to Planman about his work with the method of determining the parallax in a letter dated 25 June 1770 (Helsinki University Library Ms. Coll. 171):

> I have been commissioned to calculate [Georg Moritz] Lowitz' and [Christopher] Euler's observations [from Gur'ev and Orsk, respectively]; thus the biggest task [in the Astronomical part of the *Novi Commentarii*] will be my duty. As to the latter work I wish to wait for the observations from California and South Pacific. The rest that I can accomplish will be for my friends, since I have not yet planned to publish my calculations of the eclipse or those I plan to undertake on Venus.[4]

The first results of the Russian enterprise for the transit of Venus were published in 1770 in the second part of the fourteenth volume of the *Novi Commentarii* as well as in the separate book (*Collectio,* 1770). The individual reports from the various stations were followed by a long section entitled *Expositio methodorum, cum pro deteminanda parallaxi Solis ex observato transitu Veneris per Solem, tum pro invendiendis longitudinibus locorum super Terra, ex observationibus eclipsium solis, una cum calculis et conclusionibus inde deductis*[5] (*Collectio,* 1770, pp. 342–574). All calculations were exposited in full detail.

The anonymous author who based his calculations on the observations made in different parts of Russia as well as Greenwich, Cajaneborg (Kajaani) in Finland, Vardøhus in Norway, Prince of Wales Fort in present day Canada and Santo Domingo in the Caribbean, was able to deduce a mean horizontal parallax of approximately $8''.80$.[6] In an *additamentum* apparently inserted just before publication, further observations were included from North America – among these Chappe d'Auteroche's from Baja California. The anonymous author now switched to $8''.75$ as the most probable parallax[7]. The earliest contributions on the solar parallax from Russia were thus anonymous, perhaps to emphasize that the results were obtained as a joint venture and that nobody should take the blame if the result turned out erroneous, or get the credit if the contrary should be the case. Elsewhere in the *Collectio* (especially p. 575), however, Euler is singled out as the inventor of the method. Who

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[4] "Det är mig updragit at beräkna Lowitz och Eulers observationer, således faller det drygaste arbetet för den Class på min lott. Jag wil och hwad det förra arbetet angår afbida observationerne ifrån Californien och Zudsee. Hwad jag sedermera kan praestera blir för mina wänner, ty ännu har jag ei tänkt på at publicera hwarken mina beräkningar öfver Förmörkelsen eller de jag tilämnar öfver Venus".

[5] "Presentation of the methods used, both for the determination of the solar parallax on the basis of the observation of a transit of Venus in front of the Sun, and for finding the longitudes of places on the surface of the Earth on the basis of observations of solar eclipses, along with the calculations and the conclusions drawn upon these".

[6] *Novi Commentarii Academiae Scientiarum Imperialis Petropolitanae* Tomus XIV, Pars II, 1769 [published in 1770], pp. 518–519; repeated in *Collectio*, 1770, pp. 538–539: Parall[ax]is Solis nobis erit $\pi = 8,67$ quae respondeat distantia Solis a terra, quae hoc tempore erat 1,0154. Pro distantia media, quae unitate exprimi solet, haec parallaxis aliquanto fiet maior scilicet **8,80** quae quum referatur ad semiaxem telluris, distantia media inter centra Solis et terrae censenda erit aequalis 23436 semiaxibus terrae, hincque pro perigeo parallaxis $= 8,95$ et pro Apogeo $8,65$. (our emphasis)

[7] See *Collectio*, 1770, p. 556: Elementa autem Astronomica hinc sequenti ratione determinabuntur. [...] Parallaxis Solis Horizontalis 8,62. (Note that the quotation refers to the parallax on the day of the transit, which corresponded to a mean horizontal parallax of **8".75**.)

actually did the calculations is not stated explicitly, but according to the minutes of the academic conference, on 13 December 1770 (old style; i.e. on 24 December), Euler held a panegyric speech with an exuberant commendation for Lexell, stating in particular that (translated from the German) (*Протоколы засьданий конференции Императорской Академии Наукъ*, 1897–1911, pp. 792–793)

> [T]he world owes it solely to the untiring zeal of Adjoint Lexell, that the enormous expenses that were invested for the latest transit of Venus did not end up utterly wasted, in the same manner as those spent on the previous transit of 1761; without him, perhaps no one would have been able to determine from the observations made of the last transit of Venus the true parallax of the Sun, since the methods of this calculation known hitherto are entirely inadequate, as was also learned from the previous experience, and since to this day not a single scholar has proven himself to be so brilliant as to deduce only one, certain conclusion from all the observations.

Thus, starting out as an anonymous "ghost writer",[8] Lexell was gradually accorded the task of calculating the solar parallax on the Academy's behalf and soon appeared on the title pages as the sole author – no small responsibility on the shoulders of an inexperienced adjunct!

By the time the last key data sets finally reached Europe – namely the results of Captain James Cook's observation from Tahiti – three major "parallax agitators" had established themselves on the international stage. The three were Maximilian Hell, who used his own observation from Vardø along with the non-European observations to argue for a solar parallax of $8''.70 \pm 0''.01$; Anders Planman in Åbo, who used his own observation from Kajaani along with the non-European observations to argue for $8''.50$ or even lower; and Jérôme de Lalande in Paris, who essentially supported Planman and discarded Hell's observations. Lexell's own deductions were published in the Swedish *Handlingar* (Lexell 1771a,b), and in the Russian *Novi Commentarii* (Lexell 1771c). In the two latter publications, having taken the results of the observations made in Tahiti into account, Lexell settled for the parallax of 8.68 arcseconds.[9] After several attempted calculations Lalande landed on $8''.50$, or $8''.60$ as a maximum. Honour and prestige was at risk, and Lexell soon found himself bombarded by letters from Planman, Lalande, and Hell. His name was also mentioned in the columns of the major journals and magazines of learning in France and Germany. Whilst Lalande and Hell attacked each other, Lexell wrote a long treatise that was published as a monograph in Saint Petersburg late in the year 1772 (Lexell 1772b, see Fig. 1): *Disquisitio de investiganda vera quantitate Parallaxeos Solis, ex Transitu Veneris ante discum Solis Anno 1769, cui accedunt animadversiones in tractatum Rev. Pat. Hell de Parallaxi Solis* (Deliberation on the investigation of the true quantity of the solar parallax based on the transit of Venus in front of the disk of the Sun in the year 1769, to which is added comments on Honourable Father Hell's treatise *de Parallaxi Solis*). Instead of discarding Vardø in

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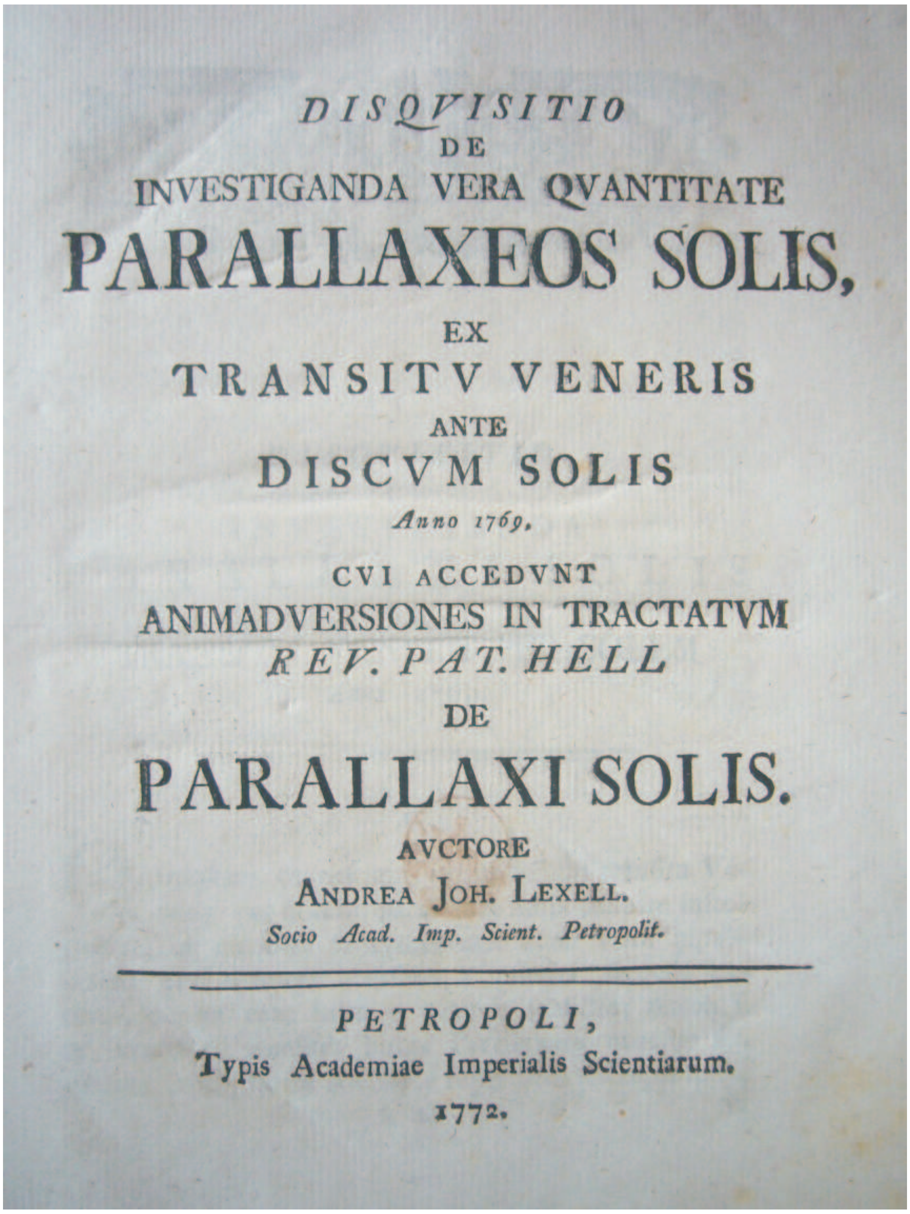
[8] Thus, the minutes of the conferences of the Petersburg Academy informs that Lexell presented the reports of Georg Moritz Lowitz, Christopher Euler and Petr Inochods'ev during conference sessions at the Academy (cf. (*Протоколы засьданий конференции Императорской Академии Наукъ*, 1897–1911) for 5 July 1770; 13 August 1770; and 28 February 1771) and that he edited at least the report of Lowitz for printing in the *Novi Commentarii*.

[9] The reason why Lexell's posterior values differ from the earlier and more correct value obtained under Euler's direction, might be in the rather arbitrary importance he gives to the observations of the inner contacts, which tends to make the parallax value a bit too small (Verdun 2010).



DISQVISITIO
DE
INVESTIGANDA VERA QVANTITATE
PARALLAXEOS SOLIS,
EX
TRANSITV VENERIS
ANTE
DISCVM SOLIS
Anno 1769,
CVI ACCEDVNT
ANIMADVERSIONES IN TRACTATVM
REV. PAT. HELL
DE
PARALLAXI SOLIS.
AVCTORE
ANDREA JOH. LEXELL.
Socio Acad. Imp. Scient. Petropolit.

PETROPOLI,
Typis Academiae Imperialis Scientiarum.
1772.

Figure 1. Front page of Lexell's great work (Lexell 1772b) on the solar parallax. Photo: Johan Stén. Collection of Mr Ilkka Paatero.

favor of Kajaani or *vice versa*, Lexell used a mean value of the two, arguing that there was no way to say which of the two observations that contained an error. Lexell's verdict was now $8''.63 \pm 0''.06$.

The debate on the solar parallax continued until 1775 with several printed contributions from the pen of Lexell (Lexell 1771a,b,c; 1772a,b and 1773) as well as numerous letters to *inter alios* Anders Planman (Helsinki University Library, Ms. Coll. 171), Pehr Wargentin (Centre for history of science at the Royal Swedish Academy of Sciences, Stockholm) and Johann III Bernoulli (Universitätsbibliothek Basel, Mscr. L I a 703). Although he was generally more sober than Hell, Lalande and Planman in his printed publications, Lexell ventilated his personal opinion on the other antagonists in the controversy in his earnest and outspoken letters to Wargentin[10]. For example, in a letter dated 3 April 1773, Lexell admits to Wargentin (Centre for history of science at the Royal Swedish Academy of Sciences, Stockholm):

> The only thing I have wanted to prove is that Father Hell has erred when he has criticized the calculations of the XIVth volume of the *Novi Commentarii* and that his own calculations are so severely erroneous, that nothing can be concluded from them. I am delighted to have been able to show Father Hell some reason; as to Planman I am more in despair, although he admitted to me when I visited Åbo that there is no reason to believe Father Hell's observation to be invented.[11]

To Lexell, the use of transparent calculations in a cool-headed, disinterested quest for Truth was all-important. His agenda was not to prove some observer's outstanding qualities or to question the credibility of any observer in particular. By operating with mean values between several observations he sought to find a statistically credible value. He had no illusions of being able to fix the solar parallax at a tiny fragment of an arcsecond; rather, he was careful to state the limits of doubt in all conclusions. Even more important than the result itself was the explanation of exactly how he had arrived at his result. In this sense, he was quite unusual in an academic environment riddled with personal ambitions and rivalry.

However, in his private correspondence, another, more temperamental side became visible. Having shown that Hell's arguments against his calculations were groundless and that the logic of Hell's own deductions were defective (Lexell 1772b, 1773), Lexell still feared that not only his own reputation was endangered, but also that of his superior Euler. Thus, in long and detailed letters he tried to convince his friends Wargentin in Stockholm, Planman in Åbo and Johann III Bernoulli in Berlin, of the solidity of his arguments and warning them against believing those of Hell. He always respected Wargentin's wise and diplomatic response, but was rather disappointed at the positions that Planman and Bernoulli had taken. He also showed a bold directness in his letters to senior astronomers such as Professor Planman (letter dated 10 February 1774, Helsinki University Library, Ms. Coll. 171):

> Allow me to admit that I had hoped for a little more consideration from you in this matter, which is not the trickiest one and in truth requires more of a sound logic and critique than sophisticated mathematics. Least of all had I anticipated that you, Herr Professor, would have put up against my reasons with a certain authority, which I, for all my appreciation of your personal character and qualities, cannot bring myself to approve. You may be convinced that not even Euler, the great Euler, is capable of convincing me on his mere authority, no more than anybody else.[12]

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[10] For quotations, see Aspaas (2010) or Aspaas (2012, pp. 322–326).

[11] "Det enda som jag welat bewisa, är at Pat: Hell haft orätt då han criticerat de räkningar som förekomma uti XIV Tomen af Comment: samt at Hans egna räkningar äro så swårt felaktiga, at af dem ingen ting kan slutas. Det fägnar mig, at jag kunnat bringa Pat: Hell til så mycket billighet, om Planman miströtar jag mera, likwäl måste han medge mig då jag war i Åbo, at ingen anledning är, at misstänka Pat: Hell observation för at wara updiktad".

[12] "Emedlertid må Herr Professorn tillåta mig at upriktigt tilstå, det jag hade förmodat lite mera öfwerläggning af Herr Professorn hwad detta ämne angår, som wäl ei är af de aldra benigaste

Even when the heat of battle had cooled down, Lexell writes in a serious and ironic tone to Bernoulli, reproaching him for being unconcerned and ignorant (24 December 1775):

> Enfin j'ai reçu le supplément de l'Abbé Hell sur la parallaxe[13], je l'ai trouvé tel que je me l'avois imaginé et même pire encore. Il faut bien, que vous Monsieur, l'aviez parcouru bien à la hâte, lorsque vous m'écrivîtes il y a un an, que j'aurai raison d'être bien content de l'Abbé Hell. J'en conviens volontiers, si je pourrois m'imaginer que ce soit par complaisance pour moi, qu'il persiste encore sur les objections, qu'il a faites contre les calculs sur la parallaxe dans le XIV Tome des Commentaires; qu'il defend toutes les fautes qu'il avoit commis lui-même; qu'il fait imprimer une de mes lettres[14] sans m'en demander la permission; qu'il y ajoute quantité des notes en partie triviales et pour la pluspart absurdes; qu'il s'approprie le droit de corriger ou plustôt pervertir mes calculs sans les entendre; qu'il propose plusieurs insinuations et imputations odieuses contre moi. Je dis, que si je serois assez bête pour me persuader, que tout ceci soit à mon avantage, j'aurais beaucoup à me louer de l'Abbé Hell. Soyez vous-même Monsieur, mon juge s'il vous plaît. Mais permettez aussi que je remarque le contraste singulier, qu'il y a entre votre conduite envers l'Abbé Hell et moi. Vous approuvez la conduite de l'Abbé Hell, sans l'avoir examiné et quand je vous demande votre sentiment sur des choses controversées entre lui et moi, vous, vous excusez par votre peu de temps. Je ne vous ai demandé, que vous disiez quelque chose au désavantage du caractère personnel de l'Abbé Hell, j'ai seulement voulu sçavoir si selon votre sentiment il avoit tort sur une telle question, ou non?

After this temperamental outburst the matter would no longer be discussed, and the correspondence continues in a respectful and polite tone on other subjects.

3. The methods of Euler and Lexell to determine the solar parallax

The methods to determine the solar parallax in the eighteenth century typically involved the following steps (Verdun 2004, 2010): 1) the measured contact moments were corrected from errors due to clock drift, giving the primary observables; 2) the epoch or the exact duration of transit were obtained as the secondary observables; 3) these observables were next reduced to the Greenwich or Paris meridian or to the Earth's center and subsequently compared to theoretical values obtained for the same location; 4) by averaging the differences between each pair of reduced observables (the observed and theoretically estimated ones) a set of averaged observed

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och i sanning mera fordrar en sund logica och riktig critique, än diupsinnig Mathematique. Aldra minst hade jag wäntat, at Herr Professorn emot mina skäl, allena tyckes wilja sätta en wiss auctoritet, som med al aktning för Herr Professorns person och egenskaper, jag icke kan finna mig uti at erkänna. Herr Professorn kan wara öfwertygad at Euler, den stora Euler, ingenting förmår öfwer mig blott genom auctoritet, mycket mindre någon annan".

[13] M. Hell: *Supplementum ad Ephemerides Astronomicas Anni 1774 ad Meridianum Vindobonensem*, Vienna, 1773.

[14] cf. (Lexell 1773). Lexell himself was contrary to publishing the letter. It is of course supplemented with Hell's own footnotes and refutations of Lexell's arguments.

differences Δ_{obs} and theoretical differences Δ_{theory} were obtained; 5) for each observation pair, the observed parallax was then given by the product of $\Delta_{\text{obs}}/\Delta_{\text{theory}}$ and the theoretical *a priori* parallax estimate π_{theory}. All the parallax values obtained in such a way were subsequently averaged and scaled according to the mean distance between the Sun and the Earth. Of course, for this procedure to be valid, the modeling equation has to be linear, which was only assumed, however.

Several variations of the method of averaging and comparison were used in 1769. As can be expected, they did not give uniform results, which caused much confusion and disagreements among the scientists. The solar parallax being an absolute constant, every pair of observation of Venus on the Sun's disk should obviously produce the same value for the parallax π. The fact that the results nevertheless differed from each other was mainly due to measurement errors, including imprecise instruments, individual reading errors, the effect of atmospheric refraction and so on. This posed a new problem of modeling: how to describe, by means of physical laws, the true observables, including the different sources of error. The problem was rarely understood at the time; among the few who did were Euler (and Lexell), as well as the French astronomer and mathematician Achille Pierre Dionis du Séjour (Verdun 2004).

Euler's method was presented as a section of the large second part of the fourteenth volume of the *Novi Commentarii*, pp. 321–554.[15] In the method, which also Lexell adopted (in its essentials) in his subsequent studies, the solar parallax was determined by fitting as many reliable measured observables to the observation equations concurrently – instead of pairwise comparison and averaging, which had been used previously, and was still used by most astronomers involved in the calculations based on the Venus transit of 1769. As indicated in the title of the work, the method was also applicable to the determination of longitude following the solar eclipse in 1769.

In Euler's method, the observables were described by mathematical relationships. All physical laws involved in the process and the quantities in these equations, the so-called model parameters, which are known only approximately because of the errors inherent in the observations, were modeled. The goal of the process is to adjust the parameters so as to minimize the sum of all estimation errors. The so-called observation equations were derived in three steps: 1° the geocentric angular distances between the center of the Sun's and Venus' discs at conjunction are determined from astronomical tables, 2° these elements are reduced to the pole of the equator and from there to the zenith of any place on Earth, and 3° the apparent distance between the centers of the Sun's and Venus' discs are determined in terms of the desired quantity, the solar parallax π. The derived observation equation contained several variables and constants to be determined. The ensuing adjustment process involved the following phases: minimizing the number of parameters by linear combinations of equations, grouping the equations according to the four contact moments, averaging the equations to determine approximations of the parameters searched for, computing more accurate theoretical elements and setting up new equations with correction terms as new unknowns. Finally, the corrections are determined so that the sum of the estimation errors is as small as possible.

Euler's method thus involved at least two novel ingredients, viz. statistical data processing and the minimization of estimation errors. The calculations were obviously very time consuming in those days – for today's personal computers they

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[15] Also in *Leonhardi Euleri Opera Omnia* Ser. II, Vol. 30, pp. 153–231.

would be the work of a few seconds – but considering that the theory of measurements, linear algebra and the method of least squares had not yet been developed, the results were astonishingly accurate.

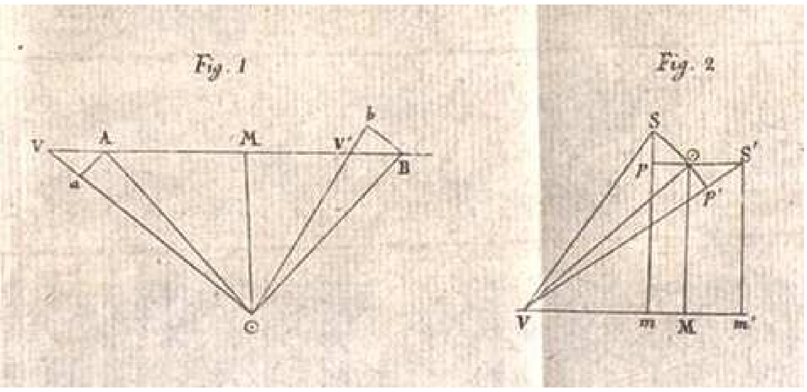

Figure 2. Pertinent to the geometry of the transit of Venus (Lexell 1771a). On the left, the effect of the parallax on the observation of Venus at ingress and egress. On the right, the corrections due to uncertainties in the observation of Venus' position.

The method Lexell used in his own contributions contains essentially the same ingredients as Euler's described above. Basically, it is given in (Lexell 1771a) written for the Swedish audience. Let us consider "Fig. 1" to the left in Fig. 2 (Lexell 1771a): Let VMV′ be Venus' orbit, $\odot$ the center of the Sun, and $\odot$M the smallest distance between the Sun and the orbit of Venus. Further, let A be the position of Venus at ingress (entry) and B its position at egress (exit), for either inner or outer contact, as seen from the center of the Earth. For the outer contacts, $\odot$A and $\odot$B equal the sum of the semi-diameters of the Sun and Venus. Correspondingly, for the inner contacts, $\odot$A and $\odot$B equal the difference of the semi-diameters of the Sun and Venus. Lexell's estimate for the semi-diameter of the Sun at the moment of transit was $947''$ and for Venus $29''$. Thus, for external contacts $\odot$A = $\odot$B = $976''$ and for internal contacts $918''$. The geocentric latitude of Venus (degrees above or below the ecliptic) was $10'13.4''$ and hence, the smallest distance $\odot$M = $606.7''$. Thus, for the external contact AM = $764.52''$, the corresponding duration for AM = $3^{\mathrm{h}}11'8''$ and hence, for the inclination of the ecliptic, the angle will be A$\odot$M = $51^\circ 33'56''$. Similarly, for the internal contact AM = $688.94''$, the duration of AM = $2^{\mathrm{h}}52'14''$ for the elements of the Sun on June 3. Hence, the angle will be A$\odot$M = $48^\circ 37'55''$. Now, V and V′ are the positions of Venus when, somewhere on the Earth, a contact (external or internal) is observed at ingress or egress, respectively. If $\odot a$ = $\odot$A and $\odot b$ = $\odot$B, then Va and V′b represent the parallax effects in the directions V$\odot$ = V′$\odot$. In the direction of the orbit VA, the effect is obtained approximately by the relationship VA = Va $\sin$(VAa) $\csc$(VAa) when the *a priori* estimate $8.''5$ for the solar parallax is used.

Next, the influence of the uncertainty of $\odot$A and $\odot$M is studied (cf. "Fig. 2" to the right of Fig. 2). First, let $\odot$V be constant while $\odot$M suffers a slight augmentation. From V, a circular arc CS is drawn, and the line Sm parallel to $\odot$M. Sm denotes the true distance between the centers of the Sun and Venus. Further, $\odot p$ is drawn parallel to VM, and Sp is the small correction needed for $\odot$M. Then, in the triangle S$\odot p$, $p\odot$ = Mm = Sp, which is the amount VM has diminished. Second, let $\odot$M be constant while $\odot$V endures an augmentation S$'p'$. If S$'m'$ is parallel to $\odot$M, then M$m' = \odot$S$' = p'$S$'$. Hence, the total correction is VM $=$ S$'p'\sec(\odot$VM$) -$ S$p\tan(\odot$VM$)$. When the parallax-effect in the direction $\odot$V is denoted $\alpha\pi$, and denoting by π the horizontal parallax, and setting S$p = y$, and S$'p' = \mu$ for external contacts and ν for internal contacts, we get the equations

$$\mathsf{VM} = 764.52 \pm \alpha\pi \sin \mathsf{V}a\mathsf{A} \csc \mathsf{VA}a - y \tan \odot\mathsf{VM} + \mu \sec \odot\mathsf{VM},$$

$$\mathsf{VM} = 688.94 \pm \alpha\pi \sin \mathsf{V}a\mathsf{A} \csc \mathsf{VA}a - y \tan \odot\mathsf{VM} + \nu \sec \odot\mathsf{VM},$$

for external and internal contacts, respectively. Correspondingly, knowing the speed of Venus with respect to the Sun, the durations for the respective distances VM are

$$\mathsf{T} = 3^{\mathrm{h}}11'8'' \pm 15(\alpha\pi \sin \mathsf{V}a\mathsf{A} \csc \mathsf{VA}a - y \tan \odot\mathsf{VM} + \mu \sec \odot\mathsf{VM}),$$

$$\mathsf{T} = 2^{\mathrm{h}}52'14'' \pm 15(\alpha\pi \sin \mathsf{V}a\mathsf{A} \csc \mathsf{VA}a - y \tan \odot\mathsf{VM} + \nu \sec \odot\mathsf{VM}).$$

Finally, for each site of observation, expressions are formed for the external contact at ingress T, the internal contact at ingress T$'$, the internal contact at egress T$''$ and the external contact at egress T$'''$. Then a series of equations follow for each observation site and when they are compared to the actually measured times at respective stations, they lead to an over-determined system of equations, to which a best possible estimate is sought (with respect to some unspecified norm), allowing certain corrections in longitude (μ and ν) and latitude y.

4. Conclusions

Anders Johan Lexell had high scientific ideals. While wishing to stand aloof from petty quarrels and vanity in his dedication to "pure science", he soon found himself in the midst of a scientific controversy guided by other factors entirely than the pursuit of Truth. To Lexell's dismay, the vices of personal ambition and protonationalistic sentiments dominated the academic scene. Hell, Lalande and Planman were all senior professors; Lexell a mere adjunct. Being the youngest and least merited, his "claim to fame" on the international stage was perhaps less obvious, but acting as he was on behalf of the high-ranking Imperial Academy of Sciences of Saint Petersburg and the world-famous Euler, his calculations nevertheless gained considerable attention. The determination of the solar parallax had been Lexell's first test as an astronomer. When reading through his various publications on the subject, one may conclude that he succeeded better than most contemporaries to focus on the scientific rather than the non-scientific. Lexell was always careful to argue *ad rem* instead of *ad hominem*. Apart from his Latin and Swedish publications already mentioned, Lexell's German contributions in the *Astronomisches Jahrbuch* of Berlin (1775a,b) published in 1775 contain the summit of his contribution to parallax computations, not only the parallax of the Sun, but of any star or distant object. The clarity and mathematical perspicuity of his texts make them well worth re-visiting.

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Politicians, Patriots and Plotters: Unlikely Debates Occasioned by Maximilian Hell's Venus Transit Expedition of 1769

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Abstract. This paper discusses the cultural and political contexts and reception of the most important by-product of Maximilian Hell's famous Venus transit expedition of 1768–69, the *Demonstratio. Idioma Ungarorum et Lapponum idem esse* (1770) by Hell's associate János Sajnovics. Now considered a landmark in Finno–Ugrian linguistics, the *Demonstratio* addressed an academic subject that was at that time almost destined to be caught up in an ideological battlefield defined by the shifting relationship between the Habsburg government, the Society of Jesus, and the Hungarian nobility. The "enlightened absolutist" policies of the former aimed at consolidating the Habsburg monarchy as an empire, at the expense of privileged groups, including religious orders as well as the noble estates. In the situation created by the 1773 suppression of the Jesuit order (a signal of declining patronage from the dynasty), the growing preoccupation on the part of ex-Jesuits like Hell and Sajnovics with "things Hungarian" could have been part of an attempt to re-situate themselves on the Central European map of learning. At the same time, the founding document of this interest, the *Demonstratio*, evoked violent protests from the other target of Habsburg policies, the Hungarian nobility, because its basic assumptions – the kinship of the Hungarian and the Sámi (Lappian) language – potentially undermined the noble ideology of social exclusiveness, established on the alleged "Scythian" ancestry of Hungarians. By exploring the complex motives, intentions, reactions and responses of the chief agents in this story, it is possible to highlight the extra-scientific constraints and facilitators for the practice of knowledge in late eighteenth century Central Europe.

1. Hell's 1768–69 expedition in context

For obvious reasons, most of the contributions to these proceedings can be firmly located in the history of astronomy, or indeed the study of the pursuit of astronomy in the past and the present. This article is a reminder that more often than not, the practice of field science is pluri-disciplinary, heavily context-dependent and contingent, and as such it tends to be caught up in a complex web of constraints and agendas, many of which are extrinsic to science "proper". Voyages of exploration and scientific expeditions are just too expensive: few, if any, patrons can afford restricting the recognition they might earn from their sponsorship to achievements in a narrow disciplinary area, and even if they could do so, they tend to prefer throwing the net wider. The 1768–69 Venus transit expedition to Vardø, hallmarked by the name of the Viennese Imperial and Royal Astronomer Maximilian Hell, is a case in point.[1] For the purposes of the expedition, Hell temporarily became a servant of two masters: Christian VII of Denmark–Norway, who issued the invitation and secured the finances, and his regular employer Empress Maria Theresa. From the

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[1] For the most recent and most comprehensive discussion of the expedition as a whole, see Aspaas (2012).

perspective of the former, besides the astronomical observations, geomagnetic and other measurements carried out during the trip, and a general mapping of the resources of the northern fringes of the realm offered attractive prospects, while the latter seems to have encouraged an already existing interest on the part of Hell and his associate János (Joannes) Sajnovics in the empirical verification of the theory of the kinship between the Sámi (Lappian) language with Hungarian. Below, I shall be preoccupied with this last aspect, and argue that as this theory had ideologically sensitive implications, the reception of the whole achievement of the expedition can only be fully assessed by a consideration of its overall cultural and political context in the contemporary Habsburg Monarchy.

The cross-disciplinary dimension of the expedition of 1768–69 was accurately, if synoptically, indicated by Hell both in the introductory section of the main product of the expedition, the *Observatio transitus Veneris ante discum Solis die 3 junii anno 1769* (Copenhagen, 1770; also printed in the Leipzig-based *Nova Acta Eruditorum* in 1770, and in the annual edited by him, the *Ephemerides astronomicae ad meridianum Vindobonensem* for the year 1771). It was also mentioned in the call for subscriptions of the grand project which never came to be accomplished: a richly illustrated three-volume *Expeditio litteraria ad Polum Arcticum*, which would have consisted of a "historical", a "physical" and a "mathematical–astronomical" volume. The expedition targeted a largely unexplored geographic area, not reached by the famous predecessors in the region. The 1732 Lapland expedition of Linnaeus was motivated by "the utility of scientific journeys within the fatherland": sponsored by the Uppsala Royal Society for Science, it was a patriotic venture to explore "natural" resources from minerals through plants and animals to local technologies and ethnography, with an eye to the "economical" and to classifying the finds as national secrets.[2] At the same time, the regions of the far north were subject to a scientific exoticism that in certain respects is reminiscent of the curiosity about distant continents. In 1736–1737, a French geophysical survey headed by Pierre Louis Moureau de Maupertuis and intent on determining the shape of the Earth once and for all had traveled to northern Scandinavia ("Laponie" as they exoticized the Torne Valley where they carried out their triangulations),[3]. In a way, the Hell expedition aimed to unite the features of these two enterprises. Although in terms of subject matter unrelated to the issue of the transit of Venus, the main preoccupation of the expedition, Hell assured the readers of the *Observatio* that "nor have we neglected the facts that throw light on or supplement the natural history of the animal and vegetable world, such as mussels, herbs, algae, mosses, and making other observations especially useful in regard of their economic applications" and the "origins, language and different dialects of the Lappian nation living scattered in the North". Thus, even if "as a result of adverse weather conditions ... I were to be disappointed in regard of the often mentioned observation, this scientific expedition were still not entirely fruitless for the sciences and the useful arts".[4] The expedition held out the promise of a wealth of new information capable of breaking new ground in several fields of knowledge, which Hell expressed in the enlightened language of improvement.

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[2] For the cameralist-style preoccupation of "Linnean travel" with an endeavor to explore and establish a frame for rationalistically-governed autarchy, see Koerner (1994, 1996, 1999), Frängsmyr (1985) and Sörlin (1989).

[3] See Terrall (2002), Chapter 4.

[4] Hell (1770), p 4.

2. Sajnovics' *Demonstratio*

Apart from Hell's theory of Northern Lights and a few weather reports, nothing was published of the "physical volume" of the *Expeditio Litteraria*. The proposed contents of the *tomus historicus* fared much better. Although the diary kept throughout the more than two years between their departure from Vienna and arrival back there never got published, a version of the proposed ethnographic, linguistic and historical treatment of the Sámi (i.e. Lappians) appeared soon after their return in the form of Sajnovics' treatise *Demonstratio. Idioma Ungarorum et Lapponum idem esse* (Tyrnau, 1771 – extended Latin version of the text already published in Latin and Danish in Copenhagen in the previous year). True, among the scientific and learned public of Western Europe it received considerably less attention than even the partial accounts of the astronomical results of the expedition. In Hell's and Sajnovics' native land, however, the situation was the exact opposite, and the reasons for this were to be found in the peculiar cultural-political atmosphere of the times in the Kingdom of Hungary and her relations with the Habsburg administrative center.

Sajnovics was initially rather unenthusiastic about the task of studying the possible relation between Hungarian and Sámi, but under the influence of Hell – who was aware of the widespread preoccupation with Nordic cultures in contemporary Europe in general as well as some of the specific literature – and especially the experience of the first encounters with natives along the journey, his interest gradually awoke. The *Demonstratio* is considered a landmark in Finno–Ugrian linguistics, whose methodologically innovative features – especially the fact that beyond vocabulary and tone, he put a great emphasis on grammatical comparison in demonstrating linguistic kinship – eclipse such dilettante aspects of the work as the derivation of the Lappians from northern China, and the further speculation on the kinship of Hungarian and Chinese (prompted by Hell and the recognition, in a Chinese vocabulary, that certain Chinese words when read backwards resemble Hungarian ones). It both fitted into the development of eighteenth-century linguistic studies, and gave them further impetus, which was usually recognized by contemporaries in Europe.[5]

By itself, the positing of the kinship of Hungarian and Lappian was nothing new; nor, it must be added immediately, was it the achievement of Sajnovics' work as a piece of academic linguistics that it met a torrent of response, predominantly negative, in Hungary. Ever since the Hamburg scholar Martin Fogel (Fogelius), mainly on the basis of shared etymologies, first raised the idea seriously in *De lingua indole Finica Observationes* (1669), the notion of a Finno–Ugrian community of languages and the special relationship of Finnish, Lappian and Hungarian recurred in the work of scholars from several European countries: Swedes (including Philipp Johann von Strahlenberg, the first to focus on the comparison of the "most ancient" stock of vocabulary: numerals, limbs, simple tools and actions), Germans (such as Leibniz, as well as Johann Eberhard Fischer), and Hungarians. Among the latter, the remarkable Lutheran antiquarian scholar Dávid Czvittinger was the first to embrace the Finno–Ugrian theory in his *Specimen Hungariae Litteratae* (1711). There were several others to prepare the ground for Sajnovics, including individuals who did so despite their uneasiness with the theory, such as Mátyás (Matej) Bél, who presumed to identify the remnants of the "Hungarian–Scythian" language in Finnish.[6]

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[5] For a concise discussion in English, see Vladár (2008).

[6] In this sketch I am relying on Domokos (1998).

The idea of a prestigious steppe kinship of the Hungarians with the mighty Huns, which is also apparent in Bél's mild statement, was the standard narrative of the subject matter ever since the early Middle Ages.[7] It became firmly tied up with the theory of a corporate polity, in which the scions of an (originally) military aristocracy enjoy pre-eminence, in the *Gesta Hungarorum* of Simon Kézai (1282/1285). Scythianism refers to both a theory of national origins and the privileged status of those defined as members of the *corpus politicum* after the dissolution of the ancient self-governing community, which ensued because of the contempt of some for the call to arms issued "in the name of God and the people". It then received reinforcement from legal humanism in the *Tripartitum* of István Werbőczy (1517),[8] a culmination of the centuries-old process of collecting "the customary law of noble Hungary", and was still a staple of Hungarian late baroque noble consciousness, also underpinned by the traditional classification of the Hungarian language as one of the "oriental" languages, along with Turkish and Mongolian (and Hebrew, and Chaldean and Arabic, and Armenian, and Persian . . .). Questioning one pillar of this complex intellectual edifice constituted a challenge to the entire ideological frame and, especially in politically critical times, could expect an appropriate response.

This is more or less what happened in the case of the *Demonstratio.* In regard of its reception it is meaningful to distinguish between the international and academic on the one hand, and the domestic and lay-literary on the other hand. Already in the *Allgemeine nordische Geschichte* (1771), relying extensively on Fischer's books (*Sibirische Geschichte*, 1768; *De Origine Ungrorum*, 1770), the famous Göttingen scholar August Ludwig Schlözer recognized Sajnovics' achievement, and later encouraged Sámuel Gyarmathi's work, who pursued Finno–Ugrian research beyond Sajnovics in both methodological and empirical terms.[9] In fact, strictly academic circles almost invariably welcomed Sajnovics' theory in Hungary too. Even the Jesuit scholar, György Pray, the greatest contemporary authority in historical research, felt compelled to modify his earlier views on the subject in his *Dissertationes historico-criticae in annales veteres hunnorum, avarum et hungarorum* (1775) – although, like Bél before him, by simply claiming a Hun pedigree for Finno–Ugrian peoples as well.[10] It must also be added that the only *linguist* to champion the alternative concept in Sajnovics' lifetime, György Kalmár, published his relevant work nearly simultaneously with the *Demonstratio*, so his *Prodromus idiomatis Schytico-Mogorico-Chuno-(seu Hunno-) Avarici, sive adparatus criticus ad linguam Hungaricam* could not have been a response to Sajnovics (Éder 1999, p. 49). In other words, the issue here was not (yet) that of an academic debate,[11] the more so as contemporary scholars used the terms "linguistic family" or "linguistic kinship", if

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[7] For a brief introduction to this tradition and its ideological significance, see Kontler & Trencsényi (2007); see Szücs (1981) for more details.

[8] Several studies in Rady (2003).

[9] For Schlözer and his Hungarian connections, see Balázs (1963); Poór (1989); Futaky (2007).

[10] Kosáry (1980), p. 575. In the abridged English edition, there are short summaries of eighteenth-century historical and linguistic scholarship, as well as the literary and cultural significance of the noble "bodyguards" (Kosáry 1987, pp. 149–154; 160–162; 195–200).

[11] This somewhat revisionist view of Hungarian scholarship on the subject is summarized, with references to the now extensive literature, in Lőrinczi (2000). During the subsequent century, however, a veritable "Ugrian–Turkic war" gradually unfolded and culminated in the 1860–1870s, among linguists and ethnographers, in which the notions of linguistic, cultural and genetic affinity and kinship became increasingly confounded.

ever, metaphorically at best, and without any clearcut frontlines between, say, the Scytho–Hungarian and the Finno–Ugrian "schools" (Hegedüs 2006, p. 300).

3. The political and ideological stakes of the *Demonstratio*

There was, however, one important and influential group on the public intellectual scene, which acutely realized the *political and ideological* stakes of the matter, and reacted accordingly: the men of letters of noble origin who dominated that scene before the 1780s and included, besides the chief Hungarian "Voltaireans" like Lőrinc Orczy and János Fekete, Ábrahám Barcsay, whose poetry gave expression to sensibility as well as anti-court political sentiment, and György Bessenyei, the emblematic figure of the Hungarian Enlightenment as a whole. Together they gave voice to the sentiments of a sizeable elite group whose cultural and intellectual horizons, thanks to their education as members of Maria Theresa's famous Hungarian Guards,[12] were broadly European, but whose vision of the future restoration of the erstwhile greatness of the Hungarian nation was predicated on galvanizing their own class to a new dynamism through modern letters and knowledge practices. This was a vision of improvement which, in their own view, depended on maintaining a discourse of identity built on a prestigious pedigree and social exclusiveness, both under serious attack from the mid-1760s on by the Viennese court and government, towards which their attitudes were therefore highly ambivalent. In this atmosphere, the implications of Finno–Ugrianism – understood by them as not only linguistic but also ethnic kinship – seemed to them highly disturbing.

Barcsay's poetry abounds in rebuffs addressed to Sajnovics whose "yoke" was perceived by him a vital threat to ancient liberties, established on the cornerstone of the idea that Hungarians are "the valiant grandsons of Scythians". Similarly, in his "The Errors of Star-Watcher Sajnovits and Hell Being Refuted", Orczy casts doubt on the allegation that the progeny of Alexander the Great's brave opponents should be related to mere Lappians munching on dried fish – but recommends "the astronomer" to return to these "kind relatives" of *his*: a hint at Sajnovics' *Slavic* ethnic background. This tacit reference to Slavic mischief as a possible motive to Sajnovics' work leads us to the political context. Just a few years earlier, the diet of 1764–1765 ended in bitter estrangement between the Hungarian nobility and the Viennese government, the court having failed to push through a package of administrative and social reforms which drew inspiration from the work of the newly established chairs of cameralist sciences and natural law at the University of Vienna, hallmarked by the names of Karl Anton von Martini and Joseph von Sonnenfels.[13] Court propaganda on behalf of the proposed measures received a boost from a treatise by Adam Franz Kollár, *De originibus et usu perpetuo potestatis legislatoriae circa sacra apostolicorum regum Ungariae*. Kollár, who was proud of his Slovak commoner origins, called into question many of the political and social privileges of the Hungarian ecclesiastical and secular elites, criticizing Werbőczy in especially sharp terms, and causing great consternation among the clergy and the

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[12] On the Hungarian Guards, with references to the figures mentioned, see Deme (1988). The Hungarian language literature is respectable. However, historians have hitherto largely yielded the field to literary scholars, whose main preoccupation has been the rise of vernacular literature, and are yet fully to discover the subject and approach it with their own questions. The standard monograph is Bíró (1994).

[13] For a contextualized assessment of these initiatives, see Klingenstein (1994). Cf. Kontler (2012).

nobility. Characteristically, Kollár's anti-feudal polemics was readily associated by this constituency with anti-Hungarian sentiment, identified in his commentary on *Hungaria*, a work by the sixteenth-century humanist Miklós Oláh (Nicolaus Olahus), which Kollár edited and published in 1763.[14] These comments, which refer to the statistical minority of Hungarians in the Kingdom of Hungary and predict the gradual demise of the language as well as the nation itself, became European currency through being quoted in Schlözer's *Allgemeine nordische Geschichte*, which in turn seems to have inspired Herder's famous "prophecy" to the same effect. The latter's prediction that the Hungarian nation, amidst the "ocean" of Slavic peoples, will inevitably perish, was underpinned by his theory (available in publication for the first time also in the late 1760s and early 1770s) on the crucial role of language in the formation of human identities. Herder claimed that "all conditions of awareness in [man] are linguistic" – thus, as language acquisition took place in communities, reason and the capacity of thinking, the very distinguishing feature of the human animal, was bound to have as many modes as there were human communities.[15] Members of the Hungarian intellectual elite had good reasons for being attentive to his views, and also for taking them as an alarm bell. These developments also established Schlözer's notoriety as an "anti-Hungarian", apparently confirmed by the fact that his social and political views were based on the same foundations as the Viennese reformers – no wonder that the next, "Josephist", generation of young enlightened Hungarians cultivated his courses at the University of Göttingen.[16] In any case, by championing the Lappian cause, for an influential segment of the contemporary enlightened political public, Sajnovics and his mentor Hell seemed to be the Jesuit hirelings of a hostile court, employed in a plot which also involved willing collaborators from the camps of old and new national enemies, Germans and Slavs.[17]

Finally, in many ways, Bessenyei is a category of his own with his comprehensive programme urging the improvement of public happiness through the cultivation of the arts and sciences, of historical and political knowledge in the vernacular. His engagement with the topic of national origins, and thus (ethno-)linguistic kinship, was conceived in the peculiarly eighteenth-century genre of philosophical history, works which also highlight the fundamental principles of this programme, in all their ambiguity.[18] In many ways, he employed the standard enlightened narrative to give an account of Hungarian history in a European framework as the successive

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[14] Cf. Evans (1990); Dümmerth (1963; 1967).

[15] *Treatise on the Origin of Language* (1772), in Herder (2002), p. 131, 150; see also *Fragments on Recent German Literature* [1767–1768], in op. cit., p. 49.

[16] On the central role of the University of Göttingen as a point of orientation and a source of inspiration for the rank-and-file of Hungarian Josephists, see Balázs (1967), pp. 86–117. Some of the argument is worked in Balázs (1997).

[17] A Google search on Hell and Sajnovics demonstrates in a few seconds that this representation is still alive and well among a somewhat less enlightened segment of the political public. – Late eighteenth-century attitudes to Jesuits, both before and after the dissolution of the order, were diverse. On the one hand, in scholarly circles there was a great deal of mutual respect and communication between Jesuits and Protestant scholars, and even personally expressed sympathy by the latter on the occasion of the dissolution. On the other hand, in the public-political domain the old Protestant topoi about the "conspiratorial bent" of the Jesuits remained common currency.

[18] On Bessenyei's project and its different aspects, see Bíró (1998), esp. pp. 69–92; 161–185. On some aspects of Bessenyei's work in the genre of philosophical history, see Penke (2000), pp. 176–183; 211–218.

stages of the "mitigation" of rude manners, resulting from religion and learning, but also claimed that military glory and polite letters, rather than being antagonistic, could mutually supplement one another.[19] This, of course, nicely dovetailed with his overall conviction that *vera nobilitas* could derive from proficiency in letters as well as armsbearing. Assigning an unassailable social pre-eminence to the nobility on account of its historical roles, what he sought was a new justification for these roles, to be found in superior learning, while he still regarded the gulf that separated the nobility from the commoners, especially the peasantry as unbridgeable – and supported this from Werbőczy in a political terminology recalling the staples of Scythianism.[20] Thus the ideological stakes of the available discourses of origin, to which the position taken by Sajnovics was directly relevant, were as formidable for him as for any of the above authors.

Though Bessenyei's relevant statement – significantly enough, contained in a work entitled *Magyarországnak törvényes állása* (The Legal Status of Hungary) – derives from the times of his retirement to his estate, some thirty years after Sajnovics' treatise burst onto the scene, in it he advanced views most probably first developed and discussed with other opponents, back in the 1770s. Bessenyei bluntly claimed that "it is impossible to displace something of such a great consequence, on the basis of so little a circumstance [as language], and set it on a different footing", and suggested that "instead of words, one should consider moral character and manners" (the standard analytical categories of philosophical history). This lens shows the "Scythian" and the "Lappon" to be separated by a yawning gap: in the subsequent representation, the latter becomes the target of consistent "othering" by Bessenyei. In contrast to the people of Attila, marked by "its thirst for triumph, valour and glory, as well as its sagacity required for domination", the "Lappon" was deformed in his outward appearance as well as his manners: on top of his "ugliness of form, the Lappon is vile and fearful, it is such a subterranean mole of a Nation, which loathes the fight, and never wages war."[21]

4. An interesting paradox

We are dealing here with an interesting paradox. Bessenyei defended a view of national origins which was scientifically obsolete and was under challenge by one that was sound. The former theory, Scythianism, was deployed by him, in the best traditions of Enlightenment social science, with reference to the category of manners and virtues (or the lack of them), while at the same time in the polemic against "Lappianism" coming dangerously close to being conveyed in racial terms. To be sure, this combination was by no means unusual among eighteenth-century scholars:

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[19] The latter principles were developed in Bessenyei's *A magyar néző* [The Hungarian spectator, 1778], to be supported with a historical argument in *A magyar nemzetnek szokásairul, erköltseirül, uralkodásának modjairul, törvényeirül, és nevezetesb viselt dolgairul* [The customs, manners, modes of government, laws and important deeds of the Hungarian nation, 1778] and its appendix on "the form of the whole of Europe in the eleventh century" (*Egész Európa' formája a XI^{dik} Százban* – excerpted from Voltaire's *Essai sur les moeurs*, pp. 39–46), intended to demonstrate that in those times Hungarians were not any more barbarous than other European nations.

[20] Bessenyei (1992), p. 175, 177.

[21] Bessenyei (1986), pp. 231–5. The passage is almost a literal translation from the national characters in Dom Joseph Vaissete's *Géographie historique, ecclésiastique et civile, ou description des toutes les parties du Globe terrestre* (Paris, 1755).

suffice it to refer to the derogatory observations of Cornelius de Pauw to the natives of North America,[22] or – in an academic environment with which late eighteenth-century Hungarians were intimately familiar – the unflattering classification of the "Mongol" race (supposedly giving rise to the peoples of Eastern Asia, North America and Africa) by the Göttingen historian Christoph Meiners.[23] However, language, although recognized as an important racial marker – and a more inherent one than manners – did no more seriously enter into their considerations than in those of Bessenyei. This sort of "enlightened racism" was tailor-made to the Hungarian writer's agenda, a programme of elevating the cultural level of the country, in the conviction that while martial valour is capable of being translated into virtue in letters, dumb and smelly fishermen would never attain to this. Kinship with the latter was therefore repudiated in violent terms of othering, together with the phenomenon of language as representing any *analytical* value, albeit – to amplify our paradox – its cultivation, as a *tool* of improvement, was deemed by Bessenyei indispensable for the achievement of his ends. However much he claimed, famously, that "as long as her own language remains uncultivated, no Nation in this World will become learned in foreign tongues,"[24] he retained his scepticism about language as the constitutive element of community. Hungarian enlightened patriots like him continued to insist on the role of "virtue" in cementing the community, only they urged that virtue in arms ought to be replaced by "virtue in letters", i.e., promoting improvement. The scientifically sound Finno–Ugrian theory on the other hand gave a boost to ethno-linguistic definitions of nationhood, which started to emerge in the context of efforts by the same enlighteners who dismissed that theory but still fostered the cultivation of the mother tongue with a view to the requirements of socio-cultural progress. Conversely, Hungarian ethno-nationalism, which received an initial impetus from the discovery of Finno–Ugrian theory, has yet continued – to this day – to take immense satisfaction in the Scythian myth.

While Hell and Sajnovics were astronomers by employment, they possessed a broad-ranging erudition not only in the physical and mathematical sciences, but also in each of the diverse fields which they set out to explore during the expedition. The latter was therefore conceived by them – on the testimony of Hell's views expressed in the preface to the *Observatio*, but also Sajnovics' journal – as a unitary scientific enterprise. Yet this unity crumbled in the reception. While in Copenhagen and Trondheim Sajnovics was rewarded with academy membership for the findings of the *Demonstratio*, which also stimulated the interest of Schlözer at Göttingen and caused a great deal of agitation in Hungary, elsewhere it seems to have been taken little notice of. Conversely, while Hell's *Observatio* was quite extensively reported and reviewed in international venues of scientific communication, in Hungary – no doubt, in a large measure because of the virtual absence of such venues – appreciation for the team's achievements in astronomy remained sporadic, and in the existing fora of learned sociability references to their being "star-watchers" were ironic, intended to question their competence in the fields of language and ethnography. The reasons for this discrepancy may be partially found in the failure of Hell's grandiose – and perhaps not entirely realistic – project of serial publication. It may also have to do with the rather different character and level of technicality involved

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[22] For the classic exploration on de Pauw's thesis on the inferiority of native Americans and the debate provoked by it, see Gerbi (1973, Chapter 3); for developments upon Gerbi's perspective, Cañizares Esguerra (2001, Chapter 1); Sebastiani (2008, esp. Chapters 3–4).

[23] Lotter (1987); Marino (1995).

[24] Bessenyei (1983, p. 32).

in astronomical versus linguistic-ethnographic discourse and the concomitant divergence of the respective audiences. There is much further research to be done on each of these aspects, and many more. For the time being, one needs to stress once again the complexity, even inconsistency of contexts – aims and intentions, collaborations, simultaneities, conflicts – in whose hub the expedition can be located. It was these contexts, many of them definitely outside the domain of "pure science", that decisively influenced the selection strategies which local agents applied vis-à-vis the results of a scientific venture which its chief protagonists regarded as one and indivisible.

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OTHER TRANSIT HISTORIES 17th to 20th CENTURY

If any one desires to form an adequate idea of the difficulties
of measuring the Sun's distance to a million of miles,
let him try to measure the thickness of a florin-piece,
looked at, edge on, a mile off.

Isobel Sarah Black (Mrs. D. Gill)

MEETING VENUS
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From Keplerian Orbits to Precise Planetary Predictions: the Transits of the 1630s

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Abstract. The first transits of Mercury and Venus ever observed were important for quite different reasons than were the transit of Venus observed in the eighteenth century. Good data of planetary orbits are necessary for the prediction of planetary transits. Under the assumption of the central position of the Sun, Johannes Kepler published the theory of elliptical orbital motion of the planets in 1609; this new astronomy made it possible to compute noticeably improved ephemerides for the planets. In 1627 Kepler published the *Tabulae Rudolphinae*, and thanks to these tables he was able to publish a pamphlet announcing the rare phenomenon of Mercury and Venus transiting the Sun. Although the 1631 transit of Mercury was only observed by three astronomers in France and in Switzerland, and the 1639 transit of Venus was only predicted and observed by two self-taught astronomers in the English countryside, their observation would hardly been possible without the revolutionary theories and calculations of Kepler. The *Tabulae Rudolphinae* count among Kepler's outstanding astronomical works, and during the seventeenth century they gradually found entrance into the astronomical praxis of calculation among mathematical astronomers and calendar makers who rated them more and more as the most trustworthy astronomical foundation.

1. Introduction

The worldwide fame of Johannes Kepler (1571–1630) is based above all on his contribution to celestial mechanics and astronomy. Aided by the accurate observations of Tycho Brahe, he published a mature system of the world based on elliptical astronomy, celestial physics and mathematical harmonies: *Epitome astronomiae copernicanae* (Kepler 1618–21/1995). His groundbreaking and innovative work reached beyond the three laws on which his fame mainly rests today. Kepler also practiced what he preached and made astronomical predictions by his laws. Starting in 1617, he published planetary ephemerides that showed a marked increase in accuracy as compared to other tables that were in use at the time. After Kepler had published the *Tabulae Rudolphinae* in 1627 (Kepler 1627/1969), more and more ephemerides were calculated on the basis of this work in the following decades. Because of the high reliability of Kepler's tables, the Copernican doctrine gained more esteem (Gingerich 1968/1993). Although this was first restricted to the mathematical foundations of the system, as well as to Kepler's laws, it was more and more accepted that the Copernican doctrine was not just a new and useful mathematical hypothesis, but a reflection of reality.

Kepler, like many of the leading natural philosophers before him, had some explicit metaphysical guiding principles for his work. He firmly believed that God had created a harmonious well-ordered universe, and he saw his work as a God-given mission to understand its nature, principles and design (Kozhamthadam 1994; Methuen 1998; Martens 2000). The driving goal for Kepler was to carefully read the "book of Nature" and discover the orderly structure God had created in the universe. This order of nature was supposed to be expressed in mathematical language and its quantitative calculations.

Tycho Brahe had estimated the distance between the Sun and the Earth at 8 million kilometer. In *Epitome* Kepler estimated the solar distance to be 3469 Earth radii, actually the largest of his several estimates. This meant that the distance to the Sun was 24 million kilometers, and the solar parallax 1 arcminute. The solar parallax is the angle subtended by the equatorial radius of the Earth at its mean distance of the Sun. Kepler based his estimate on Tycho's attempted measurements of the parallax of Mars and on his own calculations of eclipses, which had convinced him that a solar parallax of more than $1'$ gave unsatisfactory results (van Helden 1985, 1989). We know now that this solar distance was roughly seven times too small,[1] and Kepler's understanding of absolute distances within the solar system remained considerably faulty although he mainly worked with *relative distances* based on the Earth–Sun unit, the so called *astronomical unit*.

On the basis of Tycho Brahe's observations, Kepler early in his career had calculated that Mercury would pass in front of the Sun at the end of May, 1607. He used a pinhole camera (camera obscura) to observe the event, and on May 28 a black spot was visible on the Sun's image between clouds. He concluded that he had seen a transit of Mercury, and published his observation in the report *Phaenomenon singulare seu Mercurius in Sole* (Kepler 1609/1941). Later on, when the sunspots had been discovered by the newly invented telescope, he realized that he had seen a sunspot, and he admitted his error in print.

2. Mathematical solution

Kepler was operating in a long-standing tradition of numerical calculation in astronomy. His new planetary theory was much more complicated than anything that had been done before. In the earlier theories, the orbit of the Earth and the planets were represented by two large circles, the deferent and the epicycle. Kepler's first law states that the planetary orbits are elliptical, and to compute areas inside the ellipse is not easy. For the astronomers time was represented by an angle, and in the Keplerian model there was no simple or exact way to find explicitly the position angle corresponding to a given time, and consequently there was no direct way to calculate the planetary position exactly from its date, as it had always been possible before Kepler. However, Kepler made his non-circular astronomy operational and computable by applying a set of innovative numerical methods (Thorvaldsen 2010).

In fact it was the use of an auxiliary circle that aided Kepler at this point. One of the fundamental properties of the ellipse is the ratio-property, that for any Q and P on a line perpendicular to CD, see Fig. 1:

$$QR/PR = \text{constant} \qquad (1)$$

Kepler's law states that time is proportional to the ellipse area ADP. This area is composed of the triangle ARP and the segment RDP. By Eq. 1 the triangle is proportional to the triangle ARQ and the segment is proportional to the segment RDQ. Consequently, time is proportional to the circle area ADQ which is

$$\beta + e \sin \beta \qquad (2)$$

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[1] The currently accepted value of the solar parallax is $8''\!.794$. The mathematical procedure behind computing the parallax based on transits of the Sun can be found in Teets (2003).

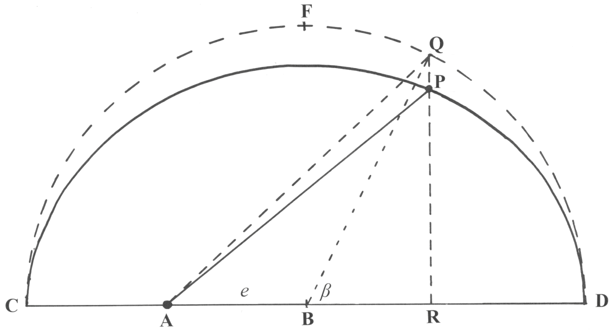


Figure 1. A is the position of the Sun and B is the center of the auxiliary circle. The planet is at P, and Q is its projection on the circle. Kepler's problem is to determine the angle β (the eccentric anomaly).

Here e is the constant AB and β the angle QBD called the *eccentric anomaly*. Analytically, Kepler expressed the problem by the equation

$$M = \beta + e \sin \beta$$

where M is the quantity used to designate time (the *Mean anomaly*). Kepler measured M as a fraction of the area of the full circle, i.e. an area of 360° (21600′, or 1296000″). The Mean anomaly is proportional to the time elapsed, and it is as a function of time that we wish to find the position of the planet P. So the important problem is to find β when M and e are given. This transcendental equation is called *Kepler's equation* and turned out to be a famous problem as it is fundamental in celestial dynamics (Colwell 1993). Kepler could only solve it by approximations (Swerdlow 2000; Thorvaldsen 2010).

The problem was stated at the very end of *Astronomia nova* (Kepler 1609/1992, 600). In *Epitome*, book 5, part II, chapter 4 (Kepler 1618-21/1995, pp. 158–59) he gives a numerical example with three iterations as shown in Table 1. The eccentricity e is determined from the area of the triangle ABF, which he says he earlier had calculated to be 11 910″.

Table 1. Kepler's numerical solution of his equation in *Epitome*, book 5, part II, chapter 4, compared to a simple computer iteration based on $\beta_n = M - e \sin \beta_{n-1}$ in `Microsoft Excel`. Eccentricity $e = 0.05774$, and the Mean anomaly $M = 50°09'10''$ ($= 0.87533$ radians). The convergence is quite rapid in this case.

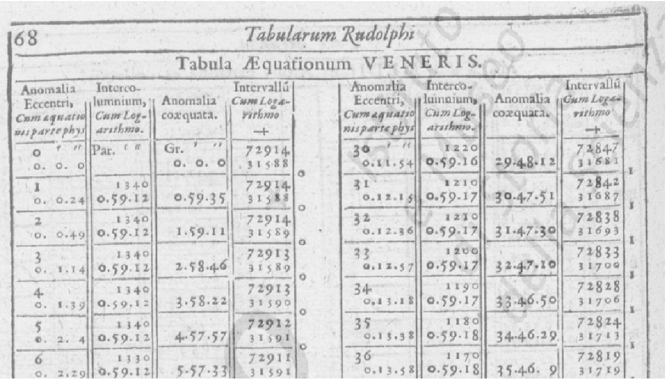
Kepler in *Epitome*		Calculated	
degrees	radians	radians	iteration #
44° 25′	0.77522	0.77522	β
46° 44′	0.81565	0.83492	β_1
47° 44′ 6″	0.83313	0.83253	β_2
47° 42′ 17″	0.83260	0.83262	β_3

Kepler's method can be described as a simple numerical "fixed point method", that is, an iterative algorithm that generates a convergent sequence whose limit is the solution of the proposed problem: $\beta_n = M - e \sin \beta_{n-1}$.

He called his method to solve equations the *regula positionum* (rule of supposition), probably an allusion to the classical method of *regula falsi* (rule of false position). But he made no closer examination of the speed of convergence or errors involved. Later, in his *Tabulae Rudolphinae*, Kepler solved the equation for a grid of uniformly spaced angles, that determined a set of non-uniformly spaced times. By an interpolation scheme the desired values of time could be determined, and hence the tedious iterations were avoided for the users of his tables.

During the years 1614–1630 John Napier's (1550–1617) discovery of *logarithms* rapidly spread within mathematics, and was exploited by Kepler to speed up the astronomical calculations and ease the pain of the process. He was deeply impressed by the discovery when he got a copy of Napier's book in 1619. Lacking any description of their construction, he recreated his own tables by a new procedure. Kepler's logarithms were different from Napier's work, which had started from visible geometric notions. Contrary to this, Kepler derived his numbers purely arithmetically by starting from the theory of proportions. Some years later he published his own theory and tables *Chilias logarithmorum*, composed in 1621–22 and printed in 1624.

Kepler's *Tabulae Rudolphinae* were completed in 1624, and printed in 1627, see Fig. 2. The tables were based on Tycho Brahe's data, which were much more accurate observations than any made before, and Kepler's new mathematical model. Instead of providing a sequence of solar and planetary positions for specified days (like modern almanacs), the *Tabulae Rudolphinae* were set up to apply interpolation for the calculation of solar and planetary positions for any time in the past or in the future. The finding of the longitude of a given planet at a given time was based on Kepler's equation and he exploited logarithms for this tabulation. In European history these tables were the third truly new set of planetary tables, following the tables of Ptolemy and Copernicus' defenders. Kepler considered these tables his principal astronomical result. The *Tabulae Rudolphinae* were intended for general use among academics with the necessary knowledge of astronomy, and according to Kepler, the first edition was apparently as large as 1000 copies. The tables of Philip van Lansbergen (1561–1632) were the main competitor in the 1630s (van Lansber-



68 *Tabularum Rudolphi*

Tabula Æquationum VENERIS.

Anomalia Eccentri, *Cum æquationis parte phys*	Intercolumnium, *Cum Logarithmo.*	Anomalia coæquata.	Intervallū *Cum Logarithmo* +		Anomalia Eccentri, *Cum æquationis parte phys*	Intercolumnium, *Cum Logarithmo.*	Anomalia coæquata.	Intervallū *Cum Logarithmo* +	
0 ′ ″ 0. 0. 0	Par. ′ ″	Gr. ′ ″ 0. 0. 0	72914 31588	0	30 ′ ″ 0.11.54	1220 0.59.16	29.48.12	72847 31681	1
1 0. 0.24	1340 0.59.12	0.59.35	72914 31588	0	31 0.12.15	1210 0.59.17	30.47.51	72842 31687	1
2 0. 0.49	1340 0.59.12	1.59.11	72914 31589	0	32 0.12.36	1210 0.59.17	31.47.30	72838 31693	1
3 0. 1.14	1340 0.59.12	2.58.46	72913 31589	0	33 0.12.57	1200 0.59.17	32.47.10	72833 31700	1
4 0. 1.39	1340 0.59.12	3.58.22	72913 31590	0	34 0.13.18	1190 0.59.17	33.46.50	72828 31706	1
5 0. 2. 4	1340 0.59.12	4.57.57	72912 31591	0	35 0.13.38	1180 0.59.18	34.46.29	72824 31713	1
6 0. 2.29	1330 0.59.12	5.57.33	72911 31591		36 0.13.58	1170 0.59.18	35.46. 9	72819 31719	

Figure 2. Portion of one of the pages in the *Tabulae Rudolphinae* from 1627. This particular table provides data for predicting the position of Venus, and is used in converting the planet's Mean anomaly M to eccentric anomaly β, that is, in the solution of what was later called Kepler's transcendental equation.

gen 1632). They supported Copernican theory, but rejected Keplerian ellipses by preferring the traditional eccentrics and epicycles instead.

Kepler, apparently, did not get much response from the leading natural philosophers of his time. Bacon, Hobbes, Pascal, Galileo and Descartes failed to notice what are today considered to be Kepler's major achievements (Applebaum 1996), although they were not the mathematical astronomers to whom his work was directed.

3. Prediction of the 1631 transits

Those who had reservations about Kepler's theory generally were willing to wait for empirical verifications. In preparing ephemerides for the years 1629–1636 from the *Tabulae Rudolphinae*, Kepler found that a transit of Mercury would take place on November 7, 1631, followed a month later by a transit of Venus (see Fig. 3). Hence, the new theory was put to an important empirical test, and in 1629 he published the eight-page pamphlet *De raris mirisque Anni 1631 Phaenomenis* (Kepler 1629)

JOANNIS KEPLERI
Mathematici Cæſarei, &c.
De raris mirisq;
Anni 1631. Phænomenis,
Veneris putà & Mercurii in Solem
incurſu,
ADMONITIO AD ASTRONO-
MOS, RERUMQVE COELESTIUM
STUDIOSOS:
Excerpta
Ex EPHEMERIDE Anni 1631. & certo
AUTHORIS conſilio huic præmiſſa, & edita
à
M. JACOBO BARTSCHIO,
Laubano, Mathem. & Med. C.

LIPSIÆ,
JOAN-ALBERTUS MINZELIUS excudebat.
ANNO M DC XXIX.

Figure 3. Kepler predicted the 1631 transits (Kepler 1629).

about these rare phenomena, though the last one would possibly not be observable from central Europe, but "sailors navigating the ocean and learned men living in America, Mexico and the neighboring provinces" might have the pleasure of the celestial spectacle. The astronomers in Europe were asked to observe and time the transit of Mercury. According to his calculations, Venus should appear on the solar disc as a dark spot with nearly a quarter of the Sun's diameter. The work contained no estimate of the size of Mercury.

Kepler did not live to see the prediction fulfilled. His old friend professor Wilhelm Schickard (1592–1635) at the University of Tübingen was one of those who prepared for observing Mercury with a kind of pinhole camera, but was hindered by bad weather.

Only three observers are known to have witnessed this important celestial event and to verify the reliability of Kepler's predictions. In Paris the transit of Mercury was observed by the French philosopher, mathematician and astronomer Pierre Gassendi (1592–1655). The transit was also observed from Innsbruck by Johann Baptist Cysat (1588–1657), a Swiss astronomer and Jesuit, whom Kepler had visited in Ingolstadt. Finally, the transit was observed by Johannes Remus Quietanus (1588?–1632?) in Rouffach in the North-East of France (Upper-Rhine, Alsace), and by anonymous Jesuit observers from Ingolstadt.

All these observers used telescope projection, and an adaptation of what by then was the standard method for viewing sunspots. Observers using techniques based on pinhole cameras saw nothing. One important discovery that impressed the observers was the surprising smallness of the projected Mercury image. Gassendi, Cysat and Quietanus reckoned it to be $20''$, $25''$ and $18''$, respectively, when measured as a fraction of the already known solar diameter. Both Schickard and Cysat argued that this smallness may be because the Sun illuminates more than half of Mercury's globe since it is so much larger, and perhaps Mercury also had a solid core surrounded by a transparent edge that refracted the sunlight passing over it. Another important discovery was the planet's perfect roundness and very black appearance suggesting that Mercury was a spherical, solid globe instead of being made of a self-luminous and possibly translucent "quintessence", or fifth element, as the geocentric astronomers had argued.

Gassendi's observation (Fig. 4) was the only one to find its way into print, and in his open letter to Schickard, he reported (Gassendi 1632, translated by van Helden 1976):

> When the Sun returned just after nine o'clock I aligned the diameter of the circle through the supposed spot in order to measure its distance from the center of the circle, hoping should Mercury perhaps appear later, to compare him with this spot in various ways. If indeed we were to rejoice in this opportunity and the occurrence was observed by others by a similar method, something could be said about the parallax, either very small or zero. I therefore ascertained that distance to be sixteen divisions [from the periphery of the circle]. After a sensible delay between observations, and having restored the Sun again along the direction of that diameter, as before, I observed that the said distance had become four divisions greater. Thereupon, thrown into confusion, I began to think that an ordinary spot would hardly pass over that full distance in an entire day. And I was undecided indeed. But I could hardly be persuaded that it was Mercury, so much was I preoccupied by the expectations of a greater size. Hence I wonder if perhaps I could not have been wrong in some way about the distance measure earlier. And

> then the Sun shone again, and I ascertained the apparent distance to be greater by two divisions (now, in fact, it was twenty-two), then at last I thought that there was good evidence that it was Mercury.

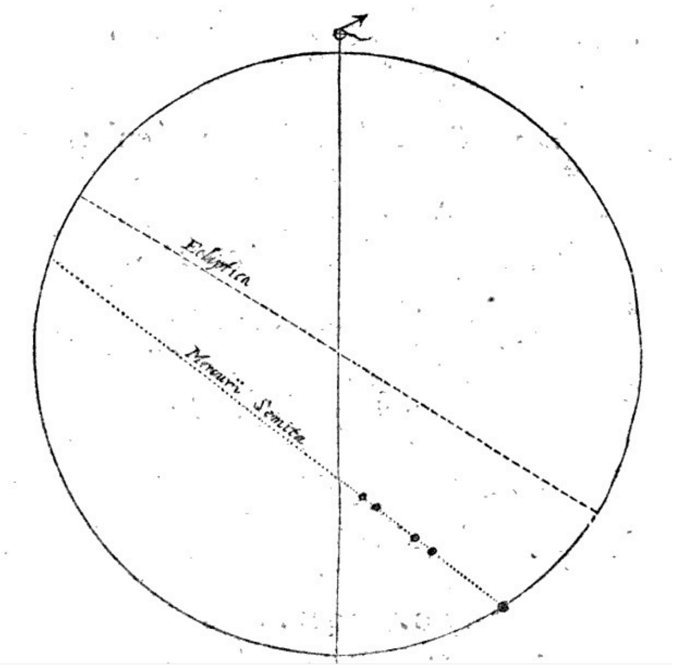


Figure 4. Gassendi's transit obervation of Mercury in 1631. Reproduced from the 1656 edition of his textbook *Institutio Astronomica* (1656, p. 184).

This is probably the first time that measurement of parallax is mentioned in relation to solar transits. Schickard found that Kepler's table gave more accurate prediction than any others, and he concluded that Kepler's theory was sound. The transit of Venus, which was to occur on 6–7 December 1631, was not observed, owing to the fact that it occurred at night for Europeans, and there were few if any astronomical observers active in America.

4. Horrocks improving Kepler's work

Jeremiah Horrocks (ca. 1618–1641) and *William Crabtree* (1610–1644) were two young astronomers in England who accepted Kepler's elliptical astronomy (Wilson 1978; Chapman 1990, 2004), and it was particularly the new and difficult mathematical astronomy as an empirical science that interested them. Horrocks entered Emmanuel College, Cambridge in 1632 as a sizar (poor student). The curriculum was mostly arts, divinity and classical languages (particularly Latin). Crabtree had not been to university, but had learned Latin at school and worked as a cloth merchant and had means to buy astronomical books. He was to be Horrocks' main scientific correspondent from 1636 to 1640. Both were as far as we know, completely self-taught in the "new" astronomy of Kepler.

By 1636 both Horrocks and Crabtree had encountered a common problem: why were the principal astronomical tables then in use, so often defective when it came to making good predictions of astronomical events such as eclipses, conjunctions and lunar occultations? The planetary tables of Philip van Lansbergen in particular received many negative remarks because they were unreliable.

In 1637 Horrocks obtained a copy of Kepler's *Tabulae Rudolphinae*, and his reactions were enthusiastic. The same year he developed a method of approximation necessary for finding areas of ellipse-segments that was simpler than Kepler's method, and gave results with almost the same precision (Applebaum 1996). He also made adjustments to various planetary parameters to bring the Keplerian theory into agreement with recent observations, including his own and Crabtree's.

By 1638 Horrocks had demonstrated that the lunar orbit around the Earth was not the eccentric circle of traditional Ptolemaic astronomy, but a Keplerian ellipse. This discovery was utterly irreconcilable with the classical model of the celestial objects being carried upon crystalline spheres, and it gave new insight into the big question of what was the force that governed the motions of the planets and moons in space. Newton (Newton 1687/1934 Book III, Scholium) later went as far as to say that

> Our Countryman Horrox was the first who advanced the theory of the moon's moving in an ellipse about the earth placed at its lower focus.

Horrocks was familiar with the earlier work on planetary transits by Kepler and Gassendi. Kepler had prepared the ephemeris only up to 1636 and consequently failed to notice that his own *Tabulae Rudolphinae* predicted a second Venus transit three years later.[2] Horrocks made improvements for Venus, and in October 1639 he realized that transits of Venus occurred twice in each of the major cycles found by Kepler, with a gap of eight years between the pairs of occurrences. Kepler's statement that after the 1631 transit there would not be another transit of Venus until 1761 was wrong, and on November 24 1639 it would pass directly across the solar disk.[3] By telling Crabtree and others with whom he appears to have been in correspondence, and encouraging them to keep watch, Horrocks hoped to ensure that the event was well observed and recorded. He wrote to Crabtree on November 5, 1639 (van Helden 1985, p. 107):

> The reason why I am writing you now is to inform you of the extraordinary conjunction of the Sun and Venus which will occur on November 24. At which time Venus will pass across the Sun. Which, indeed, has never happened for many years in the past nor will happen again in this century. I beseech you, therefore, with all my strength, to attend to it diligently with a telescope and to make whatever observation you can, especially about the diameter of Venus, which, indeed, is 7' according to Kepler, 11' according to van Lansbergen, and scarcely more than 1' according to my proportion.

In his detailed and posthumously published analysis of his and Crabtree's transit work, *Venus in Sole Visa*, or "Venus seen upon the Sun" (Whatton and Horrox

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[2] Owen Gingerich has recalculated the Venus transit of 1639 based on Kepler's tables and found that they predict the transit (Kollerstrom 2004). The tables predict a distance of $-7'45''$ between Venus and the solar center at the Sun–Venus conjunction, an error of approximately one arcminute according to modern methods, but they predicted the event nine hours early because their Venus longitude erred by half a degree. Kepler's own calculation of the future 1761 transit erred by only two days.

[3] 24 November in the Julian calendar then in use in England, corresponding to 4 December in the Gregorian calendar.

1662/1859), Horrocks displays a meticulous knowledge not only of current European astronomy, but also, in particular, of previous Mercury and Venus transits (see Fig. 5). Horrocks acknowledged the importance of Kepler's and Gassendi's work, and by and large he applied Gassendi's observing technique, which was the standard method for viewing sunspots. Horrocks reported on Crabtree's observations (Whatton & Horrox 1859, p. 125):

In the second place, the distance between the centres of Venus and the Sun I found, by three observations, to be as follows:—

	The Hour.		Distance of the Centres.
At	3 . 15	by the clock.	14′ 24″
„	3 . 35	„	13′ 30″
„	3 . 45	„	13′ 0″
„	3 . 50 the apparent sunset.		

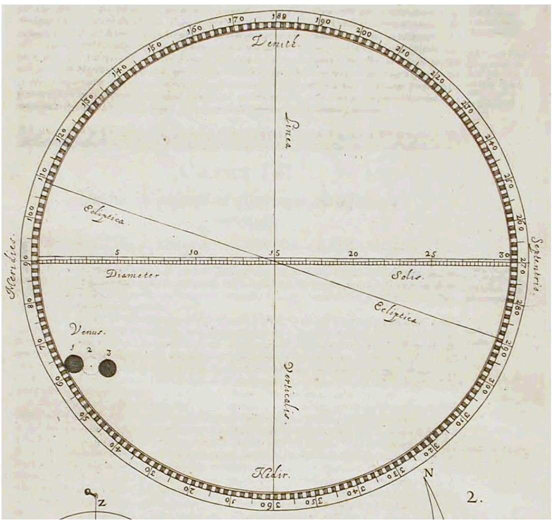

Figure 5. Observations and drawing from Horrocks (1662): *Venus in Sole Visa*, translated by Whatton (1859). The drawing was added in the publication by Johannes Hevelius in Danzig, but it is not very accurate. The three positions of Venus are spaced equally in Hevelius' drawing, whereas the three observations by Horrocks were made at intervals of 20 and 10 minutes respectively.

> But a little before sunset, namely about thirty five minutes past three, certainly between thirty and forty minutes after three, the Sun bursting forth from behind the clouds, he at once began to observe, and was gratified by beholding the pleasing spectacle of Venus upon the Sun's disc. Rapt in contemplation, he stood for some time motionless, scarcely trusting his own senses, through excess of joy; for we astronomers have as it were a womanish disposition, and are overjoyed with trifles and such small matters as scarcely make an impression upon others...

When he was analyzing the results of his prediction and observation of the 1639 transit of Venus, Horrocks realized that he was able to use the geometrical position of the Sun in the ecliptic – which was one of the best known points in the sky to seventeenth-century astronomers – to extract a new and greatly superior value for the orbital position of Venus in space. In particular, he was able to use the three successive Venus positions on the solar disk, observed between 3.15 and 3.45 p.m., to determine the exact time and place of the nodal point of Venus's orbit – the node being the point where Venus's orbit cuts the ecliptic on a line of sight from the Earth.

Horrocks found that the diameter of Venus was about $\frac{1}{25}$th of that of the Sun, and calculated Venus' apparent diameter during the transit as $76''$ and accepted Gassendi's $20''$ for Mercury. Kepler's third law determines the relative distances between the planets. Hence, from these measurements, both Mercury and Venus would have apparent diameters of about 28" as seen *from the Sun*. Was this just a coincidence? Horrocks extended this mathematical harmony to other planets – even though the measurements made of them were by methods far less reliable. He then asserted as a "probable conjecture" (Whatton & Horrox 1859, p. 213) that the Earth may also appear as 28″ from the Sun, and used this to estimate the solar distance:

> . . . what prevents your fixing of the Earth as the same measurement, the parallax of the Sun being nearly 0′14″ at a distance, in round numbers, of 15000 of the Earth's diameters?

This figure would put the Sun 95 million km away. Horrocks based this calculation on the suggestion that the planetary distances as seen from the Sun were proportional to their diameters, but he was well aware that this idea and estimate was rather speculative.

5. Concluding remarks

The transits of the 1630s were important in selecting the best model for the solar system based on empirical measurements, and represented one step in favor of Kepler's elliptical astronomy. Van Lansbergen's tables for the path of Venus across the solar disk in 1639 had three times greater error than the *Tabulae Rudolphinae*, and van Lansbergen placed the transit of Mercury in 1631 more than a day too early (Gingerich 2009). The New Astronomy made it possible to compute noticeably better ephemerides for the planets, and Kepler's tables improved planet positions by a factor of 10. Kepler's arrangement to work within a model with a chosen level of precision constituted a vital break away from the Greek tradition. But based on empirical testing, Kepler's principles were gradually recognized as reliable tools for predictions and discoveries. During the seventeenth century the Keplerian orbits increasingly made their entrance into the astronomical praxis of mathematical astronomers and calendar makers who rated them more and more as the most trustworthy astronomical foundation, although a general approval did not occur until Newton.

Both Mercury and Venus were observed to be much smaller than expected, and this smallness was another important result of the observations of the transits of 1631 and 1639. This result indicated that the solar system and cosmos was much bigger than the traditional ideas. Gassendi's and Horrocks' transit observations could not be used directly to compute the distance to the Sun, and in Gassendi's influential textbook *Institutio Astronomica* (1647) he only presented the traditional values. However, the observations revealed that Mercury and Venus subtend approximately equal angles as seen from the Sun, and by assuming that this also was the case for the Earth, Horrocks estimated the solar parallax as 15″ and 14″ in various writings between 1638 and 1641 (van Helden 1984, p. 111). In 1644 astronomer Gottfried Wendelin made the first suggestion in print that the solar distance was greater than Kepler had made it (Wendelin 1644). Wendelin's argument was also based on the rather hypothetical assumption that all planets, including the Earth, covered an apparent diameter of 28″ or at most 30″ as seen from the Sun. This implied a solar parallax of at most 15″.

We should also acknowledge that while this scientific revolution in continental Europe had been the product of great universities and royal patronage, it came about in England through the work of a small group of dedicated, self-funded amateurs living in rural Lancashire. Although it may be somewhat anachronistic to call Horrocks an "amateur" astronomer, since in his times there were no official observatories in England, and Cambridge and Oxford had no department and nothing like a degree in astronomy.

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The French Savants, and the Earth–Sun Distance: a Résumé

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Abstract. Transits of Venus have played an important rôle during more than two centuries in determining the Earth–Sun distance. In 2012, three centuries after Cassini's death, the issue has been finally settled by the latest Resolution formulated by the International Astronomical Union.

1. Prologue

From Antiquity up to the sixteenth century, values of the Earth–Sun distance were considered as being 10 to 20 times smaller than nowadays. Then came the Copernican revolution that brought new ideas about the solar system, followed by Johannes Kepler (1571–1630) and Galileo Galilei (1564–1642) and, later in the seventeenth century, Christiaan Huygens (1629–1695), Jean Picard (1620–1682), Gian-Domenico Cassini (1625–1712) and Isaac Newton (1643–1727) with his *Principia*. Powerful instruments were built, new pluridisciplinary groups formed, and novel concepts were presented.

In France, Louis XIV created in 1666 the *Académie Royale des Sciences* and the following year, 1667, the *Observatoire Royal* on the southern outskirts of the capital. Soon after, he demanded, from his academicians, a new geographical map of his kingdom. Picard presented ideas and new instruments to be built, and he performed a careful determination of the dimension of the Earth, along a meridian line represented by the symmetry axis of the observatory under construction. He himself devised three instruments to obtain the needed data: a portable quadrant, a zenith sector, and a level. The campaign occurred in 1669 and 1670.

Meanwhile, in 1666, Louis XIV had invited Huygens, with his famous pendulum clocks, to join the *Académie* and, in 1669, he invited Cassini to join his Parisian colleagues who were monitoring his accurate predictions of the eclipses of the Galilean satellites of Jupiter: at that time, this was the best way for longitude determination inland.

A new era was begun, with all these astronomers meeting within the frame of the *Académie Royale*, fully committed to determining the dimension of the solar system.

2. The first modern determination of the Sun–Earth distance

The result of the 1669–1670 campaign of Picard led him to publish, in 1671, his *Mésure de la Terre* that yielded, for the length of one degree of latitude, the value of 57 060 French *tosses*, the *toile* being equal to 1.95 m. For the radius of the Earth, at that time considered as a sphere, its value in *tosses* was equivalent to 6 375 km. Curiously, the value adopted by the International Astronomical Union in 2009, for the equatorial radius of the Earth is 6 378 km with – of course – four additional decimals, and it is now known that the Earth has not a spherical form: its flatness ratio is $\frac{1}{298}$.

Whatever was the shape of the Earth, Picard's value of the Earth's dimension could be used to obtain the Earth–Sun distance by using Kepler's third law that the planets around the Sun follow an elliptical orbit in such a way that the ratio of the square of their period of revolution to the third power of their average distance to the Sun is a constant.[1]

The method to be employed by the French academicians was the solution of a triangle with baseline that lies between Paris and a place as far away as possible on the Earth. The chosen place was to be Cayenne (Guyana) where the *Académie* sent Richer (1630–1696), one of its members; at that time Mars was at its closest distance from the Earth. The expedition was made in 1672 and 1673. Richer, as well as the astronomers in France, observed the position of Mars relatively to surrounding stars. In a letter, preserved in the Archives of the *Observatoire de Paris*, Richer wrote to Cassini (Ms B5, a, dated *A Caïenne le 20 juillet 1672*)

> ... J'espère que ces observations vous satisferont et M. Picard aussi & que par la vous connoitres si la parallaxe du soleil est sensible ou non...

The result obtained by Cassini, $9\frac{1}{2}''$ is reported, for the year 1673, in *Histoire de l'Académie Royale des Sciences* (Tome I), and the full text in *Mémoires de l'Académie Royale des Sciences* (Tome VIII, p. 53, 117, Paris, 1730), while the *Recueil* had appeared in 1733, the text itself is dated 1684. These various dates led to some confusion.

A detailed study was recently published in the journal *l'Astronomie* by C. Vilain from the *Observatoire de Paris* with a careful examination of the publication *Observations astronomiques et physiques faites en l'Isle de Caïenne* (Vilain 2011). The voyage had several purposes, but in the present paper, the Earth–Sun distance, as determined by Cassini is the only one considered; Vilain's conclusion is that this distance corresponds to about 22 000 Earth radii, compared to 23 445 nowadays adopted, confirming that this distance was known at not more than 10 %. A few years earlier, Toulmonde (2004) published a paper *Parallaxe du Soleil*, in which he gave many technical details.

The parallax of the Sun, – that is, the angle under which the radius of the Earth is seen from the Sun – has now been determined as $8''.794$ (IERS[2] conventions 2009 and 2010); it is remarkable that some astronomers of the time obtained such value within an error of the order of $0''.1$ – perhaps less – although Halley (1716) could not decide for any value of the range 1200–7000 Earth radii, see Aspaas (2012), p. 200.

A few years after Richer's return in 1675, the Royal Observatory in Greenwich was created: a new institution to develop astronomy was born.

3. A new method for the Earth–Sun distance: the Venus transits

The story of the first Venus transit ever observed (on December 4, 1639) is very well known. It begins with Kepler's prediction, and is followed by Jeremiah Horrocks

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[1] i.e., t^2/a^3.

[2] International Earth Rotation and Reference Systems Service, `http://www.iers.org/IERS/EN/DataProducts/Conventions/conventions.html?__nnn=true`

(1619–1641), the only one, with his friend William Crabtree (1610–1644), to be fortunate enough to catch Venus and the Sun between clouds, see also Thorvaldsen's paper in these Proceedings.

Kepler had announced together with the 1631 transit (not 1639), the following one for 1761; astronomers, after 1639, had to wait more than twelve decades... Meanwhile, in 1663, James Gregory (1639–1675) had pointed out that transits over the Sun could lead to determination of the solar parallax. Edmond Halley (1656–1742), who had observed a transit of Mercury on November 7, 1671, showed in his *Catalogus Stellarum Australium* (published 1679) that such transits[3] would thus provide a new method to determine the Earth–Sun distance. But Halley died in 1742, before the 1761 transit. Joseph-Nicolas Delisle (1688–1768) in France took over the task of drawing the astronomical community's attention to the coming transit of Venus, sending out more than one hundred copies of his call together with a corresponding *Mappemonde*; unfortunately, none of these documents is included in the Archives of the *Observatoire de Paris*, see also the paper by Dumont & Gros in these Proceedings. Apparently two of them are known, one in the *Bibliothèque nationale de France* and one at the *Académie des Sciences*.

In the Archives of the *Observatoire de Paris*, there is a manuscript (Ms A 6.9) entitled *Description et usage d'une Mappemonde sur laquelle on a marqué tous les lieux qui doivent voir le passage de Venus sur le Soleil et principalement ceux qui sont les plus avantageusement situez pour trouver la distance du Soleil à la Terre par les observations que l'on enfera présentée au Roy le* (white) *1760 par M. De L'Isle de l'acad. R. des Sciences*. It is to be noted that *au Roy* has replaced *à l'Académie* and, before the date 1760, Delisle had written 1759.

Delisle adds that the *Mappemonde* is the same he employed previously for a transit of Mercury on May 6, 1753. Delisle's work is based on Halley's tables and contains about fifty pages of his handwriting. On the occasion of this Mercury transit Delisle submitted another way for the determination of the Venus and Sun parallaxes. Halley had proposed to provide the determination from the duration of the transit observed from two different places, thus requiring observation of the entire transit. Delisle, however, proposed a slightly different approach: only one of the contacts is necessary, observed from two places. The best contacts are the second or the third contact of Venus with the limb of the Sun with their timings at the two places; but they have to be accurate and another condition is that the local geographical coordinates need to be known with the best possible accuracy. If these conditions are met, the number of potential stations increases by a factor of two.

4. Back to Mars for the Earth–Sun distance

Still waiting for the 1761 Venus transit, the astronomers and, among them Nicolas-Louis Lacaille[4] (1713–1762) returned to the closest approaches of Mars and Venus. While others had observed some Mercury transits, Lacaille launched a call to his European colleagues, indeed with several objectives: observe stars of the southern sky to improve navigation in this hemisphere, test the lunar distance method proposed by the British for this purpose, observe the Moon simultaneously to Joseph-Jérôme Lalande (1732–1807) in Berlin (more or less at the same longitude as the Cape of

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[3] Halley at first thought that Mercury as well as Venus transits could serve, but he became convinced that Venus was the only possibility.

[4] Also written as La Caille.

Good Hope),[5] observe Mars and Venus for their parallax, measure the length of one degree in latitude, determine longitude and latitude of various places (mostly islands), etc.

Leaving Paris in 1750, Lacaille was well equipped for all these purposes. Before leaving France he had sent his call to astronomers providing them with all the needed data for their observations. Back in 1754, Lacaille determined, among other things, the parallaxes in comparing his observations from South Africa with those made in Europe. Despite the increasing quality of the astronomical instruments since the sixteenth century, Lacaille's solar parallax $9''.5$ to $10''.2$ was more or less similar to Cassini's results.

5. The 1761 and 1769 transits of Venus

For France, some astronomers were sent to various locations in the world to catch the whole phenomenon. Such were Alexandre-Guy Pingré (1711–1796) at Rodrigues Island, Jean-Baptiste Chappe d'Auteroche (1728–1769) in Siberia (Tobolsk). In France itself the observers could get only the end of the transit but they were very numerous and among them were Giovanni Domenico Maraldi II (1709–1788), Edme-Sébastien Jeaurat (1724–1803), Charles Messier (1730–1817), Jérôme Lalande, Pierre-Charles Le Monnier (1715–1799), Charles-Marie de La Condamine (1701–1774), Nicolas-Louis de La Caille, Jean-Paul Grandjean de Fouchy (1707–1788), Réginald Outhier (1694–1774). In other places in Europe can be mentioned César-François Cassini de Thury (1714–1784) who observed from Vienna with Joseph Liesganig (1719–1799), Pehr Wilhelm Wargentin (1717–1783) in Stockholm and Mikhail Vasil'evich Lomonosov (1711–1765) in Saint Petersburg.

In total sixty-two stations sent their results to the *Académie Royale des Sciences*. They were analysed by several astronomers. Nevil Maskelyne (1732–1811) who went to Saint Helena, provided $8''.6$, while the largest parallax value, by Pingré, was $10''.6$.[6] The difference was $2''$, representing about 20 % of the average of these two values. It was larger than the 10 % obtained almost one century earlier by Cassini I and with whom John Flamsteed (1646–1719) in Greenwich was in good agreement.

The astronomers from these various observatories, and various locations in the world thought that they were not organized well enough. Among them some wanted to go as far as possible from Europe. Some astronomers would be new observers such as Johann Euler (1734–1800) – son of Leonhard (1707–1783) – and Jorge Juan Y Santacilla (1713–1733), a Spanish officer. A special mention has to be made of the famous voyage of Capt. James Cook (1728–1779), who observed from Tahiti, the island that was discovered in 1767 by the British.

Among the French, a special mention must be made of Chappe d'Auteroche, who was in Siberia in 1761 and who went to California in 1769 and died there after the observation; and to Guillaume Le Gentil de la Galaisière (1725–1792) who had arrived in India in due time (in 1761) but could not disembark, decided to wait until 1769, only to suffer bad weather conditions. In Norway, Maximilian Hell (1720–1792) observed the transit from the site of Vardø, providing with California and Tahiti one of the longest distance bases on the Earth. More than a dozen stations

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[5] The seemingly important role of Sweden in the same project is described in Aspaas 2012, pp. 224–225. See also the paper by Widmalm in these Proceedings.

[6] For original texts and more details, see Aspaas 2012, pp. 200–201.

were placed in order to be able to catch the complete transit. The number of observations sent to the *Académie* was about one hundred and twenty.

The difference between the smallest solar parallax 8″.40 and the largest one 8″.80 was substantially reduced, representing about 5 % of their average, instead of 20 % (Aspaas 2012, p. 324–327); some people decided to make a new analysis of the data such as Pierre-Simon Laplace (1749–1827) with 8″.81 and Johann Franz Encke (1791–1865) with 8″.57. Indeed, the further examinations yielded several values, the extremes being 8″.55 and 9″.12. Two values appeared as the most probable: 8″.8 and 8″.5. Instead of 5 %, the difference appears of the order of 3 %, not so much.

The next transit, however, was not expected until 1874; no observer from the 1760s would be given a chance to witness that. On the other hand, some tried to improve the results obtained in 1761 and 1769, and Carl Friedrich Gauss (1777–1855) provided a new method during the first decade of the nineteenth century: the least-squares determination of error to be associated to their means, weighted or not. Most of them had given ± 0.04", which represents about 3 %.

6. The 1874 and 1882 Venus transits

The astronomers began to search other ways for the determination of the Earth–Sun distance. Some employed the motion of the Moon leading to 8″.6 or 8″.9 such as Peter Hansen (1795–1874) in Denmark. Others made their analysis through the aberration of light, long after its discovery, with the velocity of light by Rømer (1644–1710) and with James Bradley (1693–1762), for the phenomenon of aberration itself. On the Earth the speed of light was obtained around mid-nineteenth century by Hippolyte Fizeau (1819–1896), followed by Léon Foucault (1819–1868) indoors, leading Wilhelm Struve (1793–1864) to 8″.86 and Alfred Cornu (1841–1902) to 8″.80. Urbain Le Verrier (1811–1877) himself made a determination yielding 8″.95, from a study of the motion of the gravity center of the Earth–Moon system around the Sun. All determinations were published just as astronomers were preparing for the 1874 transit of Venus.

Indeed, in France the astronomers began to work on this subject in 1872, the *Académie des Sciences* created a *Commission du passage de Vénus* to make sure that the best places were chosen for the observations. Its president was Hervé Faye (1814–1902), Pierre Puiseux (1820–1883) being its secretary; among the other members were Charles Delaunay (1816–1872) and Le Verrier. This Commission chose five stations: Campbell Island, Saint-Paul Island, Noumea, Peking (not yet Beijing) and Saigon; to observe the complete transit the Indian Ocean was the best place, as well as some eastern parts of Asia. The *Académie* sent a mission to Kompira-Yama mountain (close to Nagasaki) under the direction of Jules Janssen (1824–1907), including Félix Tisserand (1848–1896) and others.

The equipment of astronomers underwent further improvements. The clocks became much better for the timings; there were, besides refractors, also reflectors equipped with silvered mirrors, in addition to small theodolites and transit circles for determination of the local coordinates, latitude and longitude. A new instrument had appeared with Janssen: the *revolver photographique* as he named it; the electric telegraph allowed to synchronize the clocks for both the timings of the contacts and for longitude determinations with a better accuracy. The new technique, issued from photography was well developed from mid-nineteenth century into "astrophotography", under the shorter name astrography, equipping an astrograph with glass plates, also named, if for the Sun, photoheliograph.

Most of the European countries, already engaged in the eighteenth century transits were interested to contribute to the 1874 campaign, and the USA was present with Simon Newcomb (1835–1909) from Washington. The extreme values obtained from the campaign were $8''.76$ and $8''.88$; the difference between theses values, $0''.12$ is not small enough if compared with the $0''.18$ obtained one century before, with the 1769 transit. Harkness (1881, 1888) discussed the relative accuracy of different methods of determining the solar parallax. At the end of his very detailed paper, he assumed that the most probable error would be $\pm 0''.06$ while at the beginning of such measurements it could have been $2'$. It is also a very informative paper regarding the evolution of the measurements of the Sun–Earth distance.

Some astronomers, such as David Gill (1843–1914) at the Cape of Good Hope chose in 1877 to observe Mars again, this time from Ascension Island. From the value $8''.78$ obtained, Gill determined that the mean square error was $\pm\ 0''.01$. For the first time the error attained such a small value, leading to the idea that direct observation of such a planet could be more successful than Venus transits. Nevertheless, astronomers decided to observe the following one in 1882.

As an example of such a campaign, the Belgian astronomers – for the first time engaging in such an operation while observing from San Antonio (Texas) and Santiago (Chile) – obtained $8''.907 \pm 0.084$ which corresponds to $8''.91 \pm 0''.08$, quite disappointing. At the international level, astronomers began to think about a uniformization of constants of general use around 1880; they made the choice of the solar parallax: $8''.80$, assumed to be correct within $\pm 0''.02$. This was made after a careful analysis of a set of constants to be adopted on the occasion of the international project named *Carte du Ciel* launched in 1887. This was formally made on the occasion of the *Conférence internationale des étoiles fondamentales* held in 1896 and involved eighteen observatories. It was confirmed by Jean Bouquet de la Grye (1827–1909) in a memoir on the solar parallax, he presented to the *Académie* in 1904, considering that $8''.80$ was known within $0''.01$.

7. The giant role of the small planets

The first small planet discovered occurred during the night of December 31, 1800, and January 1, 1801, when Giuseppe Piazzi (1746–1826) saw, from Palermo Observatory, a new tiny object later named Ceres. Several others were later discovered and, in 1898, a very favorable one for the parallax determination was discovered by Carl Gustav Witt (1866–1946), Eros, being able to be very close to the Earth: its parallax could attain $60''$, far more than Mars (of the order of half this value).

Some other small planets had been previously attempted for determining the solar parallax, with Victoria, Iris and Sappho around 1890 leading to $8''.801$, $8''.798$, $8''.812$ and to $8''.807 \pm 0''.006$, for a weighted mean, with an error less than half of what was obtained previously. Arthur Robert Hinks (1873–1945) provided, after about ten years of analysis $8''.806 \pm 0''.004$ from visual observations. Such results showed that Eros would be a good candidate ten years later. The 1900–1901 international campaign was very successful: forty-two observatories participated, providing 12 000 observations obtained from photographic plates of Eros with respect to neighboring stars. The technical method employed was the same as for Mars, but the small planets look like stars, without any planetary aspect. The value $8''.80$ was confirmed, and the transits of Venus will not be used anymore. Nevertheless astronomers were waiting for the next best appearance of Eros in 1930–1931.

For the 1930–1931 Eros campaign, and under the influence of the International Astronomical Union (IAU) created in 1919, sixty-four observatories participated, and

Harold Spencer Jones (1880–1960) was in charge of the determination. After a very deep and careful study he provided the result $8''.790 \pm 0''.001$.

From observations of the same minor planet, between 1926 to 1945, Eugene Raba (1913–1974) published in 1950 the value he deduced from its perturbations mostly by the Earth, $8''.79835 \pm 0''.00039$. With such accuracy, smaller than the Spencer Jones result, the values differed far more from the sum of their assumed errors...

8. Some other methods for the Earth–Sun distance

Other possible methods were not forgotten, despite the development in the use of small planets. As an example, one already mentioned issued from the aberration of light, through its speed. In using photometric observations of eclipses for the satellites of Jupiter made at Harvard Observatory, Ralph Allen Sampson (1866–1939) derived a rather accurate value of the solar parallax yielding, in 1909, $8''.80 \pm 0''.02$.

Among such modern determinations can be mentioned the result obtained by Ernest Brown (1866–1938) and Dirk Brouwer (1902–1966), $8''.7925 \pm 0''.0005$ deduced from the parallactic inequality of the Moon; another value was given by Bernard Guinot, in 1958, $8''.787 \pm 0''.003$, issued from a new determination of the aberration constant.

As time went by, new roles were accorded to Venus, the Moon and other celestial objects with the emergence of new techniques during the second half of the 20th century. Such was radar astronomy issued from World War II in using echoes over the Moon and mostly Venus. By the end of the fifties and the beginning of the sixties in Great Britain and in the USA, it was considered that the speed of light was known with a sufficient accuracy. Very often the authors gave more decimals than the error could accept; the rounded values such obtained are from Boston $8''.8022$, from California $8''.794098 \pm 0''.15$... The IAU, in charge of the decision for the astronomical constants, made the choice of $8''.794$ in 1964. This is more or less the end of defining the Earth–Sun distance under the form of the solar parallax, this distance being derived from direct measurements; but the speed of light needs to be better known and an international value adopted. And new improvements will come, both for this numerical value, from new determinations of the length of the meter, new atomic clocks for timing and, on the other side, from the use of space research.

9. The Earth–Sun distance today

For several decades, new definitions of astronomical constants were considered by the IAU, under the responsibility of highly specialized Working Groups. The last but one such meeting occurred in 2009 during the IAU 27th General Assembly in Rio de Janeiro. The set of constants, emanating from discussions at the level of the Working Group *Numerical Standards in Fundamental Astronomy*, has defined the IAU 2009 System of Astronomical Constants.

The first constant in the list is the speed of light $c = 2.99792458\times 10^8$ m s^{-1}, close to the well-known value 300 000 km s^{-1}. The Earth–Sun distance au comes after seven other constants au $= 1.49597870700\times 10^{11}$ m, i.e., close to 150×10^6 km.

For comparison with previous values, I mention the distance Earth–Sun obtained forty years ago, viz., $1.49598845 \pm 0.000002 \times 10^{11}$, with $c = 2.997930 \times 10^8$ ms^{-1},

$1.49596600 \pm 0.00000900 \times 10^{11}$ m twenty years ago, with the same value for the speed of light ($c = 2.99792458 \times 10^8$ ms^{-1}) $1.49697870691 \times 10^{11}$ m.

The 2009 value of the Earth–Sun distance was given in *Proposals for the masses of the three largest asteroids, the Moon–Earth mass ratio and the astronomical unit*, published by Pitjeva & Standish (2009). These proposals were issued from their detailed study of the available data and discussions among specialists from numerous countries, among whom, for example, figures Nicole Capitaine from the *Observatoire de Paris*. The most accurate values of the Earth–Sun distance was thus obtained from studies in celestial mechanics taking into account small planets, the Earth–Moon system and, as usual for astronomical research, the most fundamental variable: time.

But new discussions took place and, in 2010, a *Proposal for the re-definition of the au* was submitted in Vienna during the *Journées 2010 Systèmes de référence spatio-temporels,* according to previous suggestions (Klioner 2008, Capitaine & Guinot, 2009). The reason is that in the modern context, astronomers wanted to make the system of astronomical constants as compliant as possible with modern dynamical astronomy. The astronomical unit (au) will keep the value of its defining number, as previously given under the form of a conventional number.

At the 28th IAU General Assembly in Beijing in 2012 the discussions on a re-definition of the astronomical unit of length led to the acceptance of IAU RESOLUTION B2 (2012) that recommends the re-definition of the astronomical unit as a conventional unit of length equal to 149 597 870 700 m exactly. The integral text of this resolution is reproduced in the Appendix to this paper.

10. Résumé

J.-D. Cassini admitted $9''\!.5$ for the solar parallax, which is the angular measure for the Sun–Earth distance. Cassini's value was derived from Mars observations, and he published it in 1672. During the 1750s, Lacaille made similar observations and found the same value. Soon after, astronomers employed the two transits of Venus that occurred in 1761 and 1769. The results were more or less disappointing for the astronomers; nevertheless other astronomers, with an improved instrumentation, observed the following ones 1874 and 1882. Meanwhile other methods were attempted up to the discovery of Eros by 1898. After such campaigns and World War II, radar and later more direct measurements occurred leading the IAU to take new decisions for the Earth–Sun distance, au, i.e. astronomical unit, for astronomical unit, in August 2012.

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Appendix

IAU RESOLUTION B2

on the re-definition of the astronomical unit of length[†]

The XXVIII General Assembly of International Astronomical Union,

noting

1. that the International Astronomical Union (IAU) 1976 System of Astronomical Constants specifies the units for the dynamics of the solar system, including the day ($D = 86400$ s), the mass of the Sun, M_S, and the astronomical unit of length or simply the astronomical unit whose definition[1] is based on the value of the Gaussian gravitational constant,

2. that the intention of the above definition of the astronomical unit was to provide accurate distance ratios in the solar system when distances could not be estimated with high accuracy,

3. that, to calculate the solar mass parameter, GM_S, previously known as the heliocentric gravitation constant, in Système International (SI) units[2], the Gaussian gravitational constant k, is used, along with an astronomical unit determined observationally,

4. that the IAU 2009 System of astronomical constants (IAU 2009 Resolution B2) retains the IAU 1976 definition of the astronomical unit, by specifying k as an "auxiliary defining constant" with the numerical value given in the IAU 1976 System of Astronomical Constants,

5. that the value of the astronomical unit compatible with Barycentric Dynamical Time (TDB) in Table 1 of the IAU 2009 System (149 597 870 700 m±3 m), is an average (Pitjeva and Standish 2009) of recent estimates for the astronomical unit defined by k,

6. that the TDB-compatible value for GM_S listed in Table 1 of the IAU 2009 System, derived by using the astronomical unit fit to the DE421 ephemerides (Folkner et al. 2008), is consistent with the value of the astronomical unit of Table 1 to within the errors of the estimate; and

considering

[†] For the source of this text, and all references, see `http://www.iau.org/static/resolutions/IAU2012_English.pdf`

[1] The IAU 1976 definition is: "The astronomical unit of length is that length (A) for which the Gaussian gravitational constant (k) takes the value of 0.017 202 098 95 when the units of measurements are the astronomical unit of length, mass and time. The dimensions of k^2 are those of the constant of gravitation (G), i.e., $L^3M^{-1}T^{-2}$. The term "unit distance" is also for the length A." Although this was the first descriptive definition of the astronomical unit, the practice of using the value of k as a fixed constant which served to define the astronomical unit was in use unofficially since the nineteenth century and officially since 1938.

[2] Using the equation $A^3k^2/D^2 = GM_S$ where A is the astronomical unit and D the time interval of one day, and k the Gaussian gravitational constant.

1. the need for a self-consistent set of units and numerical standards for use in modern dynamical astronomy in the framework of General Relativity,[3]
2. that the accuracy of modern range measurements makes the use of distance ratios unnecessary,
3. that modern planetary ephemerides can provide GM_S directly in SI units and that this quantity may vary with time,
4. the need for a unit of length approximating the Sun–Earth distance, and
5. that various symbols are presently in use for the astronomical unit,

recommends

1. that the astronomical unit be re-defined to be a conventional unit of length equal to 149 597 870 700 m exactly, in agreement with the value adopted in IAU 2009 Resolution B2,
2. that this definition of the astronomical unit be used with all time scales such as TCB, TDB, TCG, TT, etc.,
3. that the Gaussian gravitational constant k be deleted from the system of astronomical constants,
4. that the value of the solar mass parameter, GM_S, be determined observationally in SI units, and
5. that the unique symbol "au" be used for the astronomical unit.

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[3] Relativistically a solar system ephemeris, for which the astronomical unit is a useful unit, is a coordinate picture of solar system dynamics. SI units are induced into such a coordinate picture by using the relativistic equations for photons and massive bodies and by relating the coordinates of certain events with observables expressed in SI units.

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Austrian–Hungarian Astronomical Observatories Run by the Society of Jesus at the Time of the 18th-Century Venus Transits

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Abstract. The Venus transit in June 1761 was the first one to be observed on a truly international scale: almost 250 astronomers followed this rare celestial event (e.g. Wulf 2012, p. 115), and at least 130 published successful observations of it (Aspaas 2012, p. 423). The present paper deals with the astronomical observatories built by the Society of Jesus in its eighteenth century "Provincia Austriae", at which the 1761 transit could be observed. Five Jesuit observatories are being presented in this context: three in today's Austria, namely, two in Vienna and one in Graz; one in Trnava in today's Slovakia and one in Cluj in today's Romania. Thereafter, we briefly examine which of these observatories submitted any Venus transit observations for publication in the appendix to Maximilian Hell's "Ephemerides astronomicae ad meridianum Vindobonensem" for the year 1762.

1. Historical background

The Society of Jesus (*Societas Jesu*) is well known for its efforts to promote scientific research and teaching in catholic countries (as well as on mission) since its foundation in the sixteenth century. Jesuits were active as astronomical observers and authors of scientific articles also in the Habsburg monarchy long before the eighteenth century; however, it was only in the course of the eighteenth century that they actually founded permanent (or semi-permanent) observatories there. Most of these observatories flourished on a time scale of decades only, if they flourished at all, before the Society of Jesus was suppressed in 1773. Given that the Jesuit observatory in Vienna – the oldest one of those examined here – was founded in 1733, the time span covered by this article is only four decades (1733–73).

As far as the geographical scope of our article is concerned, the term *Provincia Austriae* still needs to be explained. In terms of modern country borders, this region essentially comprised today's Austria, Hungary, Slovakia, Slovenia, Croatia, as well as the western part of today's Romania, small parts of Ukraine and a part of northeastern Italy. It is noteworthy that the Czech Republic with the ancient imperial city of Prague (where a Jesuit observatory was founded in 1722) was not part of the "Austrian Province" of the Society of Jesus.

The observatories of the *Provincia Austriae* are not very well known internationally, and apart from a recent study, there are not many source-based studies of their history (cf. Aspaas et al. 2013). Within the context of the Venus transits, their role has been virtually ignored until now.

2. The observatories

2.1. Vienna

As mentioned above, Vienna – at that time the residence of the Habsburg empire – was the first of the cities here examined to host a Jesuit observatory, namely since the 1730s. The construction works began in 1733 and were finished in 1735. In the latter year, Charles VI, Holy Roman Emperor, came to visit the observatory (Hamel et al. 2010, p. 173). The first observations were carried out in 1736. The first director of this observatory was Joseph Franz SJ (occasionally spelled Frantz), who was born in Linz in 1704 and who had held a chair of mathematics at the University of Vienna since 1734. Franz continued to be observatory director until 1755 (cf. ADB 1878).

The observatory site was close to the geometrical center of the city: less than 400 m to the East of Saint Stephen's cathedral, at the junction of today's Postgasse with today's Bäckerstraße. The observatory building was a tower (like most eighteenth century university observatories), erected on top of the pre-existing Jesuit college (which had a height of 21 m), adding three floors to it and thus reaching a total height of 45 m. The observation chamber in a narrower sense was located on the last of the three additional floors, was 86 m^2 large and had a height of 11.5 m. Unfortunately, nothing is left of this certainly impressive tower, which is known to have existed at least until 1786.

Among the instruments used there, one was especially remarkable, namely a mural quadrant with a radius of 10 foot (3.1 m). It was equipped with a telescope and a micrometer. Another noteworthy instrument at this observatory was a mobile azimuthal quadrant that had once been used by Tycho Brahe.

The observatory also possessed a celestial globe, about 1.4 m in diameter, on which stellar positions were charted, according to the Jesuits' own observations. The famous German author Johann Christoph Gottsched wrote an impressive Latin description of this celestial globe (Gottsched 1750, pp. XXV–XXVII).

The observations made at the old Viennese Jesuit observatory were published in different journals abroad, but also, from 1756, in the *Ephemerides astronomicae ad meridianum Vindobonensem* edited by Maximilian Hell.

The successor to Joseph Franz in 1755/56 was Joseph Liesganig. He was born in 1719 in Graz and had become professor of mathematics at the university of Vienna in 1752. His merits were mainly in geodesy, where he participated, among many other projects, in the triangulation from Vienna to Paris, cooperating with Cassini de Thury in the early 1760s – around the time of the first transit of Venus in the eighteenth century (see below).

At the time when Liesganig became director of the Jesuit observatory, in 1755, the Austrian Empress Maria Theresa founded yet another astronomical observatory in Vienna, namely the so-called "Imperial and Royal Observatory of Vienna" (Latin name: *Observatorium Caesareo-Regium Viennense*; we will refer to it as the Vienna University Observatory, see Fig. 1). One year before, in 1754, another important scientific institution had been founded in Vienna: the Botanical Garden (in Latin: *Hortus Botanicus Vindobonensis*). The foundation of the new, state-owned observatory also coincided with the construction of a new central campus house for the university, on top of which it was erected. The new observatory was thus again built on top of a building whose lower floors were used by other institutions of the university (notably, its assembly hall was located at a lower floor). With the observatory on top, the maximum height of the new building amounted to 38 m (7 m less than the older Jesuit observatory).

The above mentioned J. Franz was heavily involved in the construction of the new observatory; but it was Maximilian Hell SJ who was to become the first director of this institution (and to remain director until his death in 1792). Continuous observations at the Vienna University Observatory began in 1757. The university observatory was run by Jesuits until the suppression of the Society of Jesus, in the same way as all other observatories described here; however, its fate after the suppression of the order was quite different from that of the others: as a state-owned (public) observatory, it was supposed to "survive", and as an institution it did so until the present time (physically, however, Vienna's University Observatory was transferred to the outskirts of the city in the 1880s, where a very large new observatory was to be built in the 1870s).

As for the Venus transit in 1761, astronomers followed this celestial event both at the Jesuit observatory and at the University Observatory in Vienna. The following observers were present at the older Jesuit observatory: César-François Cassini de Thury (director of the *Observatoire de Paris*) with his own, 9-foot telescope (*tubus dioptricus*, equipped with a micrometer); J. Liesganig, at that time director of the Jesuit observatory as mentioned above; Archduke Joseph Prince of Austria (who would become Emperor in 1765); Karl Scherffer SJ; Karl Mastalier SJ; Anton Steinkellner SJ; and Joachim Richtenburg SJ. At the Imperial and Royal Observatory, Father Herberth SJ, professor of physics at the university, Magister Rain SJ, and Abbé Lysogorski, a Polish priest, were observing, each of them of course with his own telescope (Hell 1761, pp. 17–18).

The remarkable presence of the then only 20 years old Archduke Joseph is also mentioned by Cassini de Thury in his observation report; he writes (Cassini 1763, p. 410, our translation):

> While I was waiting for the Sun to become visible again, I was honored by the presence of his Excellence Archduke Joseph, who had left [his residence] Laxenburg at 4 a.m. in order to witness my observations; fortunately, the Sun re-appeared and the Prince observed Venus several times and posed several questions which proved the extent of his knowledge.

Hell himself used yet another observing platform, i.e. another tower within the university campus, attached to the former university library (now university archive). In his observation report, he calls it a place remote from the crowd (*aedes aliae ab omni tumultu segregatae*) and says that he had his instruments transferred to this place on the second of June already (Hell 1761, p. 1). Hell used a 5-foot telescope equipped with a micrometer. Observations of δ Orionis (passing through the field of view) had yielded a field-of-view value of 30 arcminutes for this instrument. The accuracy of time measurements, according to Hell, was better than 1 second (Hell 1761, p. 2).

2.2. Graz (Graecium)

The University of Graz was founded in 1585 in the course of counter-reformation, which aimed at repelling the Protestants in many areas of society, among them higher education.

Back in the sixteenth century, there was however nothing like an astronomical observatory at the University of Graz, whose old main building dates from the years 1573–1609. The Protestant Johannes Kepler (who came to the higher Protestant school in Graz – one might also call it a "university" – in 1594 but was expelled in 1600 for religious reasons) and the Roman Catholic Paul Guldin SJ both made

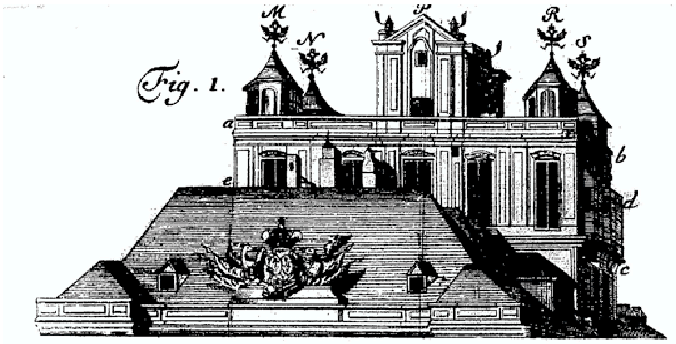

Figure 1. The Vienna University Observatory, founded in 1755, and built on top of the contemporary central campus. View from about 1772. After Bernoulli (1777).

important contributions to astronomy and mathematics. Kepler, however, did not construct any astronomical observatory in Graz, and little is known about the small observatory built by Guldin in the first half of the seventeenth century (Guldin died in Graz in 1643).

The actual Jesuit observatory of Graz University was constructed in 1745 (cf. Steinmayr 2011, also for the following). It was built on top of the west wing of the above-mentioned courtyard house that had been finished in 1609. It is possible, but could not be proven so far, that Joseph Franz, at that time director of Vienna's Jesuit Observatory, was also involved in the planning of the Graz Jesuit Observatory. The observatory's layout was 42 m long and 18 m wide; it had a height of 12 m (again, on top of the pre-existing floors), resulting in a wide panorama. The first floor hosted a museum of mathematics and physics, where "physics" is to be understood in a wider sense than today, i.e. as science in general. More specifically, a rich collection of minerals and insects was a part, and actually the most important part, of this museum (Flügel 2006). The mineral collection contained more than 800 minerals and fossils and was among the first ones in Austria. The second floor was designed in such a way that those astronomical observations that required only a narrow azimuth range could be carried out (measurements with mural quadrants, meridian circles, etc). One of the quadrants used there had a radius of about 2.5 m. The top floor, finally, consisted of a platform in the form of a walkway, where portable instruments could be placed. Further instruments used at this observatory included precise clocks, a planet clockwork, gnomons, globes, meteorological instruments as well as a camera obscura.

Less than 30 years after its foundation, in 1774, the Jesuit Observatory in Graz was closed down, and the chair of astronomy was abolished. In 1782, the University of Graz was downgraded to a lyceum (which it remained until 1827); in 1787, another unfortunate event took place: the demolition of the observatory upon the order of the government.

Still 10 years before, in 1777, Anton Mayer SJ, the last director of the Jesuit observatory in Graz, had made an appeal to the university administration and had asked for the institute's conservation, arguing that a lot of money had been invested, that it still contained valuable collections of scientific instruments, minerals, plants and insects, and that it could still serve the purpose of spreading scientific knowledge (cf. Krones 1886, p. 456ff). Mayer's appeal, however, had no lasting effect; it could not prevent the demolition of the observatory a decade later, in 1787. Figure 2

Figure 2. The courtyard of the old university in Graz, founded in 1585, with the west side in the background, on top of which the Jesuit observatory was located between 1745 and 1787. Contemporary photograph by Th. Posch.

shows a contemporary view of the old Jesuit university courtyard, with hardly any traces of the former observatory left.

2.3. Trnava (Tyrnavia)

Trnava is located in today's Slovak Republic. Before the twentieth century, it used to be an important city in Upper Hungary, a part of the Austro-Hungarian empire. Trnava – in Latin called Tyrnavia, in Hungarian Nagyszombat, in German Tyrnau – lies about 100 km east of Vienna.

A Jesuit college was founded there in 1561; in 1635, this college achieved the status of a university, which existed there until 1777, when it was transferred to the city that we call Budapest today ("Buda" at that time).

Tyrnavia became the location of the first astronomical observatory in the Hungarian Kingdom in the years 1753–1755, when an astronomical and mathematical tower was attached to the "Collegium Tyrnaviense". In 1756, the Jesuit Franciscus (= Franz = Ferenc) Weiss was appointed director of this new observatory. Weiss in Trnava and Hell in Vienna thus both had five years as newly appointed observatory directors to prepare for the Venus transit in 1761.

Franciscus Weiss was the most important figure in eighteenth century astronomy in the city of Trnava, where he was born in 1717. We shall see that it was he who submitted observations of the 1761 transit of Venus to the Viennese *Ephemerides*. He was to remain director of the Tyrnavian observatory until 1777.

The observatory building had a height of 35.6 m. The ground floor hosted a museum of chemistry (*Musæum Chemicum*), the first floor hosted a collection of instruments used in physics (*Musæum Physicum*). The second and third floor contained the astronomers' living rooms and the *Musæum Astronomicum*. On top of all these floors, the actual observatory was located, with an extra height of 18 foot and a layout of 56×40 foot (cf. Weiss, in Vargha 1992).

Among the instruments that were used at the Jesuit observatory of Tyrnavia since 1756 were a 5-foot refractor, a 4.5-foot reflector and a 4-foot reflector. In addition, even large instruments were used, e.g. reflectors of up to 8 foot, since – and this was a distinctive feature of the observatory – one of the Jesuits working there, Ferenc Kéry, was actively producing astronomical instruments. After 1768, the following instruments were also available: an 18-foot refractor, a zenith sector with 3.2 m radius, three astronomical clocks (two of which came from the estate of the Viennese astronomer Marinoni), celestial globes and a magnetic compass (Bartha 2006).

In the context of Venus transits, it must be said that János Sajnovics SJ, who accompanied Maximilian Hell on his 1768/69 expedition to observe the Venus transit in Vardø, had worked as Weiss' assistant in Tyrnavia before departing to northern Norway at the age of 35 (cf. Aspaas 2012, p. 116–117).

Finally, it is worth mentioning that still today, a professional astronomical observatory exists relatively close to Trnava – 30 km to the west, next to the village of Modra in the mountain range of the Little Carpathians (Malé Karpaty), at an altitude of 531 m. It was established in 1988 and is operated by the Comenius University in Bratislava. Areas of research in which the observatory is involved include solar physics and photometry as well as astrometry of minor planets (more than 160 asteroids have been discovered at Modra).

2.4. Cluj (Claudiopolis)

Cluj or Cluj-Napoca – in Latin Claudiopolis, in German Klausenburg, in Hungarian Kolozsvár – used to be the capital of Transylvania, a part of today's Romania, which, even though located several hundred kilometers away from Vienna, was a vital part of the Habsburg empire in the eighteenth century. Its connection with the capital, Vienna, was much weaker than in the cases of Trnava and Graz, though, and the same holds true for the Jesuit observatory built there.

In 1753, the Jesuit college of Cluj obtained the status of a university; in the same year, the foundations of an astronomical observatory were laid. The person who was in charge of the construction was no other than Maximilian Hell. After studies in Vienna, a few years (1743–45) as an assistant to Joseph Franz and a short time of being involved in the planning of the observatory in Trnava, he was called to Cluj as a mathematician and, again, as an observatory designer. The three years he spent in Cluj until becoming professor in Vienna in 1755 seem to have been too short to achieve more than "to lay the basis of an astronomical observatory" (thus stated in a much later letter written by Hell to Thomas Bugge in Copenhagen, 24 July 1789). The fact that he did not see the completion of the planned facility is proven by the circumstance that he made his astronomical observations in his private apartment during his time in Cluj.

Only in 1766 – five years after the Venus transit of 1761 and eleven years after Hell had left Cluj – the observatory seems to have been completed. At this time, a person named Ferdinand (Nándor) Hartmann, who had become a Jesuit in 1753, was appointed professor of experimental physics in Cluj. Hell, who was obviously still interested in the fate of the Transylvanian observatory, sent a movable 3-foot quadrant, a pendulum clock and a 5-foot Newtonian reflector to Hartmann (cf. Hell's letter to Jean Bernoulli III, dated 15 February 1777, University Library of Basel). However, as far as we can see, he never got any observation reports back.

Further drawbacks to astronomy in Cluj were the suppression of the Society of Jesus and a fire which destroyed the observatory tower in 1798 (Szenkovits 2006).

2.5. A network of observatories

With respect to *all* the observatories mentioned above (the two in Vienna as well as those in Graz, Trnava and Cluj), it should be noted that they were intimately interconnected by frequent exchanges of students and staff. The mathematicians and astronomers at any of the mentioned universities would typically have studied and worked at least at one of the other three places. In addition, there were other Jesuit colleges that were part of this network, and which had chairs of mathematics, but no astronomical observatories or chairs of astronomy (see Aspaas 2012 for details).

3. Selected results of the Austrian-Hungarian Venus transit observations in 1761

3.1. Venus transit observations in 1761 at Vienna and Trnava

Among the observatories presented above, only those at Vienna and at Trnava were able to deliver publishable results on the 1761 transit of Venus. At Cluj, bad weather and/or a lack of appropriate instruments may have been the cause for the lack of any printed observation reports. The observatory in Graz should have been well enough equipped in 1761 to enable successful observations, but maybe clouds covered the Sun there. It may also have been the case that observations were made without finding their way into the *Ephemerides Astronomicae* of Maximilian Hell; in fact, the relationship between the Imperial Astronomer and his colleagues in Graz seems not to have been very close (cf. Aspaas 2012, p. 86–89).

In Trnava, the weather was quite fine ("serenum") during the decisive morning hours of June 6 (Hell 1761, p. 96). Franciscus Weiss, observing the Sun with a 4-foot Newtonian telescope, managed to record the time of both the third and the fourth contacts. The difference between the two measured times yields a duration of the "emersio" phase of 18 minutes and 27 seconds.

The observational efforts in Vienna have already been described above. It might be added that the weather in the capital was variable. The Sun and Venus were covered by clouds repeatedly; however, the very last minutes of the transit could be clearly seen and time measurements could be made.

However, the time of the fourth contact was $9^{\mathrm{h}}\ 42^{\mathrm{m}}\ 35^{\mathrm{s}}$ according to Scherffer, while it was $9^{\mathrm{h}}\ 43^{\mathrm{m}}\ 10^{\mathrm{s}}$ according to Hell (Hell 1761, p. 32), implying a maximum difference between the Viennese end time results of 35 seconds. But it should be noted that similar differences between the results of different observers at one and the same location occurred in other Venus transit observation reports as well (Wulf 2012).

3.2. The diameter of Venus according to Hell's 1761 observations

A longstanding question – since the seventeenth century transits of Venus – was the angular diameter of Venus in front of the Sun. Hell gives a short summary of previous measurements, going back to Jeremiah Horrocks and William Crabtree. He reports that Horrocks had derived a Venusian diameter (during the transit) of $1'16''$ while Crabtree had found a value of $1'8''$ (Hell 1761, p. 25).

Concerning the results of the transit in 1761, Hell writes: "diametrum Veneris in disco Solis versantis non majorem, nec multo minorem apparuisse 58 Secundis Circuli maximi [...]." (Hell 1761, p. 25). In other words, he derives a Venusian diameter of 58 arcseconds, which coincides remarkably well with the corresponding present-day value.

Hell also mentions that contemporary observers had found significantly larger maximum values of the Venusian angular diameter based on observations before and after the transit (while Venus was shining from the sky and not appearing as an opaque body in front of the Sun). The differences amounted to almost 20 arcseconds! Hell correctly suspected this effect to have an "optical cause" (Hell 1761, p. 25).

Furthermore, Hell calls for follow-up observations in 1769 – not only during the transit of Venus in that year, but also before and after it, "in the whole month of May, and in the whole month of June", in order to settle this issue (Hell 1761, p. 28).

3.3. The solar parallax value proposed by Hell in 1763

At the end, we may ask the question which value of the solar parallax Hell derived from all the Venus transit observation reports that became accessible to him during the months following June 1761. In this respect, there is an interesting passage in the appendix to the *Ephemerides astronomicae* for the year 1764 (published in 1763), which reads thus: *Ex his igitur omnibus concludendum arbitror, interea, [...], assumendam ex omnibus arithmetice mediam Parallaxim, scilicet = 9.″0. Est enim [...] minima deductio = 8.″2 & maxima = 10.″2 atque adeo media = 9.″0.* (Hell 1763, p. 225).

So Hell proposes to use – until the 1769 transit of Venus would eventually deliver a better result – a solar parallax of 9.0 arcseconds. This value is, coincidentally, by only 2.34% smaller than the currently accepted value of 8.″794 (cf. USNO 2011), implying an Astronomical Unit of about 146.1 million km. It should be noted, though, that the largest parallax value mentioned by Hell, 10.″2, corresponds to an Earth–Sun distance of 128.9 million km, while the smallest parallax value mentioned by him, 8.″2, corresponds to an Earth–Sun distance of 160.4 million km, which means that the Hell's "mean value" may more appropriately be written as 146 million km ±11%.

Nevertheless, this was a significant progress compared to the results of seventeenth century estimates of the Astronomical Unit: Horrocks had derived a solar parallax of 15 arcseconds from the observations of the transit of 1639, corresponding to an Earth–Sun distance of 87 million km.

4. Concluding remarks

The Venus transit observations at the Jesuit-run observatories in the Habsburg empire are far from prominent in the historiography, and that for good reasons. The 1761 transit took place during the very early morning hours of Central Europe, meaning that only the end stage of the transit was in fact visible. The 1769 transit, occurring as it did in the middle of the night, was not observable at all. Despite the insignificance of the data sets the "Austrian" Jesuits managed to provide, the infrastructure for observational astronomy that existed within the Habsburg empire merits a mention in the global history of the transits of Venus.

The report compiled by Maximilian Hell for the 1762 volume of his ephemerides was conspicuous not so much for the observations from the "Provincia Austriae" that were included. His theoretical discussion of various lessons to be learned from the 1761 transit appears to have been far more important. However, a comprehensive analysis of the impact of eighteenth-century Jesuits within the field of theoretical astronomy falls outside the scope of the present article.

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MEETING VENUS
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The Important Role of the Two French Astronomers J.-N. Delisle and J.-J. Lalande in the Choice of Observing Places during the Transits of Venus in 1761 and 1769

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Abstract. Joseph-Nicolas Delisle, as a member of the *Académie Royale des Sciences* of Paris and professor at the *Collège Royal de France*, went to England in 1724 to visit Newton and Halley. The latter suggested observations of the transits of Mercury and of Venus in order to obtain the solar parallax. Delisle was also interested in the Mercury transits. After a stay of 22 years in Saint Petersburg, on his return to Paris, he distributed *avertissements* (information bulletins) encouraging all astronomers to observe the same phenomena, like the solar eclipse of 1748. Later, in 1760, Delisle presented an *Adresse* to the King and to the *Académie* in which he detailed his method to observe the 1761 transit of Venus. This was accompanied by a *mappemonde* showing the best places for observations. Copies of the text, together with 200 maps, were sent to his numerous correspondents in France and abroad.

Following the advanced age and finally death of Delisle, his assistant and successor Joseph-Jérôme Lalande presented a *mémoire* related to the 1769 transit of Venus and an improved map of the best observing places. We detail the role of Delisle and Lalande in the preparation of the international collaboration related to these two transits.

1. Joseph-Nicolas Delisle and Joseph-Jérôme Lalande, two activist-astronomers?

Joseph Nicolas Delisle (or de L'Isle) (1688–1768) was born in Paris; being very gifted in Astronomy, he was admitted in 1714 as the student of Giacomo Filippo Maraldi (1669–1729) at the *Académie Royale des Sciences*. Two years later he was appointed a member of the Academy, first as an adjunct (1716), and then as an associated member (1719, see Fig. 1). He was known as Delisle *le cadet* since his older brother, Guillaume (1675–1726) was also a member of the Academy. In 1719 he succeeded the late Philippe de La Hire (1640–1718) as professor of mathematics at the *Collège Royal*. In 1717 Tsar Peter the Great (1672–1725) came to France and visited the Royal Observatory where he met Delisle. In 1721 the Tsar invited Delisle to come and teach astronomy and geography in Russia. After his death, his wife and successor Tsarina Catherine I (1684–1727) maintained his invitation. From 1726 to 1747 Delisle developed the teaching and practice of both astronomy and geography at the Russian Academy of Sciences in Saint Petersburg. He equipped an observatory and began the measurement of a meridian. His younger brother Louis (1687–1741), known as Louis de la Croyère, also a member of the Paris Academy, came with him to stay in Russia. Louis de la Croyère took part in the exploration of the Northern part of the Pacific Ocean by the Russian navy.

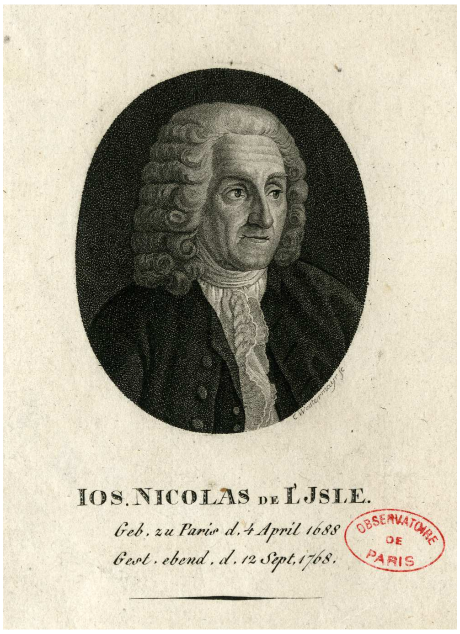

Figure 1. Old Joseph Delisle. Engraving by Westermeyer (1765–1834). Bibliothèque de l'Observatoire de Paris.

On his return to Paris in 1747, Delisle was appointed to the chair of mathematics at the *Collège Royal* again; he was appointed astronomer of the French royal navy – *astronome de la Marine* – and set up an observatory in the *Hôtel de Cluny* (nowadays the Museum of the Middle Ages in Paris). During his stay in Russia Delisle had created a large network of correspondents, over Europe and among the Jesuit missionaries in China and India. He had supplied numerous astronomers with *Avertissements* (information bulletins) encouraging them to observe the same phenomena: the first one concerned the solar eclipse of July 25, 1748, the second was an exhortation from Nicolas-Louis de La Caille (1713–1762), asking astronomers to observe the Moon, Mars and Venus in conjunction with him being stationed at the Cape of Good Hope (1751–1752).

Joseph Jérôme Lefrançois (1732–1807), born in Bourg-en-Bresse on July 11, after studying in Jesuit schools first in Bourg and then in Lyon, arrived in Paris in the autumn of 1748 to study law. His name was then changed to Lefrançois de Lalande, which soon became Delalande or Lalande when he reached fame (Fig. 2). By chance he got accommodation with a *procureur* (royal prosecutor) at the *Hôtel de Cluny* where he was happy to have a look at the observatory and to meet Delisle. In Bourg, while he was a young boy, he had admired the comet of 1744; later, when he was a pupil at the college of Lyon, father Béraud (1702–1774) had shown him the solar eclipse of July 25, 1748. So, while studying law to satisfy his parents, Lalande had the opportunity to observe and learn about astronomical facts with Delisle; the following year he studied with Pierre Charles Lemonnier (1715–1799), also professor at the Collège Royal; in 1751, Lemonnier provided him with an astronomical mission to Berlin to observe the Moon in conjunction with La Caille, who was then, as already mentioned, at the Cape of Good Hope.

On his return to Paris with some good observations, Lalande was admitted to the Academy (1753). From his own observations of the Moon and those sent to the Academy by La Caille, Lalande deduced the parallax of the Moon. Later, in 1758,

Figure 2. Lalande, 1783, work by Gatteaux (1751–1832). Bibliothèque de l'Observatoire de Paris.

following a request of Alexis Clairaut (1713–1765), with the help of Mme Lepaute (1723–1788), he calculated the perturbations induced by Saturn and Jupiter on the orbit of the comet now known as Halley's comet, and, as a consequence, he obtained a more precise time of perihelion passage; thanks to his successful results, Lalande gained the reputation as an able astronomer, both as an observer and as a calculator.

In 1760, 72-year old Delisle appointed his young friend Lalande his *"survivancier"* in his teaching at the *Collège Royal*. Lalande thus lectured here, as Delisle did before him, and, when Delisle passed away in 1768, he became the successor to his chair of mathematics that became, in 1774, a chair in astronomy. Lalande stayed at the *Collège de France* until his death. Like Delisle, Lalande developed a large network of correspondents and exerted a marked influence on the international community of astronomers.

2. Delisle and the transits of planets over the solar disc

Assiduously observing, Delisle was much interested in important astronomical events, like the transit of Mercury over the solar disc of 9 November 1723 and the total solar eclipse of 22 May 1724, both of which he observed at the Royal Observatory in Paris. This same year, to prepare for his mission to Russia, Delisle went to London with a member of the *Académie Française*. There, he visited Isaac Newton (1643–1727), who gave him his portrait, and the Astronomer Royal Edmond Halley (1656–1742).

In 1677, Halley had proposed a method to evaluate the solar parallax. First he proposed to use the observations of the Mercury transits over the Sun's disc, then the Venus transits predicted to occur later, in 1761 and 1769. Halley developed his method while, on the Island of Saint-Helena, he attended and observed a transit of Mercury; his method consisted in recording the local time of both the second and third contacts of the transit from two observing places with different latitudes. This information was supposed to infer the distance Earth–Mercury, and, by using the third law of Kepler (1571–1630), the distance Earth–Sun. However, in the case of Mercury, the precision proved to be insufficient; for this reason, Halley recommended to observe the 1761 transit of Venus over the solar disc from two specific places: the Hudson Bay and some site in India. Delisle, who had already observed a transit of Mercury, is likely to have discussed this subject with Halley during his visit. Be that as it may, when Delisle returned to Paris, he was a Newtonian natural philosophy enthusiast and still a strong supporter of observations of the Mercury transits, the next transits of Venus being in a so remote future, i.e., more than forty years ahead!

Delisle later, while in Russia, embarked upon an expedition to Siberia to observe the Mercury transit of May 2, 1740, from Beresov on the banks of the River Ob near Tobolsk, – after asking some of his correspondents to observe the Moon in conjunction with him. Delisle proceeded through Russia as quickly as possible to reach his destination on the Ob. Unfortunately, the transit day was cloudy, and his correspondent Johann Wilhelm Wagner (1681–1745), wrote to him that it had rained in Berlin during the whole transit. By the end of August/beginning of September Delisle returned to Saint Petersburg; he soon sent advice to astronomers in various countries including a letter to Jacques Cassini (1677–1756) for improving the observation of the next transit of Mercury, predicted to occur on November 4, 1743.

Back in Paris in 1747, Delisle suggested a method to obtain the solar parallax that differed from Halley's; one needed to record the exact time of just one single inner contact of the planet with the Sun from two different observing places, the latitude and longitude of which must be precisely known. Hence observation of either the second or the third contact would be sufficient; it was no more necessary to observe both the ingress and the egress of Venus as required in Halley's method.

In theory, this new method should be more successful than Halley's. However, the observation proved difficult to carry out with the eighteenth century's astronomical instruments and clocks: it was indeed necessary to note the exact timing of the interior contact of the planet with the solar limb. For this reason Delisle supplied his correspondents with a printed information bulletin to observe the next Mercury transit of the May 6, 1753; this *Avertissement* was accompanied with a *Mappemonde* (map of the world), which he himself had drawn and engraved. On this map, the possible observing sites are indicated. Since Delisle is also a geographer, he explicitly points out

> où l'on voit les nouvelles découvertes faites au Nord de la mer du Sud.[1]

Various French astronomers observed the 1753 Mercury transit from different sites in France; Pierre-Charles Le Monnier showed it to King Louis XV in Meudon, at the Bellevue Castle, one of the residences in which Mme de Pompadour lived. All the astronomers who had the opportunity to observe this transit, attempted to observe it. And it was a good rehearsal for the next transit of Venus, predicted to occur less than ten years later; it should be added that the observations of this transit of Mercury led to a more detailed study of the movement of the planet.

Before the 1761 transit of Venus, the astronomers were very busy with the return of the 1682 comet announced by Halley for 1758 or 1759; it was only at the end of 1759 that Delisle, with the help of his calculating assistants, Libour and Claude-Étienne Trébuchet (1722–1784), made some verifications of Halley's calculations

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[1] "Where it is possible to see the new discoveries made in the north of the Southern Sea": the Bering Strait, then recently discovered – but not yet so designated. Delisle learned about its existence when he was in Russia (the South Sea is nowadays called the Pacific Ocean).

concerning the best places from where to observe the coming Venus transit of June 6, 1761. Some errors in the calculations were detected, which led to a change for some of the selected sites as proposed by Halley: it meant that the English astronomers had to give up the proposed expedition to the Hudson Bay in North America, where it would not be possible to observe this transit. Delisle now re-used his 1752 engraved *mappemonde*, scratched out all that concerned the Mercury transit, drew and engraved the lines which defined the places where observation of the transit of Venus on 6 June 1761 would be possible. This *mappemonde*, with an explanatory *Mémoire*, was then presented to the King

> par le Sieur De L'Isle, lecteur et professeur Royal[2]

on April 27, 1760, and to *l'Académie des Sciences* during the assembly of Wednesday, April 30 (Fig. 3).

The Academicians in Paris were convinced of the importance to observe this astronomical event from different places; they decided, on May 10, that *Messieurs* the astronomers would gather on the next Wednesday, after the meeting of the Academy, to discuss the upcoming transit. During the May 14 *assemblée* of the Academy, Lalande ended the reading out of his *Mémoire* by pointing out that

> Ainsi la véritable étendue du système solaire, la grandeur des orbites de toutes les planètes, la théorie des éclipses, la connaissance des masses, des volumes, des densités, des diamètres, tout dépend de la parallaxe du Soleil [. . .]. L'occasion que nous présente ce célèbre phénomène est un de ces moments précieux, dont l'avantage, si nous le laissons s'échapper, ne saurait être ensuite compensé.[3]

It was probably after this meeting of the Academy that the gathered astronomers planned the French expeditions. The war between England and Prussia on the one hand and France, Austria and Russia on the other hand (Seven Years War) also had to be considered. It was decided that *abbé* Jean Chappe d'Auteroche (1722–1769) would go to Tobolsk in Siberia. Guillaume Joseph Hyacinte Jean Baptiste Le Gentil de la Galaisière known as Le Gentil (1725–1792), who asked for, and obtained, orders from the King to go to Pondicherry, embarked on March 26. Another expedition to the southern hemisphere was planned: in May 1760, Lalande showed the advantage of observing from the western coast of Africa but, in August, it was decided that Alexandre Guy Pingré (1711–1796) would go to Rodrigues, which is close to the Île de France Island (now Mauritius) in Eastern Africa. The choice of these three expeditions was an appropriate one, since the three selected observing stations are located on quite close meridians. César-François Cassini de Thury (1714–1784), meanwhile, would observe in Vienna.

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[2] Mr. De l'Isle, reader and royal professor.

[3] Thus, the true expanse of the solar system, the size of planetary orbits, the theory of eclipses, the knowledge of masses, volumes, densities, diameters, of everything depends on the solar parallax [. . .]; the opportunity that we are offered by this famous event is one among those precious moments, the advantage of which, if we miss it, can not be compensated.

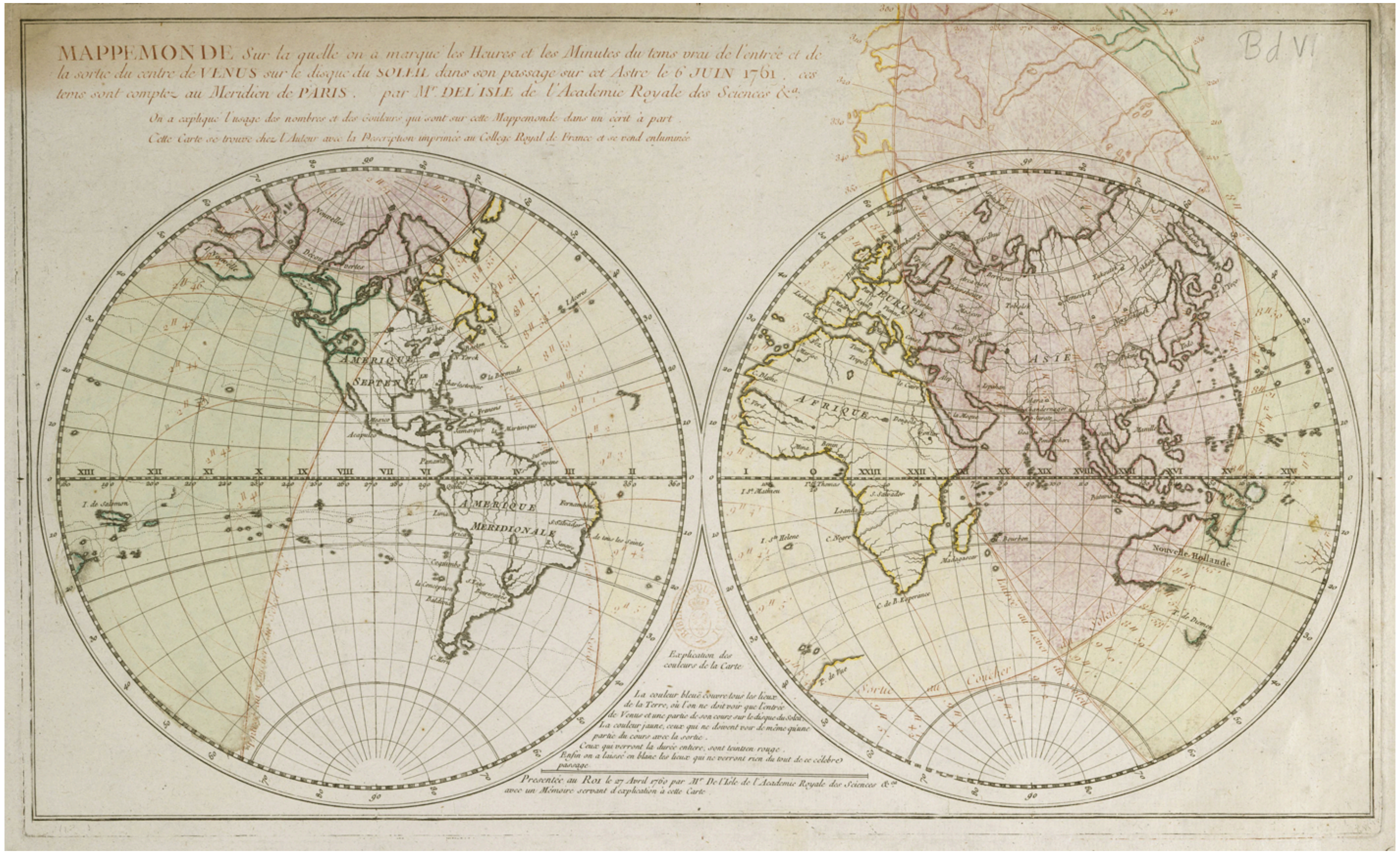

Figure 3. *Mappemonde sur laquelle on a marqué les heures et les minutes du temps vrai de l'entrée et de la sortie du centre de Vénus sur le disque du soleil.* (Mappemonde where the hours and minutes of true time of ingress and egress of the center of Venus over the Solar disc are indicated). Delisle (1760), dimensions: 41 × 59 cm, Bibliothèque nationale de France.

To motivate the astronomical community, Delisle distributed 200 copies[4] of his map with some explanatory elements, in which the following points were clarified: the places where the ingress of Venus over the solar disc and some part of the transit would be visible were to be colored in blue,[5] the places where just some part of the transit and the egress of Venus (as in Paris) would be visible should be colored in yellow, and the places where the whole transit would be visible were to be colored in red. The places with no possible observation of the transit were of course to remain in black and white.

Delisle generously gave one or several copies of these two publications to his astronomer correspondents and to the interested Parisian Academicians. Furthermore, Delisle equipped Chappe d'Auteroche, before his departure to Tobolsk, with a memoir and colored glasses to have safe observations of the Sun; he also provided the Jesuit Father Ruggero Giuseppe Boscovich (1711–1787), who arrived in Paris in 1759 where he stayed during six months, with three *mappemondes* for the Royal Society of London. Early in 1760, Boscovich left Paris to go to London where he was elected a Fellow of the Royal Society on June 15, 1761. Delisle had informations on English plans for Venus transit expeditions from newspapers published in Holland: they would go to Saint Helena Island (instead of the expedition to North America as proposed by Halley) and Bencoolen in Sumatra Island. Delisle also asked for, and received, news about the English expeditions from John Bevis (1693–1771) and Charles Morton (1703–1768), the mails circulating probably through Holland. Besides, Delisle entertained an extensive correspondence with Dirk Klinkenberg (1709–1799), an astronomer in The Hague, who recommended to send instructions to the governors in the Dutch colonies, in Ceylon, The Cape, the Dutch Eastern Indies; the professor Jean Nicolas Sebastien Allamand (1713–1787), in Leiden, had the opportunity to reach them by mail.

In spite of the informations and the distribution of passes, there were to be some difficulties: Pondicherry was won over by the English Navy just before Le Gentil de la Galaisière's arrival; Alexandre Guy Pingré, in Rodrigues Island, had his ship captured by the Royal Navy and was forced to wait for a hypothetical rescue. One of the English expeditions, sailing to Sumatra, was attacked by French corsairs, and was forced to return to London; the involved astronomers would afterwards sail to the Cape of Good Hope.

There were 130 collected observations (Aspaas 2012, p. 423). Delisle was receiving the results obtained by his correspondents up until August 1764 when the last ones, those obtained by Jesuit Father Gaston-Laurent Coeurdoux (1691–1779), became available; Coeurdoux, in 1761, had managed to escape from Pondicherry with some instruments including a second pendulum clock and a telescope, so he could observe the Venus transit from Tranquebar, then a Danish colony. Delisle, a 73-year old man, did not carry out the calculation of the solar parallax; he just transmitted all the observations to the Academy and to his collaborator and close friend, Lalande. The obtained values for the solar parallax varied from 8.6 to 10 arcseconds.[6] In Paris, the key persons in the calculations were Lalande and Pingré, who settled for parallaxes of $9\overset{\prime\prime}{.}00$ and $10\overset{\prime\prime}{.}25$, respectively.

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[4] Four of these maps are nowadays known in London, Paris and Utrecht.

[5] Print in color was impossible in those days, hence the accompanying text gave instructions for the application of color by the recipient.

[6] Other values are listed in Aspaas (2012), pp. 200–201.

Figure 4. Lalande (1764a): “Figure du passage de Vénus sur le disque du Soleil qu'on observera le 3 juin 1769. Sur laquelle on voit les momens de l'entré et de la sortie de Venus pour tous les Pais de la Terre réduits au méridien de Paris Avec l'effet des parallaxes, et le choix des Pais de la terre ou ce Passage devra être observé pour en conclure la distance du Soleil et de toutes les Planettes a la Terre”. 1764, dimension 47 × 66.5 cm, Bibliothèque nationale de France.

3. Jérôme Joseph Lalande and the transit of Venus over the Sun of June 3, 1769

As early as 1760, on May 14, Lalande presented a long memoir to the *Académie* where he gave his first estimates about the Venus transit which was to occur in 1769. This memoir was first published in the *Histoire de l'Académie Royale des Sciences, Mémoires* pour l'année 1757 (but printed later, in 1762). In this memoir Lalande first outlines Delisle's work on the 1761 transit. Then he points out how useful the mappemonde proposed by Delisle was, but notes that Delisle did not indicate how he calculated the lines that define the places where the observation of the transit was possible. Lalande thereafter details his own method to graphically obtain these curves. He underlines that, since a mappemonde is plotted according to a stereographic projection, as a result all circles on the terrestrial globe become circles on the mappemonde, larger or smaller depending on their location. Lalande gives the duration of the transit of Venus over the solar disc of June 3, 1769, both in Saint Petersburg and Mexico, two widely separated places, where he has estimated the accuracy of the expected observations. In this volume of *Histoire de l'Académie Royale des Sciences* (année 1757, published 1762) one finds a first *mappemonde* established by Lalande with the places where it should be possible to observe the 1769 Venus transit.

In 1764, with the agreement of the *Académie,* Lalande published another *mappemonde* devoted to the 1769 Venus transit (Fig. 4):

> elle est gravée en grand avec tous les détails & les distinctions de couleurs à Paris ches Lattré, graveur rue Saint Jacques [...][7].

This map was accompanied with a memoir which details the next missions to be undertaken and some collection of the observations already carried out during the transit of 1761. Lalande also proposed one expedition to an island of the Pacific Ocean and recommended to select two observing places where the difference in the transit lengths would be as large as possible.[8]

In 1764, Lalande also published the first edition of his famous book, *Astronomie*; *Livre XI* of the second volume of this work is devoted to a very complete presentation of transits of both Mercury and Venus over the solar disc (Lalande 1764b). One also finds a reduced reproduction of his first *mappemonde*. Furthermore, Lalande mentions the observations of some previous historical transits, like the transit of Mercury of November 7, 1631, observed by Pierre Gassendi (1592–1655) in Paris, the transit of Venus of December 4, 1639, observed by Jeremiah Horrocks (1619–1641) near Manchester; Lalande also presents the respective works of both Halley and Delisle; he ends this *Livre XI* by indicating three appropriate methods to observe the phenomenon (including among other questions, which instruments to use) and all the relevant conclusions to be drawn.

Astronomie was widely distributed abroad by its publisher Jean Desaint (1692?–1776), who exchanged half of the edition for books edited in Holland and other

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[7] it is engraved on a large scale with all details included and some differenciations in colors by Lattre, in Paris engraver at Rue Saint-Jacques

[8] *Figure of the passage of Venus over the solar disc that will be observed on 3 June 1769, with the moments of ingress and egress of Venus for all the countries reduced to the Paris meridian, with the effect resulting of parallaxes and the choice of the countries where this transit will be observed to derive the solar and all the planetary distances to the Earth.*

countries. The remaining 500 volumes in France were sold out within two years only; Lalande gave some copies to the Petersburg Academy, an honorary member of which he had been appointed in March 1764, and one copy also to Father Hell (1720–1792) in Vienna.

To all his correspondents he sent the prospectus of his *Astronomie.* It is, however, difficult to assess how much these publications influenced the various academies in their selection of the observing sites.

In 1767, A.G. Pingré also published a selection of places to observe the Venus transit of 1769.

Peace had by now returned to Europe and the academies were able to discuss a better repartition of the observers of this transit. By mail, the *Académie des Sciences* recommended Le Gentil, then in Manilla, to go to Pondicherry where he arrived late March 1768. Chappe d'Auteroche was to go to California with a Spanish team; an ocean expedition around the Atlantic Ocean was organized by the French navy Secretary Praslin (1712–1785) to test both marine clocks and methods to determine longitudes at sea. The captain of the ship *Isis*, M. d'Eveux de Fleurieu (1738–1810) did ask Lalande to join him and to make some astronomical observations; Lalande, however, had fears of sea sickness and succeeded in being replaced by Pingré since, according to him

> Pingré était déjà accoutumé à de grandes navigations, et d'une santé robuste.[9]

One should add that Pingré was an accommodating and unpretentious person; everyone had respect and affection for him. The *Isis* arrived at Saint-Domingue (Haïti) on May 23, 1769. During the call time, Pingré, with the crew officers participating, succeeded in observing the ingress of Venus over the solar disc and the transit itself during three hours. In the account of this journey submitted to the *Dépôt de la Marine* (Navy Collection), later published by d'Eveux de Fleurieu, Pingré reported that, between the two contacts, during the ingress, he saw a sort of luminous flash around Venus, still partly outside the solar disc.

Lalande was also approached in another way; for example, by Jacques-André Mallet (1740–1790), a Geneva astronomer, who asked him to be allowed to join any French expedition to observe the 1769 transit; Lalande, in 1767, answered that there was only going to be one French expedition, led by *Abbé* Chappe who had already a friend on board; instead Lalande recommended him to submit an application to the Petersburg Academy

> qui n'a guères d'astronomes capables de les faire,[10]

for any participating position in one of the four missions planned by the Academy.[11] With the help of Daniel Bernoulli (1700–1782), a member of the Petersburg Academy, Mallet's application was accepted: he stayed four months at Ponoi in the Kola Peninsula where he observed the ingress of Venus over the Sun. He was accompanied for a while by his friend and relative, Jean-Louis Pictet (1739–1781). Later, in 1772, Mallet became an appreciated academic correspondent of Lalande.

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[9] Pingré was already used to ocean navigation, with a robust health (Lalande 1803).

[10] and which has hardly any suitable astronomers to make them (observations), (Lalandiana II).

[11] Catherine II asked the Petersburg Academy to invite foreign astronomers; eventually, in 1769, there were at least 8 Venus transit expeditions in Russia (Aspaas 2012).

Around 1768, other memoirs related to the next 1769 transit were published (Lalande 1803): for instance, in London, *Instructions relative to the observations of the ensuing transit of the planet Venus over the sun's disk, on the 3d of June 1769* by Nevil Maskelyne (1732–1811); in Oxford, *The whole Doctrine of Parallaxes explained and illustrated by an Arithmetical and Geometrical Construction of the Transits of Venus and Mercury over the Sun*[12] by Edward Stone (1702–1768), and a similar memoir in the Transactions (*Handlingar*) of the Royal Swedish Academy of Sciences in Stockholm.

In total, there were at least 154 observations carried out in 78 places (Aspaas 2012). One of the most significant observations was carried out by Captain Cook (1728–1779) and the astronomer Charles Green (1735–1771), who observed the entire transit from Tahiti under perfect weather conditions.

The solar parallax was now rather well determined: from $8''\!.40$ to $8''\!.80$, values obtained from many observations and calculations.

4. Conclusion

One can assert that Delisle did motivate the European astronomers for the observation of the 1753 Mercury transit over the solar disc; an enterprise which allowed, maybe for the first time, to achieve a difficult observation: to record the right time of the contact of a planet with the solar limb. Thanks to Delisle, who made some verifications of Halley's calculations and published *mappemondes* on transit visibility, astronomers could select appropriate sites to observe the coming transits: in order to estimate the solar parallax, they could use either Halley's method or Delisle's, or a combination of the two.

Lalande, always impatient, was the first to calculate the elements of the 1769 Venus transit and to suggest some appropriate places to observe it. He thus can be seen as the initiator of the various French expeditions and, as Aspaas (2012) points out, also as a key figure in the coordination of observations worldwide.

After the publication of his 1760 *Avertissement,* 72-year old Delisle gradually retired. In his place came 28-year old Lalande, hard-working and profoundly committed to the writing of memoirs, his *Astronomie,* and the *Connaissance des tems,* as well as to his teaching at the Collège Royal and his ever increasing correspondence.

In the western tower of the Paris observatory, a painting by Edmond-Louis Dupain (1847–1933) covers the ceiling of the ground room (Fig. 5); it was ordered by director of the Observatory Admiral Ernest Mouchez (1821–1892) who led the French expedition to observe the 1874 Venus transit in Saint Paul Island. The painting pays tribute to the Venus transits and to both Halley and Delisle as the two key persons of the planet transits: it is easy to single out the Sun and Venus with a star on her head, accompanied by two white birds, a small Cupid with arc and arrow and angels observing or submitting elements to Urania or ready to announce the astronomical event. The respective faces of Halley and Delisle appear, not far from Urania, the muse of astronomy, who is presented, as usual, with a terrestrial globe in her left hand and some writing instruments in the other. A third face is visible a little farther: Urbain Le Verrier's (1811–1877), Mouchez's predecessor as the head

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[12] The subtitle of this book (i.e. "the second edition, corrected and enlarged") reads: *Enriched with a New and General Method of determining the Places where any Transit of these Planets may be best observed for the Investigation of their Parallaxes; and applied in particular to that of Venus, which will be June 3, 1769, and of Mercury, May 7, 1799.*

Figure 5. Passage de Vénus devant le Soleil by Dupain (1886). Bibliothèque de l'Observatoire de Paris.

of the Paris Observatory, also interested in the determination of the astronomical unit, but not involved in the planetary transits (see Fig. 6).

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Venusians: the Planet Venus in the 18th-Century Extraterrestrial Life Debate

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Abstract. In the seventeenth and eighteenth centuries it became possible to believe in the existence of life on other planets on scientific grounds. Once the Earth was no longer the center of the universe according to Copernicus, once Galileo had aimed his telescope at the Moon and found it a rough globe with mountains and seas, the assumption of life on other planets became much less far-fetched. In general there were no actual differences between Earth and Venus, since both planets orbited the Sun, were of similar size, and possessed mountains and an atmosphere. If there is life on Earth, one may ponder why it could not also exist on Venus. In the extraterrestrial life debate of the seventeenth and eighteenth centuries, the Moon, our closest celestial body, was the prime candidate for life on other worlds, although a number of scientists and scholars also speculated about life on Venus and on other planets, both within our solar system and beyond its frontiers.

This chapter discusses the arguments for life on Venus and those scientific findings that were used to support them, which were based in particular on assumptions and claims that both mountains and an atmosphere had been found on Venus. The transits of Venus in the 1760s became especially important for the notion that life could thrive on Venus. Here, I detect two significant cognitive processes that were at work in the search for life on Venus, i.e., analogical reasoning and epistemic perception, while analogies and interpretations of sensory impressions based on prior knowledge played an important role in astrobiological theories.

1. Introduction

The idea that life could exist on other celestial bodies has been discussed since antiquity. The debate that this idea engendered – the extraterrestrial life debate, or alternatively, the plurality of worlds debate – intensified in the seventeenth and eighteenth centuries,[1] happened for at least three reasons. Firstly, in the new heliocentric system Earth was a planet like the others and no longer the center of the universe. Secondly, the invention of the telescope revealed geographical features on the Moon, while the other celestial bodies no longer seemed to be smooth, even and perfectly spherical bodies. Thirdly, the discovery of new worlds overseas led to a heated debate on the unique status of the human being and of Christianity; cultural encounters, and the existence of life unrelated to our own culture.

Once the Earth was no longer considered the center of the universe, after the work of Nicolaus Copernicus and the publication of his *De revolutionibus orbium coelestium* in 1543, Galileo Galilei had aimed his telescope at the Moon in 1609 and found it a rough globe with mountains and seas, and physico-theologists were

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[1] For the plurality of worlds debate see: Dick (1982, 1996); Guthke (1983); Crowe (1986, 2008) and Dunér (2012).

convinced that the all-powerful Creator must have filled the entire Universe with life, then the assumption of life on other planets became much less far-fetched.[2] In the extraterrestrial life debate of the seventeenth and eighteenth centuries our closest celestial body, the Moon, was the prime candidate for life on other worlds. However, a number of scientists and scholars also speculated about life on Venus and on other planets, both within our solar system and beyond its frontiers. In general there were no actual differences between Earth and Venus. They were both planets that orbited the Sun, were of similar size, and, as some astronomers claimed, Venus also possessed mountains and an atmosphere. If there is life on Earth, then one may ponder why it could not also exist on Venus. The following discusses the arguments for life on Venus and the scientific findings that were used to support them.

2. Cognitive processes in astrobiology

The arguments in favor of life on other planets, including Venus, are, I contend, characterized by two significant cognitive processes.[3] Firstly, *analogical reasoning*, i.e., the use of analogies from existing knowledge, and secondly, *epistemic perception*, the interpretation of what has been observed based on a preconceived understanding, concepts, and prior knowledge. These two cognitive processes are very prominent in the debate on the existence of mountains and an atmosphere on Venus.

An analogical argument could be explained as a search for similarities, i.e., a way of selecting features in the source domain that are to be mapped onto the target domain, and of transferring relevant properties from the source to the target. If x has the properties n_1, n_2, n_3, n_4, …, and there is a y that has n_1, n_2, n_3, we can conclude that it also has n_4. If there is an x that has these qualities, then we conclude that all y that has some of these qualities also has the quality that we are seeking, $\exists x(P_1x \wedge P_2x \wedge P_3x \wedge P_4x \ldots\ P_nx) \wedge\ \exists y(P_1y \wedge P_2y \wedge P_3y) \Rightarrow\ \forall y(P_4y)$. This is, logically speaking, an invalid argument, but one that is widely used in science as a kind of heuristic method. The challenge is then to select the correct and relevant salient features from an infinite number of possible ones in the source domain, which features will then be transferred to and mapped onto the target domain. In the case of Venus, we know that Earth orbits the Sun, is solid, has a daily axial rotation, an atmosphere, mountains… and also life. Venus, too, orbits the Sun and is solid. If we can estimate the axial rotation and detect an atmosphere and mountains on that planet, it might also be true that it harbors life. These questions were in fact those that were investigated during the seventeenth and eighteenth centuries, and they included the length of its period of rotation and whether it had mountains, an atmosphere and life.

In the optical observations of Venus, especially during the transits of the 1760s, we also see how preconceived understanding shaped the interpretation of what the observers had seen. Through their senses, they received impressions from outer space, and they collected and collated information on distant worlds using their sight. What their senses conveyed had to be interpreted by means of specific cognitive processes before it became a reality. As observers, we do not just passively receive images from the world around us. Instead, the brain actively searches out patterns in what is conveyed to it through the senses, and interprets them through a process

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[2] Copernicus (1543); Galilei (1610); Derham (1715).

[3] Concerning cognition and astrobiology, see: Dunér (2011a, b).

that is determined by both biological and cultural factors. Perception is not a neutral, objective, and realistic recording of reality. This conceptual or epistemic vision implies an identification of what is seen, and takes place by applying our concepts to visual perceptions, that is, concepts that affect what we see, and, should we lack any concept of a specific phenomenon, then it will be difficult to distinguish it among all our impressions. The world distorts our concepts, and the concepts distort our world. Striking examples of this epistemic perception are the maps of Venus that delineated the surface of the planet, where it was sometimes interpreted as possessing mountains and other geological features. Even a dim light, faint spots and lines, and a companion moon seemed to appear when Venus was viewed through a telescope. The astronomers interpreted their obscure observations in line with their prior knowledge and their ideas of the nature of the world, and they often found what they sought. If they believed in the existence of mountains and an atmosphere on Venus, then they duly found them.

3. Life on Venus

Before I return to the question of a Venusian atmosphere and mountains, I will outline the extraterrestrial life debate from the seventeenth to nineteenth century with respect to a habitable Venus. As has been mentioned, the Moon was the prime candidate for extraterrestrial life in the early modern period, and was later succeeded by Mars at the end of the nineteenth century. Meanwhile, however, the other planets, including Venus, were also discussed in terms of their habitability. These claims of a habitable Venus are found in the borderline between science and fiction; between empirical observations and the imaginings of the human mind. This is as much a cultural as a scientific debate. A curious mystery, which can be kept in mind, is why Venus, the closest planet to Earth in the solar system, never became as popular as the Moon and Mars as a candidate for a habitable world.

The first closer observations of extraterrestrial bodies were made by Galileo in the autumn of 1609. In the *Sidereus nuncius* from 1610, he shows, based on his telescopic observations and analogical reasoning, that the Moon has mountains and therefore has the same solid, opaque and rugged nature as the Earth. The irregular border between its dark and illuminated parts is incompatible with the idea that it is a perfect spherical solid. Galileo wrote:

> Anyone will then understand with the certainty of the senses that the Moon is by no means endowed with a smooth and polished surface, but is rough and uneven and, just as the face of the Earth itself, crowded everywhere with vast prominences, deep chasms and convolutions.[4]

The Moon had a smooth appearance, though, in its contour, which he explained was because it might have an atmosphere. Another important observation in this context is that he found that Venus has phases like the Moon. It seems, though, that Galileo never stretched his analogical reasoning as far as it would extend by expressly claiming the existence of life on other planets. However, he did not consider it impossible that there were inhabitants on these spheres, but he also said that we cannot take it for granted that life elsewhere in the universe must resemble our own. In 1612 Galileo wrote:

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[4] Galilei (1610); Spranzi (2004), p. 459.

> I agree with Apelles [the astronomer Christoph Scheiner] in regarding as false and damnable the view of those who put inhabitants on Jupiter, Venus, Saturn and the Moon, meaning by inhabitants, animals like ours, and men in particular.[5]

Later in the *Dialogo ... sopra i due massimi sistemi del mondo* (1632), he stated that there is no water, no humidity, no seas on the Moon, and therefore no life.[6]

One of the most famous and popular accounts defending the existence of life outside Earth is Bernard Le Bovier de Fontenelle's book *Entretiens sur la pluralité des mondes* (1686), which consists of six evening discussions on the plurality of worlds between a philosopher and an aristocratic lady in the gardens of a country chateau.[7] Perhaps, says the philosopher, there are astronomers on Jupiter, and maybe we cause them to engage in scientific quarrels, and some philosophers have to defend themselves when they put forward the opinion that we exist. The marquise speculates in turn about the inhabitants of Venus, stating that they are perhaps, because they are closer to the Sun,

> little black people, scorch'd with the Sun, witty, full of Fire, very Amorous,... ever inventing Masques and tournaments in honor of their Mistresses.[8]

Even though these conversations are imaginary, they liberated the mind and made it possible to think about the existence of extraterrestrial life, while there did not seem to be any scientific reasons to disbelieve in the plurality of habitable worlds.

The Dutch scientist Christiaan Huygens expressed the view in his *Cosmotheoros* (1698) that there most likely was life out there.[9] He noted that liquid water is necessary for life, and he saw darker and lighter spots on the surfaces of Mars and Jupiter that he interpreted as water and ice. Beyond our solar system there are stars similar to our Sun, and he asked why these stars could not have their own planets with their own moons. As for Venus, he empirically stated that it is surrounded by a thick atmosphere. He could not clearly detect any patches on the surface that might be signs of seas and mountains. Perhaps, he said, there are no seas on Venus, or, as he believed more probable, the air and clouds around Venus reflect nearly all the light from the Sun.

Some philosophers and scientists even speculated about the inhabitants and the intelligence of these extraterrestrials. The philosopher Immanuel Kant wrote in *Allgemeine Naturgeschichte und Theorie des Himmels* (1755) that the intelligence of the extraterrestrials becomes

> more excellent and perfect in proportion to the distances of their habitats from the Sun.[10]

The Mercurians and Venusians are according to Kant less intelligent than Earthlings who are exactly in the middle. The Jovians and Saturnians are superior beings. Kant wrote:

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[5] Galilei (1612); Dick (1982), p. 86.

[6] Galilei (1632); Spranzi (2004), p. 468.

[7] Fontenelle (1686).

[8] Fontenelle (1686); Crowe (1986), p. 19.

[9] Huygens (1698).

[10] Kant (1755).

> From one side we saw thinking creatures among whom a man from Greenland or a Hottentot would be a Newton, and on the other side some others would admire him as [if he were] an ape.[11]

Interestingly, here Kant actually discusses how the body functions of humans are a result of their location in the solar system, and also how this location and their bodies affect their minds and their ability to think.

There was also a lively extraterrestrial life debate in Scandinavia. Two dissertations were defended in the 1740s in Uppsala with the professor of astronomy Anders Celsius chairing the proceedings, of which one refuted the idea of a habitable Moon, while the other defended the idea of the plurality of worlds.[12] The Norwegian historian Gerhard Schøning wrote about a fantastic voyage to Venus.[13] To my knowledge this is the first attempt at a Venusian odyssey in the history of science fiction. Venus, said Schøning, has mountains, valleys, plains, rivers, lakes, seas, forests, and a multitude of plants, stones, metals and soils. There are forests and meadows full of tame and wild creatures, the waters are full of fish, and the soil has many edible plants. There are also intelligent creatures, who, however, are in most respects very different from those on Earth. Schøning's story describes an Englishman who constructed a craft in which he took off from the highest mountain in Norway on the summer solstice of 1759. It was aimed at the Moon, but the space traveler fell asleep, veered off course and overshot the Moon. When he woke up, he was surrounded by mist and smoke through which he traveled as though beneath an ocean. He had entered the atmosphere of Venus, on whose surface he landed and he saw people passing by… and then, as the story reaches its most exciting point, the manuscript ends.

Probably one of the most original and curious contributions to this debate in the eighteenth century was a work that, without slightest irony, provided a sincere account of its author's encounters with extraterrestrials. In 1758, the Swedish spiritual visionary Emanuel Swedenborg published a book that described his encounters with extraterrestrial spirits, which he entitled *De telluribus in mundo nostro solari* (1758).[14] In it, he advanced theological arguments for the existence of extraterrestrials, i.e., that the planets and stars have a more important purpose than merely to rotate and to shine. The planets visible to our eyes, he says, can be plainly recognized as worlds, bodies made of earthly matter that reflect sunlight, mottled with dark patches like land masses on earth, revolving around the Sun, and rotating about their axes like our Earth:

> Can anyone knowing this and able to think rationally still claim that these are empty masses?[15]

In conversations with spirits, he discusses the argument that there is more than one world in the universe, based on the fact that the starry sky is so immense and contains countless stars, each one a Sun with its own planetary system.

Swedenborg not only assumes that there could be life on Venus; he even claims that he had met spirits from that planet and talked with them. He speaks of two

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[11] Kant (1755), pp. 189 f.; Crowe (1986), pp. 52 f.

[12] Celsius (1740, 1743).

[13] Johansen (2012).

[14] Swedenborg (1758); Goerwitz (1985), pp. 417–446, 477–485; Bedford (2006); Dunér (2013).

[15] Swedenborg (1758), n. 3.

kinds of people on Venus, who are of opposite characters.[16] Some are gentle and humane; others are fierce and almost like wild animals. These latter inhabitants take great pleasure in stealing, and particularly in eating what they have stolen. They are for the most part giants, and people of our world only come up to their navel. Furthermore, they are stupid and do not ask what heaven is or enquire about everlasting life.

Swedenborg also calculated the total number of people or spirits. If there were a million worlds in the universe, and three hundred million human beings in each world, and two hundred generations in six thousand years, and each human being or spirit were given a space of three cubic meters, then when all this was added together, they would still not occupy a thousandth part of the volume of this world, but perhaps the volume of one of the satellites of Jupiter or Saturn.[17] Later in 1848, the Scottish church minister and science teacher Thomas Dick also tried to estimate the number of inhabitants on the planets of our solar system by comparing their magnitude with the population of our globe.[18] If the planets were populated as densely as in England, at a rate of 280 inhabitants to a square mile, we find that Venus would have 53.5 billion people, and Jupiter, the most populated planet, would have 6,967 billion; in total with all the planets, satellites, asteroids and the rings of Saturn, there would be 21,894 billion people in our solar system.

The French popularizer of astronomy Camille Flammarion considered in *La pluralité des mondes habités* (1862) that it was absurd that the Sun was employed solely to illuminate and heat our small world. This absurdity became even more striking when Venus was found to be a planet of the same dimensions as the Earth, with mountains and plains, seasons and years, and days and nights analogous to our own. That analogy was expanded to the conclusion, that, since they are alike in their physical characteristics, they must be alike also in their role in the universe:

> if Venus were without population, then the Earth must be similarly lacking, and reciprocally, if the Earth were populated, Venus must be populated also.[19]

Flammarion demonstrates here a characteristic analogical thinking, typical of the astrobiological search for an Earth analogue. In a later work on popular astronomy he says of the inhabitants of Venus:

> this world differs little from ours in volume, in weight, in density, and in the duration of its days and nights. [...] It should, then, be inhabited by vegetable, human, and animal races but little different from those of our planet.[20]

4. Maps of Venus

It might be surprising that our closest neighbor, the solid planet Venus, was not discussed to a greater extent. My explanation for such neglect is that astronomy

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[16] Swedenborg (1758), n. 106.

[17] Swedenborg (1758), n. 126.

[18] Dick (1848), pp. 135 f.

[19] Flammarion (1862); Crowe (2008), pp. 417 f.

[20] Flammarion (1880); Sheehan & Westfall (2004), p. 214.

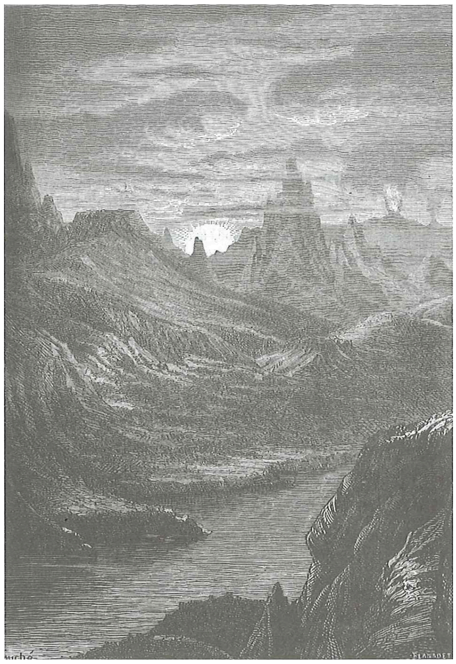

Figure 1. The mountains in the southern hemisphere of Venus, according to Camille Flammarion, *Les terres du ciel* (Paris, 1877).

of the period failed to clearly recognize geological features on its surface in the same way as those observed on the Moon and Mars. Whether these ideas about a habitable Venus were speculative or not, they were still all based to some extent on scientific observations and theories. Astronomical investigations of Venus during the seventeenth and eighteenth centuries involved its magnitude, revolution around the Sun, axial rotation, atmosphere, mountains, satellites, temperature, and chemistry.

In 1645 the Neapolitan astronomer Francesco Fontana recorded "a dark patch in the center of the disk" of Venus, which can be said to be the first attempt to note surface details there.[21] In 1667 Giovanni Domenico Cassini saw "various bright and dusky patches" from which he deduced the first estimated period of rotation of 23 hours and 21 minutes.[22] Francesco Bianchini drew the first "map" recording oceans and continents in 1726.[23] On mist-free days, at twilight, he saw rounded patches similar to lunar craters, and from their movements, he deduced that the period of rotation of Venus was 24 days and 8 hours.

There is no doubt that these records of the surface features of Venus were purely optical. Beside the fact that the optical quality of the telescopes not always was reliable, and that weather conditions could considerably influence the quality of the observations, there is obviously also an epistemic perception that changes the interpretations of the seen. The uncertain observations by Fontana, Cassini, Bianchini and others were interpreted in a particular way. If they believed in the existence of oceans and continents on Venus, they searched for them and found them, because

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[21] Fontana (1646), p. 92; Cattermole & Moore (1997), p. 9; Moore (1956), p. 32.

[22] Cassini (1667), p. 122.

[23] Bianchini (1728); Sheehan & Westfall (2004), p. 139.

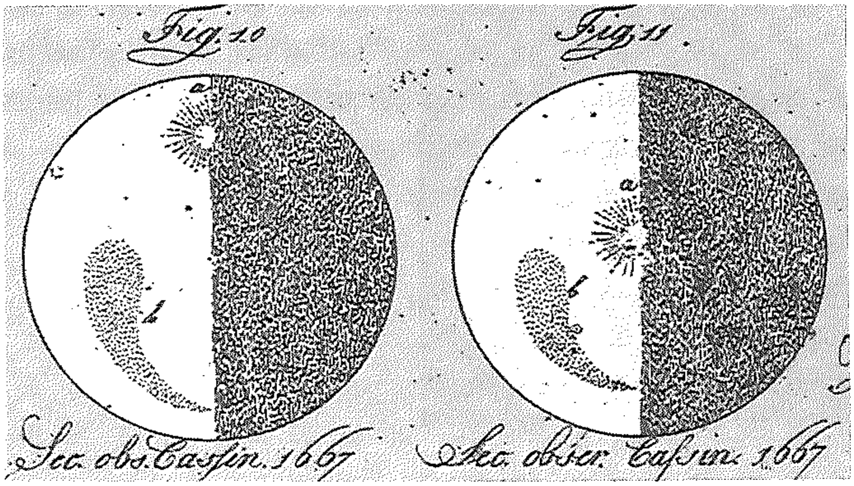

Figure 2. Drawings by Giovanni Cassini in 1667 of the surface of Venus, in Camille Flammarion, *Les terres du ciel* (1877).

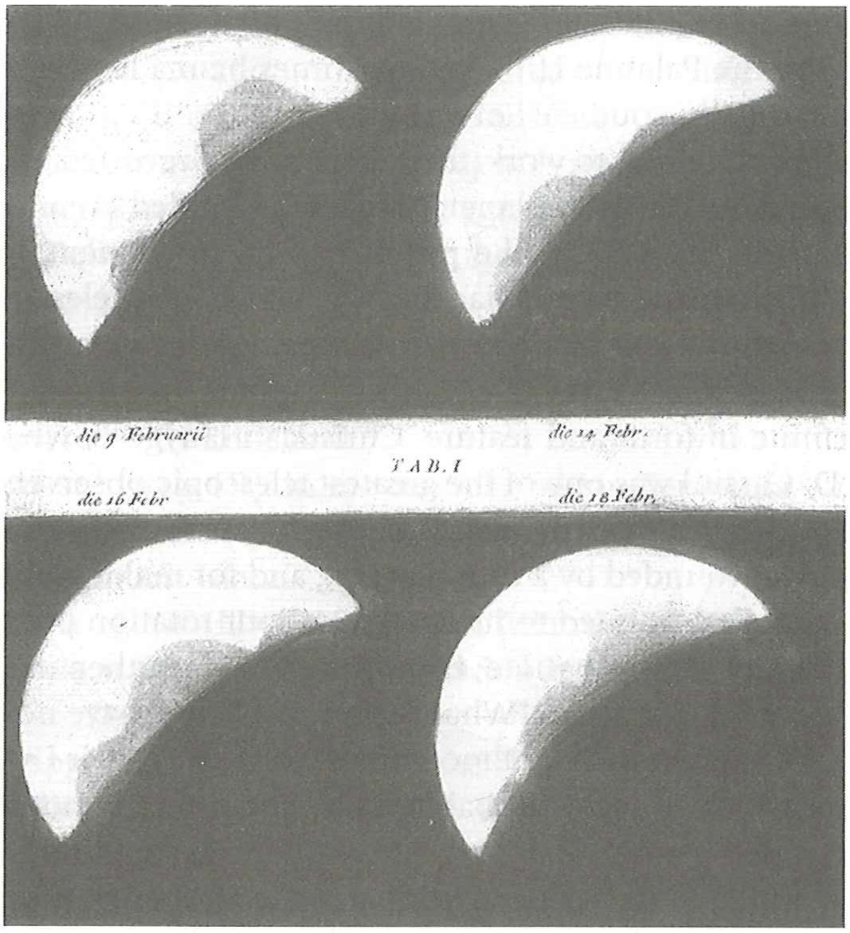

Figure 3. Francesco Bianchini's drawings of Venus in his work *Hesperi et phosphori nova phaenomena* (1728).

their prior knowledge and beliefs directed their attention towards certain interpretations. The "illusion" or "fault" in their perception did not lie primarily in the flaws in their optical equipment, but, as I maintain, in their imaginative minds, the cognitive apparatus that processed their sensory impressions.

5. The atmosphere of Venus

The first more certain telescopic observations of Venus, after Galileo's discovery of its phases, were made during the 1761 transit of Venus by, among others, Mikhail Lomonosov, who concluded that the planet is surrounded by a considerable atmosphere equal to, if not greater than, that which envelops our earthly sphere.[24] His observations were not unique. Many observers in Sweden and elsewhere reported certain phenomena during the transit that they believed to have been caused by an atmosphere surrounding Venus.[25]

Certain astrodynamic facts relating to Venus were well-known to the astronomical community, for example, its orbit around the Sun, magnitude, and phases, etc. The exact size of the solar system and the distances within it, though, were not known. The transits of Venus in the 1760s provided a unique opportunity to calculate the distance from Earth to Venus and to the Sun. Furthermore, the question of the atmosphere and topography of Venus was still unresolved, but observations of Venus against the solar disc changed that. Two dissertations on Venus were defended in Sweden during the eighteenth century, with the professor of astronomy Pehr Elvius chairing the proceedings. The student Birger Jonas Wassenius defended his thesis *De planeta Venere* in 1717, where he discussed the orbit of Venus, its distance from the Sun, diameter, motion, phases, etc., with references to Kepler, Riccioli, and Street.[26]

He followed the views of Kepler and Newton, and determined that the next transit of Venus would occur on May 26, 1761 (June 6, 1761 new style). First contact, according to Elvius and Wassenius, would occur at 08:16, which can be compared with Wargentin's observations on the actual day, 03:21.37. Last contact would occur at 15:02 according to Elvius and Wassenius (Wargentin's observation was 09:48.09). Wassenius later became known for his discovery of the prominences (protuberances) of the Sun during the eclipse of May 2/13, 1733 in Gothenburg.[27] The other dissertation, the mathematician Andreas Wijkström's *De venere in sole præsenti seculo videnda* from 1753 also included calculations in preparation for the transit of Venus.[28]

During the transit of Venus of 6 June 1761, two surprising phenomena were observed: a bright ring around Venus and the "black drop" during the contacts.[29] Almost all observers in Stockholm and Uppsala in Sweden, and Kajana in Finland saw the ring, and it was generally explained as being caused by an atmosphere on

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[24] Cattermole & Moore (1997), p. 10; Marov (2005).

[25] Concerning the history of Venus transits, see: Proctor (1874); Woolf (1959); Maor (2000); Sellers (2001); Sheehan & Westfall (2004); Wulf (2012); Aspaas (2012); Pekonen (2012).

[26] Elvius (1717).

[27] Nordenmark (1959), p. 194.

[28] Wijkström (1753).

[29] Nordenmark (1939), p. 178.

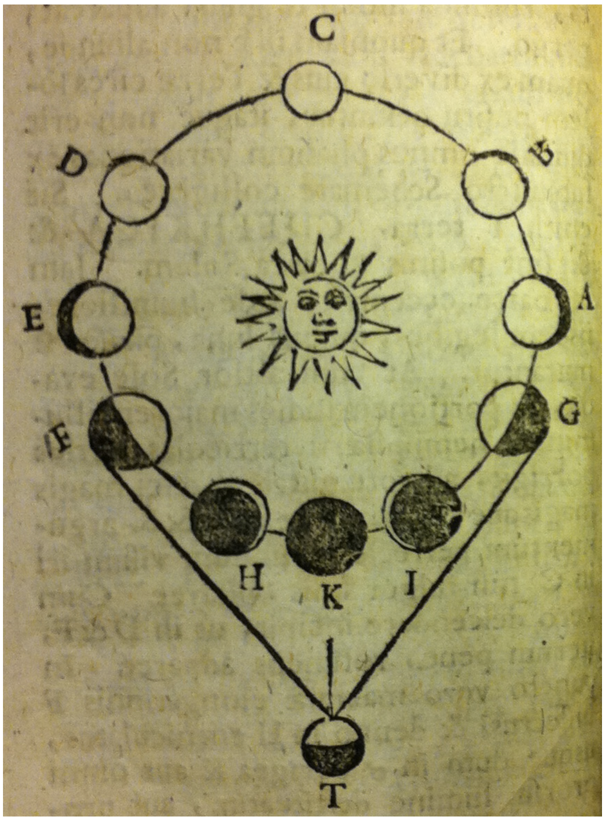

Figure 4. The phases of Venus, according to Birger Jonas Wassenius, *De planeta Venere* (1717).

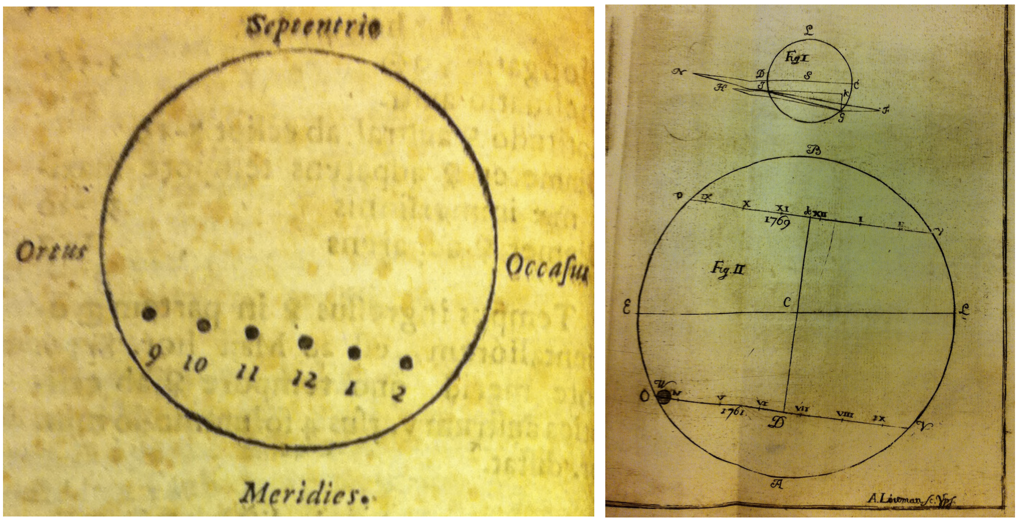

Figure 5. *Left*: The transit of Venus, according to Birger Jonas Wassenius, *De planeta Venere* (1717). *Right*: The future transits of Venus against the solar disc in 1761 and 1769, according to Andreas Wijkström, *De venere in sole præsenti seculo videnda* (1753).

Venus.[30] The Uppsala report to the proceedings of the Royal Swedish Academy of Sciences stated that Venus probably had an atmosphere, which caused refraction of the sunbeams. Just three days after the transit, on June 9, 1761, the astronomer Fredric Mallet reported to the secretary of the Royal Swedish Academy of Sciences, the astronomer Pehr Wilhelm Wargentin, that all the observers in Uppsala concluded that Venus had an atmosphere because of the light seen around it before it entered the solar disc.[31] Wargentin himself also observed the luminous ring and believed that it indicated an atmosphere. In another letter by Mallet to the Finnish astronomer Anders Planman from July 9 of the same year, he wrote that an atmosphere was visible during first contact, as he saw a light around Venus before it entered the solar disc.[32] Another Swedish astronomer, Bengt Ferner, reported from Paris:

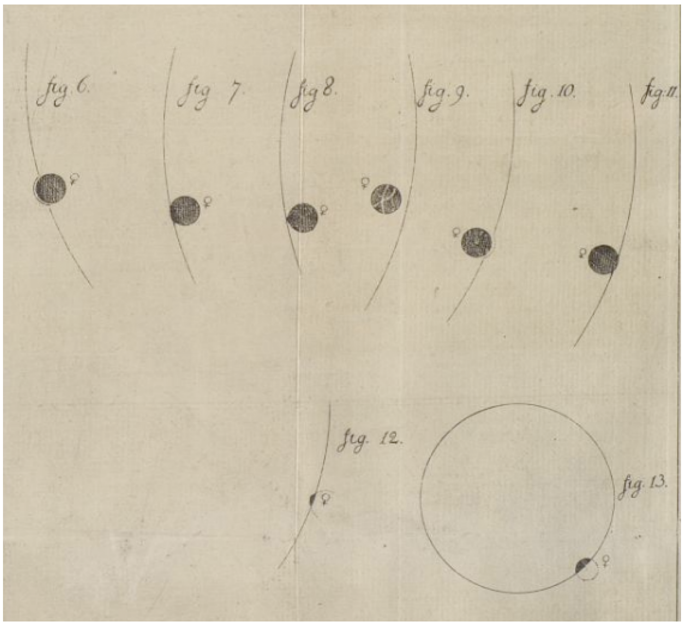

Figure 6. The luminous ring and the black drop. From the proceedings of Royal Swedish Academy of Sciences 1761. *Kungl. Vetenskapsakademiens handlingar* 1761, tab. III.

> During the whole time of my observing with the telescope, and the blue and green glasses, I perceived a light round about Venus, which followed her like a luminous atmosphere, more or less lively, according as the air was more or less clear.[33]

The scientist and chemist Torbern Bergman published the results of his observations in Uppsala in the *Philosophical Transactions* of 1762, and in the same article he

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[30] "Observationer på planeten Veneris gång genom solens discus, d. 6 junii 1761", in *Kungl. Vetenskapsakademiens handlingar* 1761.

[31] Letter from Mallet to Wargentin, June 9, 1761, Royal Swedish Academy of Sciences, Stockholm. Nordenmark (1939), p. 180; Lindroth (1967).

[32] Letter from Mallet to Planman, 9 July 1761, Helsinki University Library. Nordenmark (1939), p. 179.

[33] Ferner (1762), p. 223.

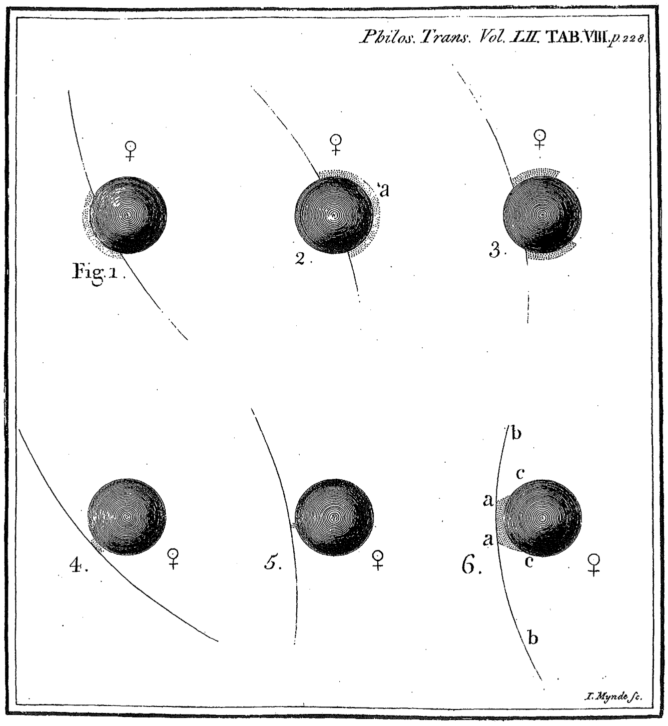

Figure 7. The luminous ring and the black drop of Venus. Thorbern Bergman, "An Account of the Observations made on the same Transit at Upsal in Sweden: In a Letter to Mr. Benjamin Wilson, F. R. S. from Mr. Thorbern Bergman, of Upsal", *Philosophical Transactions* 52 (1762).

discussed the existence of an atmosphere around Venus as an explanation for the refraction phenomenon.[34] The ring was re-observed on June 3, 1769, and its causes were still being debated even then, but this phenomenon was unanimously taken as proof of the existence of an atmosphere on Venus.[35] The professor of astronomy at Uppsala, Daniel Melanderhjelm, also tried to explain the black drop as being due to refraction in the atmosphere of Venus.[36] In 1798 he published an article discussing the atmospheres of the planets of the solar system.[37] Even though he referred to Schröter's investigations of the atmosphere of Venus, the article primarily addressed the Earth's atmosphere, and here he stated that all atmospheres of the planets in the solar system are of the same nature, of the same sort of particles.[38]

Most Swedish observers of the 1761 and 1769 transits believed that the black drop was not an effect caused by an atmosphere on Venus. Wargentin opposed Melanderhjelm's explanation of the black drop as caused by an atmosphere and

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[34] Bergman (1762), p. 228; Olsson (1956).

[35] Wargentin (1769), pp. 146–158, see also pp. 158–175; *Philosophical Transactions* 59 (1769), pp. 170–194.

[36] Melanderhjelm (1769), pp. 161–173; Nordenmark (1939), p. 181, 189.

[37] Melanderhjelm (1798); see also German edition (1800), pp. 96–112.

[38] Melanderhjelm (1798), p. 37.

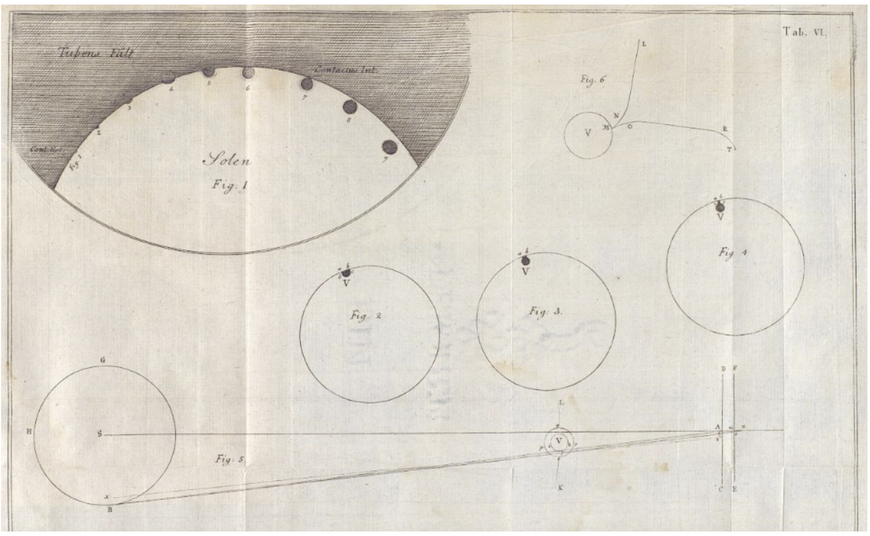

Figure 8. Daniel Melanderhjelm tried to explain the black drop as being caused by refraction in the atmosphere of Venus, in "Uttydning på de Phænomener, hvilka åtfölja Planeten Veneris Passage genom Solen", *Kungl. Vetenskapsakademiens handlingar* 1769.

explained it instead as a diffraction phenomenon.[39] Melanderhjelm's observations were, as he said, just "fallaciæ visus", optical phenomena.[40] The physician Johan Carl Wilcke performed a number of experiments during the summer of 1769 showing that the same phenomenon arises with a black body seen against a luminous body without any need to assume an atmosphere.[41] Wargentin and Wilcke did not disbelieve in the existence of an atmosphere, but the black drop could not provide proof of this. In 1770–1771 Andreas Planman published two dissertations defending the theory that the phenomena observed during the transits were caused by a Venusian atmosphere.[42] He presented a number of observations of the transit of 1761 that supported the theory of an atmosphere around Venus, among others, the luminous ring and the black drop.[43] He also made analogical comparison with the atmosphere of the Earth. Wargentin thanked Planman for the copies of the dissertations that he had sent, but he admitted that he remained unconvinced that the atmosphere of Venus was the cause of all the phenomena seen during the transit.[44]

The atmosphere of Venus was also observed in Saint Petersburg. The Russian polymath Mikhail Lomonosov argued that the observations of the transit of Venus

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[39] Nordenmark (1939), pp. 189 f.

[40] Letter from Wargentin to Planman, June 12, 1770, Helsinki University Library. Nordenmark (1939), p. 190.

[41] Letter from Wargentin to Planman, October 26, 1770, Helsinki University Library. Nordenmark (1939), p. 190.

[42] Planman (1770, 1771).

[43] Planman (1770), pp. 3 f.

[44] Letter from Wargentin to Planman, January 4, 1771, Helsinki University Library. Nordenmark (1939), p. 192.

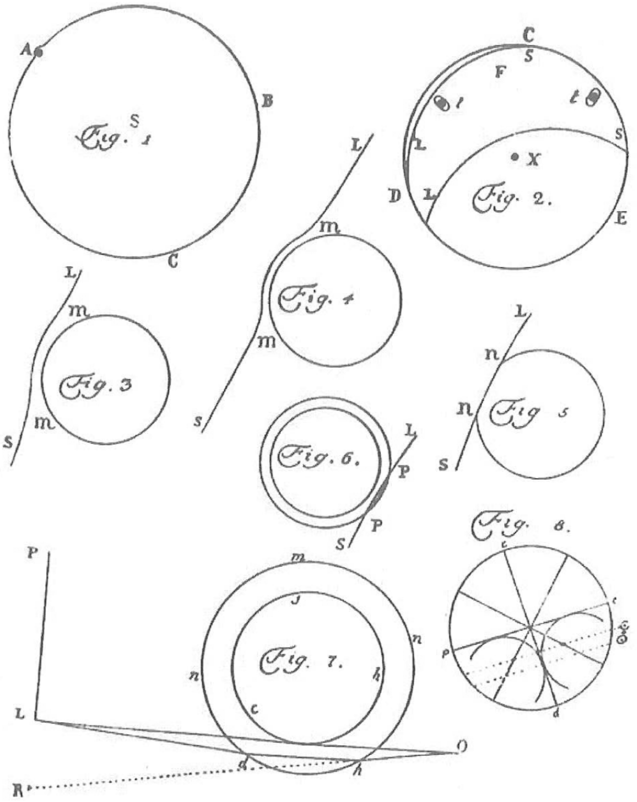

Figure 9. Mikhail Lomonosov's study of the transit of Venus in 1761. From Marov (2005), p. 215.

in 1761 supported the idea of a Venusian atmosphere.[45] Because an existing atmosphere had been proved, it could be concluded that Venus is also inhabited. Lomonosov wrote:

> Based on these observations I conclude that the planet Venus is surrounded by a distinguished air atmosphere similar (or even possibly larger) than that is poured over our Earth.[46]

Lomonosov, contrary to what has been argued,[47] was neither the first, nor the only one, to conclude that the phenomena were caused by a Venusian atmosphere. Bergman and others published their results first, even though Lomonosov showed some detailed supporting arguments for the explanation of this phenomenon, and thus the transits proved the existence of an atmosphere on Venus.

6. The mountains of Venus

Whether Venus has mountains and a surface similar to the Earth with valleys and seas, had been debated ever since the first Venus maps appeared in the seventeenth

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[45] Crowe (1986), p. 160.

[46] Marov 2005, pp. 214 f.; Lomonosov (1955a, 1955b, 1961).

[47] Marov (2005).

century. Here, again, the conclusions were often a result of analogical reasoning and epistemic perception. In 1700, Philippe de la Hire reported mountains on Venus.[48] This was later cited by Jean le Rond d'Alembert in the *Encyclopédie* as indicating that the other planets also had mountains. The changes observed on the surface of Venus, Mars, and Jupiter, indicated, furthermore, that they have an atmosphere and that other planets do too. Since planets are opaque bodies, receiving their light from the Sun, and have mountains and changing atmospheres, d'Alembert concluded that it must follow that they also have lakes and seas, in other words, they are bodies just like our Earth. Nothing, he says, can then prevent us from believing that the planets are inhabited.[49]

The great observational astronomers William Herschel and Johann Hieronymus Schröter engaged in a heated argument as to the presence or absence of mountains on Venus.[50] However, they both agreed that Venus has an atmosphere. Among arguments for the presence of an atmosphere was the fact that the horns of the crescent Venus were often seen to extend beyond the semicircle, and sometimes even stretched around the dark hemisphere forming a luminous ring.[51] It was well known in the era of Schröter and Herschel that Venus and the Earth, with regard to their size and mass, were almost perfect twins. It then became also reasonable to assume that their atmospheres were similar too, with regard to their extent and composition. Herschel, who believed in the existence of intelligent creatures on Venus, stressed the advantages of such a cloud shield.[52]

In February 1788 Schröter perceived the ordinarily uniform brightness of the disk as being marbled by a filmy streak, and he concluded that what he was seeing was the outmost part of a dense, cloudy atmosphere.[53] Moreover, the horns of the crescent were seen to extend beyond the semi-circle, which could not be the case in the absence of an atmospheric mantle. By studying spots on the shifting surface he estimated the period of rotation of Venus at 23 hours, 21 minutes and 7 seconds, and thus very close to that of the Earth. Interestingly, up to 1962, estimates of the period of rotation of Venus ranged from between less than 24 hours to up to 225 days, although no one ever expected the period to be longer than the Venusian year.[54]

Even Herschel had seen in 1780 on Venus "a bluish, darkish spot, and another, which is rather bright", and he stated: "that Venus has a motion on its axis cannot be doubted, from these observations; and that she has an atmosphere is evident, from the changes I took notice of, which surely cannot be on the solid body of the planet."[55] With regard to both Mercury and Venus, Herschel also said that

> we do not see, as in the case of the Moon, the real surfaces of these planets, but only their atmospheres, which are loaded with clouds, and

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[48] de la Hire (1700), p. 296.

[49] d'Alembert (1765), vol. XII, p. 705; Crowe (1986), p. 126.

[50] Baum (1973).

[51] Moore (1956), pp. 73 f.; Schröter (1796), p. 85; Herschel (1912), vol. I, p. 449.

[52] Moore (1956), p. 74.

[53] Cattermole & Moore (1997), p. 11.

[54] Cattermole & Moore (1997), p. 14.

[55] Herschel, 19 June 1780; Cattermole & Moore (1997), p. 11.

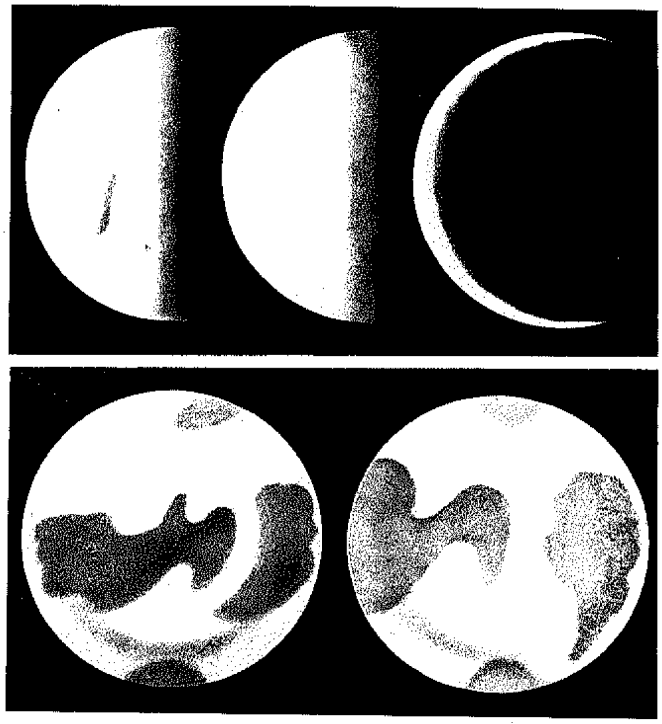

Figure 10. Johann Hieronymus Schröter's drawings of the terminator and the atmosphere of Venus. From Cattermole & Moore (1997), p. 10.

which may serve to mitigate the otherwise intense glare of their sunshine.[56]

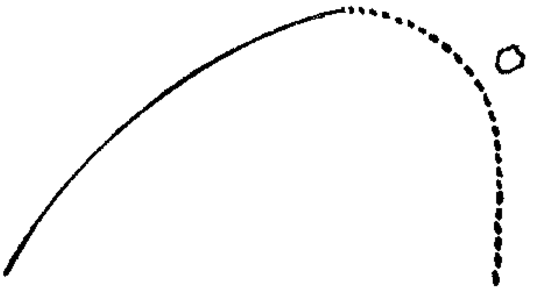

Figure 11. On December 28, 1789, Schröter saw off the southern cusp of Venus a detached point of light, an enlightened mountain. From Baum (1973), p. 52.

On December 28, 1789 Schröter saw that the southern cusp of Venus was blunted, and that there was a small luminous speck beyond it.[57] He saw the same thing again in 1790 and 1791 and concluded from these observations that it must be a very lofty

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[56] Moore (1956), p. 36.

[57] Baum (1973), p. 52.

"enlightened mountain" that was catching rays of the Sun.[58] Similar phenomena are often observed on the Moon when peaks close to sunrise or sunset are viewed clear of the terminator. Furthermore, Schröter claimed in 1792 that he had observed mountains on Venus six times higher than the highest one on Earth, that is, equal to a height of 23 miles (37 kilometers)! Schröter wrote:

> though we cannot suppose a smaller, but rather a greater force of gravity on the surface of Venus than our own globe, nature seems, however, to have raised on the former such great inequalities, and mountains of such enormous height, as to exceed 4, 5, and even 6 times the perpendicular elevations of Cimboraco, the highest of our mountains.[59]

The French astronomer Charles Marie de la Condamine had during an expedition to Peru in 1735 measured the height of Cimboraco (now Chimborazo in Ecuador) at 3,200 French toises (6,237 meters).

Herschel re-observed Venus in 1793, and he questioned Schröter's findings. He agreed that Venus has an atmosphere, but he never found those high mountains that Schröter mentioned.[60] His daily records read again and again: "No mountains visible".[61] In the *Philosophical Transactions* he states:

> As to the mountains in Venus, I may venture to say that no eye, which is not considerably better than mine, or assisted by much better instruments, will ever get a sight of them.[62]

Herschel's conclusion was that Venus in fact has an opaque atmosphere, which makes all the features of its surface invisible. Schröter responded in 1795 by stating instead that Venus generally has a clear and transparent atmosphere. Venus must have it, he says,

> I cannot think [...] that Providence would bless the inhabitants of Venus, incomparably less than with the happiness of seeing the works of almighty power, and of discovering, like a Herschel, still more and more distant regions of the universe. We must [...] adhere to this analogy, till indisputable experiments convince us of the contrary.[63]

Schröter then compiled all his findings relating to Venus in a book, *Aphroditographische Fragmente*, published in 1796, where his pluralist conviction reappears. According to Michael Crowe this was the first book ever about the planet Venus, but, as we have seen, a fifty-eight-page dissertation on it had already been published in 1717 in Uppsala, i.e., Elvius' and Wassenius' *De planeta Venere*.[64]

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[58] Schröter (1796), pp. 29–32.

[59] Schröter (1792), pp. 336 f.; Baum (1973), p. 57; Crowe (1986), pp. 71 f.

[60] Herschel (1793); Herschel (1912)), vol. I, p. 442.

[61] Baum (1973), p. 58.

[62] Herschel (1793), p. 216; Moore (1956), p. 107; Baum (1973), p. 59.

[63] Schröter (1795), p. 169.

[64] Schröter (1796), pp. 193 f.; Crowe (1986), p. 72; Elvius & Wassenius (1717).

Another pluralist, Johann Elert Bode at the Berlin observatory, accepted Schröter's claims about the existence of mountains and valleys on Venus.[65] Bode applied an apparently analogical reasoning. He concluded that if Venus had land and sea, mountains and valleys, clearings and condensations occurred in its atmosphere, and it had a companion moon, then it was entirely similar to our Earth and consequently also habitable. As late as the end of the nineteenth century there were those who supported Schröter's mountain theory. Among others, the French artist and astronomer Étienne Léopold Trouvelot recorded, as Schröter had done, luminous spots beyond the terminator, and he also observed the polar hoods of the planet.[66]

7. The illusions of Venus

The observers of Venus saw things that needed explanations and interpretations. They seemed to detect vague spots, streaks, lines, drops, a dim light, and a vague companion. Such optical misinterpretations, or rather what could be explained as an epistemic perception, were involved in the claims of observations of companion moons of Venus, which had been debated since the seventeenth century.[67] In 1686, Cassini thought he saw a luminous shape in the same phase as Venus. In 1780, Wargentin published a paper in the proceedings of the Royal Society of Sciences in Uppsala, where he discussed the hypothetical moon around Venus, and declared that all those astronomers who had seen it had been exposed to an optical phenomenon.[68]

The ashen light, the dim visibility of the non-sunlit side of Venus, when it is in the crescent stage, was first reported in 1643 by Giovanni Riccioli. This phenomenon was also the object of an epistemic perception that needed interpretations of the seen. Franz von Paula Gruithuisen in Munich declared that the light had been seen in 1759 and again in 1806, an interval of seventy-six Venusian years, and he wrote: "The observed appearance is evidently the result of general festival illumination in honor of the ascension of a new emperor to the throne of the planet."[69] However, Gruithuisen later modified his explanation and instead of a Venusian coronation, he suggested that the light might be caused by the burning of large areas of jungle to create new farmland. Other explanations were also put forward. Herschel proposed that it was caused by phosphorescent oceans, while P. de Heen proposed in 1872 that it was a kind of Venusian equivalent to the terrestrial aurorae.

In 1877 Giovanni Schiaparelli at Brera observatory in Milan recorded in detail the Martian network of canals for the first time, and was followed by the American astronomer Percival Lowell, who detected hundreds of Martian canals that he interpreted as an artificial irrigation system. Similar observations of Venusian canals were claimed at the end of the nineteenth century. Henri Joseph Anastase Perrotin in Nice recorded vague streaks on Venus. Lowell himself published a chart of the planet in 1897, and he wrote:

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[65] Crowe (1986), p. 74 f.; Bode (1801); trans. (1804), p. 34; new ed. (Stockholm, 1813); Bode (1792); Bischof (1796); Bode referred to Bianchini (1728); Schröter (1793), p. 136; Schröter (1796); and Herschel's papers in the *Philosophical Transactions.*

[66] Cattermole & Moore (1997), p. 12.

[67] Kragh (2008).

[68] Wargentin (1780), vol. III; Nordenmark 1959, p. 227.

[69] Cattermole & Moore (1997), p. 17.

> The markings themselves are long and narrow but, unlike the finer markings of Mars, they have the appearance of being natural, not artificial. [...] The markings, which are of a straw-colored grey, bear the look of being ground or rock, and it is presumable from this that we see simply barren rock or sand weathered by aeons of exposure to the Sun."[70]

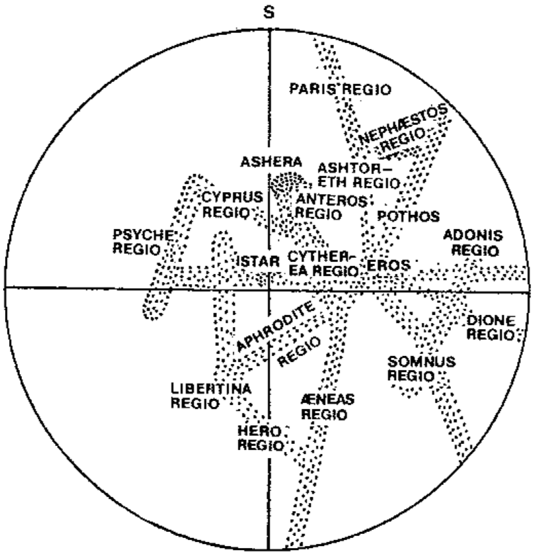

Figure 12. Percival Lowell's map of Venus. From Cattermole & Moore (1997), p. 15.

There were hopes that the invention of spectroscopic analysis in the nineteenth century would show obvious lines for oxygen and water vapor in the atmosphere of Venus, and some preliminary results seemed to support that. The idea of life on Venus was alive far into the twentieth century. In 1915, the Swedish physicist Svante Arrhenius believed Venus to be a living world, moist and steamy with luxuriant vegetation and primitive life.[71] The present climatic conditions on Venus resembled those on Earth about 250 million years earlier, when the Carboniferous coal deposits were formed. It was only in 1966 and 1967 that the Russian space probes Venera 3 and Venera 4 dived into the cloud shield, and a very hostile environment was discovered.

8. Conclusion

The history of the search for life on Venus bears witness to the inventions and imaginings of the human mind, and about attempts by the active human mind to grasp reality. Cognitive processes such as analogies and epistemic perception played an important role in the conceptualization of the universe, and in the interpretation of sensory impressions. Venus was compared to Earth, in order to find similarities and dissimilarities, and in making analogies between the two. The observations

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[70] Cattermole & Moore (1997), p. 15.

[71] Arrhenius (1915); Moore (1956), p. 108.

through telescopes of the distant planet had to be evaluated and interpreted, as the blurred surface did not immediately reveal its true nature.

Such analogical reasoning could be summarized as a search for similarities in an inductive manner, in order to pinpoint as many as possible, especially those of a significant nature, i.e., those critical features that indicate a habitable environment. It was known that both Earth and Venus were planets of a similar size, both orbited the Sun, and were exposed to its light and heat, and that both globes were opaque and had a solid ground. These similarities could be extended, as some astronomers maintained, to both of them having nearly exactly the same period of axial rotation, as well as a companion moon, an atmosphere, mountains and seas. If Earth and Venus seemed to be perfect twins, then there must be life on Venus too.

The blurred images seen in the telescope were faint sensory impressions that needed interpretations by applying prior knowledge and conceptions to what the eyes perceived. The active mind searched for regularities, order, and comprehensibility in the observations. Our impressions of the external world change our conceptions, while our conceptions in the same time change how we view the world. We can be sure that nobody had ever seen the surface of the planet, yet they imagined it, and thought they saw it, interpreting their sensory impressions in the light of their knowledge and expectations. The epistemic perception led them to conclusions about what they had seen. Unlike the shameless goddess after whom she is named, Venus the planet hides beneath an impenetrable veil of clouds.

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Jean-Charles Houzeau and the 1882 Belgian Transit of Venus Expeditions

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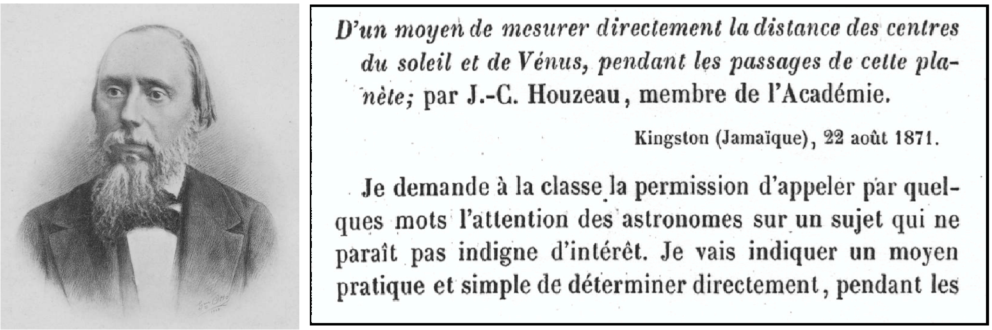
Abstract. In 1871, the Belgian astronomer Jean-Charles Houzeau developed a new approach to determine the solar parallax. His "heliometer with unequal focal lengths" produces a large and a small solar image, as well as a large and a small image of Venus. Making the small solar and the large Venus image coincide yields a measure of the angular distance of the centers of both objects. Two such instruments were built for two Belgian expeditions to observe the Venus transit of December 6, 1882: one for San Antonio, Texas, and another one for Santiago de Chile. These were the first major expeditions in the history of Belgian science. This paper documents the expeditions, and clarifies the principal instrument and its present-day whereabouts.

1. Introduction

This paper deals with a salient – though not so widely known – Belgian observational astronomer: Jean-Charles Houzeau de Lehaie (1820–1888), who proposed and carried out a novel design of heliometer with the purpose to determine the solar parallax at the occasion of the 1882 transit of Venus (Fig. 1). Houzeau's work is mostly forgotten in the historiography of nineteenth-century Venus-transit science, as most of the attention goes to endeavors of more prominent global players, i.e., scientists from France, the UK and the USA.



D'un moyen de mesurer directement la distance des centres du soleil et de Vénus, pendant les passages de cette planète; par J.-C. Houzeau, membre de l'Académie.

Kingston (Jamaïque), 22 août 1871.

Je demande à la classe la permission d'appeler par quelques mots l'attention des astronomes sur un sujet qui ne paraît pas indigne d'intérêt. Je vais indiquer un moyen pratique et simple de déterminer directement, pendant les

Figure 1. *Left*: Portrait of Houzeau (from Lancaster 1887). *Right*: Houzeau (1871), submitted from Kingston, Jamaica to the *Académie Royale des sciences, des lettres et des beaux-arts de Belgique*: "On a method to directly measure the distance between the centers [of the images] of the Sun and Venus during the transit of this planet ... I shall describe a method that is practical and simple ...".

Jean-Charles Houzeau became a prodigious writer on scientific and social topics already at an early age. For a while, he lived and studied in Paris, but in 1848, Adolphe Quételet (1796–1874), founder of the Royal Observatory of Belgium, accepted him first as a volunteer, then as a paid assistant. During the social upheavals of 1848, Houzeau took a firm republican stand and had to resign his post, left Belgium and ranged about Europe, working in various libraries and writing books on geography. In 1854 he was recalled to Belgium to do work on the triangulation of the Kingdom, but when this project was interrupted in 1857 for several years, he left to New Orleans, in search for his revolutionary dream of freedom. His first visit to San Antonio, Texas, took place in May 1858; he stayed until 1862, interrupted by almost a year of surveying work in a region south of Dallas. When the Civil War broke out, he crossed the Mexican border in March 1862. After his return to New Orleans, he served as one of the editors of the newspapers *Union* and *Tribune*, which were mainly read by Afro-Americans. He ran into trouble due to publications such as *The white terror in Texas*,[1] because of his loyalty with the slaves, his advocacy for black civil rights, and his refusal to join the confederate army. In March 1868 he definitively left New Orleans, and in June he settled in Jamaica, where he cultivated a plantation, founded a school for the young natives, and carried out studies in natural sciences and astronomy, mainly for his monumental *Uranographie Générale* (Houzeau 1878).

When Royal Observatory Director Adolphe Quételet died in 1874, King Leopold II overrode objections of his ministers and appointed Houzeau to become director of the Royal Observatory – Houzeau was about the only candidate with a vast publication record and broad observational expertise. Houzeau took his post in June 1876 and was deeply involved in the reorganization and relocation of the Royal Observatory to the suburb of Uccle/Ukkel. He resigned from the post of director at the end of 1883, but continued to work on his voluminous astronomical bibliography. In July 1888, he died from the consequences of malaria that he had contracted more than twelve years earlier.

Jean-Charles Houzeau was a very special person with a most unusual blend of characteristics: an outspoken anti-royalist with very focused political ideas displaying revolutionary attitudes, a peripatetic teacher and at the same time a scientist who severely criticized the paucity of high-precision observations collected at the Royal Observatory of Brussels in his days. His life as an observer covered astronomy, geography, geodesy and natural sciences – not only in Belgium but also abroad.

Extensive biographical notes on Houzeau are available – a monumental one by Houzeau's collaborator Lancaster (1887), others by Rankin (1984) and Evans (1990), and a more recent detailed study by Verhas (2002), see also Sterken (2009) and Sterken et al. (2004) to complement the present paper.

2. Houzeau's 1871 heliometer with unequal focal lengths

In 1871 Houzeau sent a communication to the Belgian Academy entitled *"D'un moyen de mesurer directement la distance des centres du soleil et de Vénus, pendant le passage de cette planète"*[2] (see Fig. 1). Thus, Houzeau (1871) presented the concept of the *héliomètre à objectifs inégaux*, the heliometer with non-identical objectives featuring one lens with a diameter of 22 cm and another one with diameter 3 cm, see Fig. 2. Two such instruments were built, and the telescopes with their components are still preserved at the Royal Observatory of Belgium.

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[1] *La terreur blanche au Texas et mon évasion* (Brussels, 1864).

[2] On a method to directly measure the distance between the centers [of the images] of the Sun and Venus during the transit of this planet. Note that this paper was submitted from Kingston, Jamaica.

Figure 2. The lenses of Houzeau's heliometer. Photo C. Sterken.

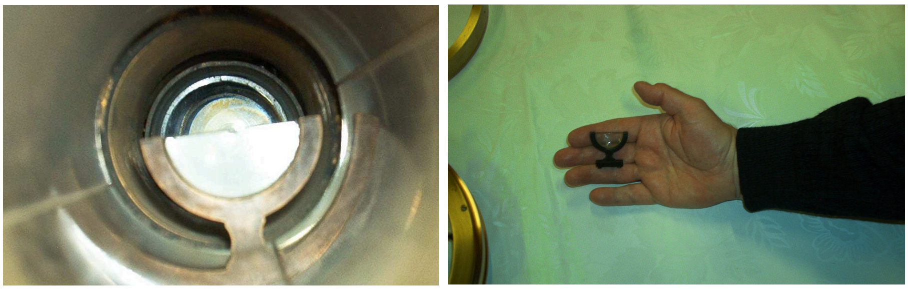

Figure 3. *Left*: the small lens mounted in the heliometer tube. *Right*: the small lens supported by the right hand of Hilmar W. Duerbeck (photographs taken by C. Sterken at the Royal Observatory of Belgium on April 5, 2004).

Two identical copies of Houzeau's heliometer with unequal focal lengths were built by Grubb (Dublin) at the initiative of Houzeau and according to plans outlined by his colleague Louis Niesten (1844–1920). A description is given in Houzeau (1884a) and in Van Boxmeer (1996). The instrument has a half-objective of 220 mm diameter and 4.34 m focal length, and a half-objective of 30 mm diameter and 140 mm focal length, which actually forms part of the eyepiece unit of the telescope (Fig. 3). The pair of objective lenses was acquired by Quetelet in 1844 with the lens-maker Cauchois in Paris. The eyepiece projects a solar image on a screen (Fig. 4), which was made in 1882 at the Royal Observatory. The projected large solar image has a diameter of 160 mm on the screen, while the diameter of Venus is about 5 mm. The short-focus objective produces a solar image that is slightly smaller than that of Venus. The relative position of both objectives can be changed by means of a graduated micrometer screw that moves the small lens. This permits to produce a precise coincidence of the small image of the Sun and that of Venus (Fig. 5). The difference in micrometer reading between the positions "small Sun centered on crosshairs, being the center of the large Sun" and "small Sun centered on large Venus", when properly calibrated, gives a measure of the distance between the centers of both images during the transit.

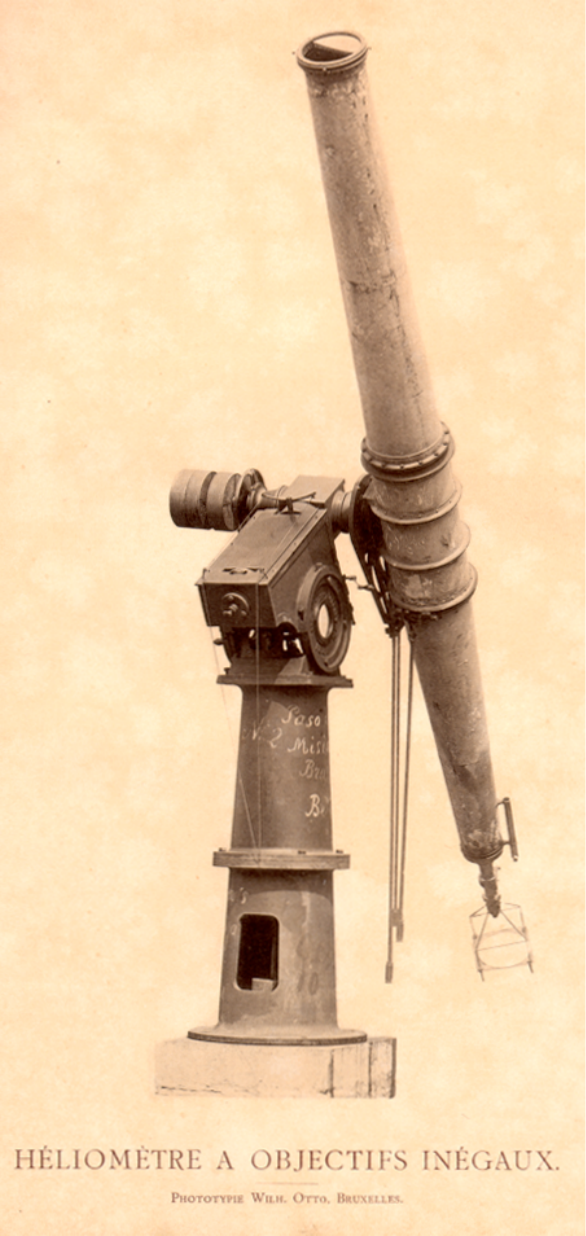

Figure 4. The heliometer with its projection screen on its equatorial mount (from Houzeau 1884b).

The measurements were done in such a way that one observer centered the "large Sun" on the screen by fine motion of the telescope, a second person did the centering of the "small Sun", first on the crosshair and subsequently on the Venus image, and a third one read the micrometer settings and the times (and recorded the observations). Both heliometers were used for the first time during the 1882 expeditions.

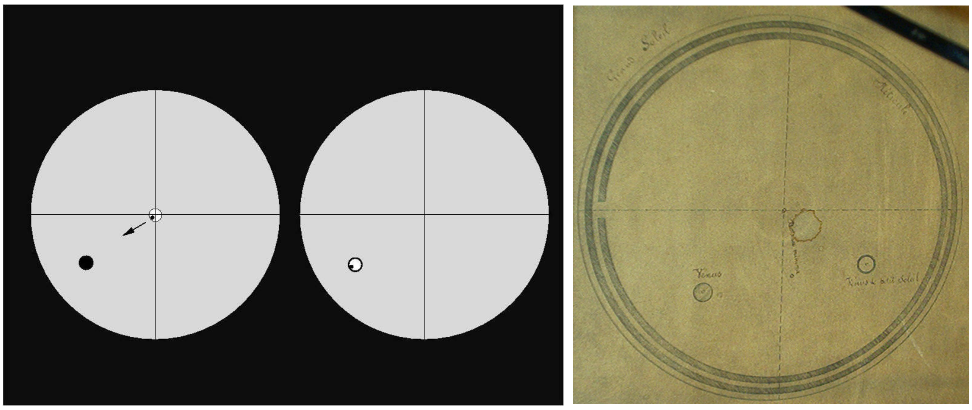

Figure 5. *Left*: The principle of measurement with the heliometer with unequal focal lengths (Sterken et al. 2004, adapted from sketches given by Houzeau 1871). *Right*: Section of projection screen with the Sun and Venus. Inscriptions: upper left: *Grand Soleil*; upper right: *Réticule*; lower left: *Vénus*; lower right *Vénus et petit Soleil*; center: *distance minimale.* The central feature is a stain caused by some fluid. The circular image is rendered asymmetric because of the off-axis position of the photographer's camera objective with respect to the support structure (part of which is seen near the upper right corner of the image). Photo C. Sterken.

3. The Belgian expeditions

Houzeau also obtained support to organize two Belgian expeditions to observe the Venus transit of December 6, 1882: one to San Antonio, Texas, and another one to Santiago de Chile. These were the first major expeditions in the history of Belgian science. For details on the expeditions I refer to Verhas (2002), Duerbeck (2003) and Sterken et al. (2004).

3.1. The Expedition to San Antonio, Texas

Houzeau departed to the United States on June 30, 1882; the instruments were loaded on August 12 on a steamer, destination Galveston, and from there they were transported by railroad to San Antonio, where they arrived on August 30 in perfect state. While in Washington, Houzeau visited the Naval Observatory and the Signal Office (telegraphy and meteorological observations), and the Smithsonian Institution. Then he traveled by railway to San Antonio, where he arrived on September 2.

The Belgian observatory was located in the back garden of a rented wooden house "in an isolated situation" 2786 m east and 2047 m north of the northern tower of the church of San Fernando ($29^\circ 26' 33''$ N and $6^h 43^m 12^s$ W, Houzeau 1884b)[3] that faced the Staff Post and the Quadrangle of "Government Hill" – its present-day name Fort Sam Houston was only assigned in 1890. Evans & Olson (1990) suspect that the house (which no longer exists) was

> probably on the south side of Grayson Street, in the block between the streets now called North Palmetto Avenue and Pierce Street. The

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[3] $98^\circ 27' 45''$ W, relative to the meridian of Paris.

> telescope piers were approximately 640 feet south and 950 feet west of the clock tower in the Quadrangle.[4]

Houzeau, as an experienced topographer, has also published a list of measurements of buildings and other features of San Antonio in the final report (Houzeau 1884b). We owe the most detailed description of the Texas observations to Lancaster (1882):

> San Antonio is the headquarter of the troups which are stationed in Texas, and the barracks are on Government Hill, 7 km NE of the city, at an isolated and elevated location, where the view passes a huge horizon and where also the Belgian station was installed [. . .] The Belgian flag floats in the wind at a small distance of that of the grand American republic [. . .]
>
> On the 5th, slight cirrus gave us some fears, but at nightfall there was no trace left. The night from the 5th to the 6th was very good till 5 in the morning, at $5\,\frac{1}{2}$, rapid clouds showed up and covered the sky in a few moments. All our instruments were ready since the evening, and pointed to the direction where Venus should appear in front of the sun. At $6\,\frac{1}{4}$ in the morning, M. Houzeau went to the American station to compare the chronometers.
>
> The moment of first contact approaches, the sky is always covered, and remains so till about 9 am; then the clouds appear to be less thick, some hazy brightenings show up here and there, and our hope returns.
>
> Suddenly we see the solar disk through a thin cloud; but another one covers it immediately, and this hope and anguish goes on for 30 minutes. At around $9\,\frac{1}{2}$, a brightening that is larger than the previous ones permit to point at Venus between the clouds, 12 minutes before the moment of the minimum distance of centers. From that moment on we can make micrometric measurements, with a few interruptions, till the end of the transit. These measures which form the main body of our observations are 124 in number, and some refer to the time when the planet was closest to the solar center. [. . .] At 1h 14m and 1h 34m we observed the two last contacts on a sky which was almost free from clouds. And everything was finished!

In his extensive obituary, Lancaster is much more detailed on Houzeau's state of mind in the morning of the transit when the sky was overcast (Lancaster 1887):

> Houzeau did not say anything, but his face became very pale; not a muscle of his face moved; we understood that he was undergoing a deep inner trouble. He returned to our little house and laid down on the floor, as he liked to do it, and said to us that we should notify him if some change in the sky conditions should arise.

And there is another line in Lancaster's (1887) obituary that merits citation with respect to the Texas expedition since nothing is found in the official reports:

> Soon after his [Houzeau's] return to Belgium [in 1876], he re-married with his sister-in-law, the widow Béatrice Discry[5], who accompanied him

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[4] All translations included in this paper were by the author in collaboration with H. W. Duerbeck.

[5] Née Béatrice Backes (1811–1894), widow of Pierre Discry.

> on his trips to Jamaica in 1878, and to Texas in 1882, and who cared for him, from the first days of his sickness to which he would finally succumb, with an unlimited devotion.

The San Antonio expedition was a success, despite the cloudy weather during almost half of the transit (see Fig. 6).

3.2. The Expedition to Santiago de Chile

Luis Ladisláo Zegers, a physicist at the *Universidad de Chile*, wrote a "*noticia histórica*" on the observations carried out in Santiago and its vicinities. He cites a lot of correspondence and newspaper clippings, talked with the Belgian and U.S-American scientists, and actively took part as an assistant of the French transit expedition.[6] Zegers is best known today because of his use of Röntgen's newly discovered X-rays for medical purposes in Chile only a few months after their first application in 1895 (Zegers & Salazar 1896). Zegers' (1883) book does not inform us about the activity of the Chilean National Observatory on December 6, 1882, since this was obviously restricted to the authorized word of its director, José Ignacio Vergara. Instead, Zegers quotes from Vergara's newspaper articles of the forthcoming event, gives a long history of the National Observatory, deplores its present state of decline, and then very briefly lists contact timings derived by Chilean personnel at the observatory ("we owe these data to the kindness of the director of the National Observatory"). And this remained the only printed result of the Venus transit observed by the Chilean National Observatory staff.

The Chilean party consisted of Louis Niesten, astronomer at the Royal Observatory of Brussels (chief of mission), Charles Lagrange, adjunct astronomer at the same institution, and Louis' brother Joseph Niesten, an artillery lieutenant on leave from the War Ministry. Details are given in Houzeau & Niesten (1883) and Houzeau (1884a), see also Duerbeck (2004) and Sterken & Duerbeck (2004). A few days after arrival, the Belgian commission began to install its instruments in an annex of the National Observatory "somewhat to the south and facing the large tower that contains the new equatorial" (Zegers 1883).

December 6, the day of the transit, was perfectly clear: "Since dawn, a clear sky – only a few clouds above the snowy peaks of the Andes – promised a wonderful day" wrote Niesten in his diary (Houzeau 1884a). Indeed, 606 measurements of the position of Venus were taken with Houzeau's heliometer, and additional observations were made with refractors. The latter ones show the phenomenon that had already plagued the eighteenth-century observers: the black spot that appears at second and third contacts, which makes accurate timings of the moments of internal contacts virtually impossible. Niesten to Zegers (1883, p. 177):

> The measurements were carried out with the utmost easiness, and with a great precision [...] During the time of the transit, the Belgian commission was able to determine 606 positions of Venus on the solar disk. [...] When the heliometric results of the two Belgian stations, that of Texas and that of Chile, will be combined, the Belgian astronomers will without doubt achieve to determine the value of the solar parallax with a completely novel method which will establish itself with all signs to be an excellent one.

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[6] The French Academy of Sciences had organized ten expeditions, one of which went to Chile.

After finishing the observations, the party went by railway to Santa Rosa (Chile), crossed the Cordillera on muleback, and again by train to Rosario (Argentina), where a steamer brought them to Buenos Aires. After short stays in Montevideo, Rio de Janeiro and Petropolis, they returned with a steamer via France to Belgium, happily finishing "the first scientific expedition organized by Belgium" (Houzeau & Niesten 1883).

4. Results

Two years after the transit, Houzeau (1884b) published the report of the campaign. A lot of – partly unforeseen – corrections had to be applied to the measurements: for example, the crosshair of the heliometer used in Santiago had been damaged on the trip, and had to be replaced by one which was not properly adjusted, thus corrections for eccentricity had to be carried out. The small Sun and Venus had of course different zenith distances, thus differential refraction corrections had to be applied, which amounted to different values in both locations, and these values directly influenced the resulting parallax value. Houzeau, as all other investigators, used a preliminary model of the Sun–Venus–Earth system, with an assumed solar parallax of 8.″86, and from the observations he worked out the corrections to the assumed values. Unfortunately, his observations carried him even further from the true value; his final result was 8.″911 ± 0.″084 for the solar parallax. While the parallax value can be taken as one based on a new and independent method, and thus something that can be regarded as a true achievement, Houzeau was less happy about the unexpectedly large error, which he mainly blamed on the poor sky conditions in San Antonio.

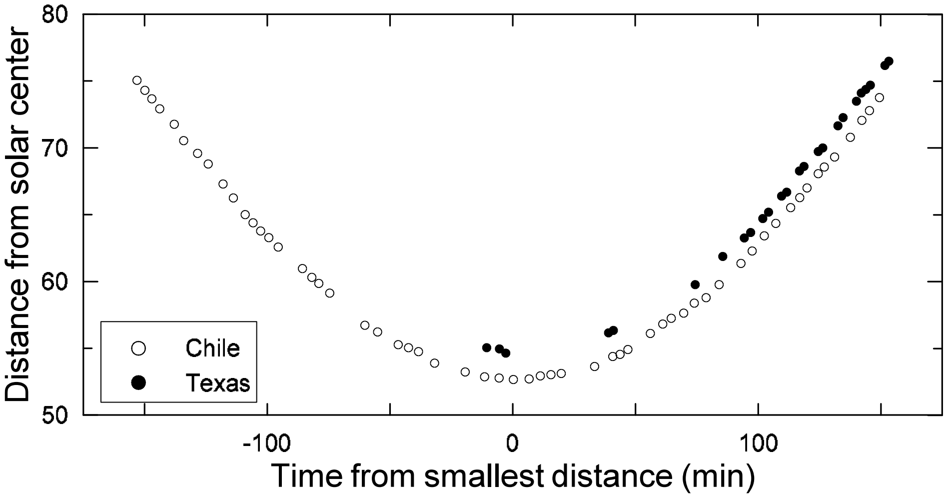

Figure 6. Measured distance from solar center (in screw revolutions) versus time for the Chile and Texas expeditions (data from Houzeau 1884b). The offset between parabolic fits to both curves amounts to 1.637 screw revolutions, well within the error range given by Houzeau. Source: Sterken (2009).

Figure 6 shows the measurements for both sites. The resulting difference Texas *minus* Chile was 1.632 ± 0.016 at 12.″067 per screw revolution,[7] or 19.″66. From

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[7] Scale factor corrected for temperature.

this he derived the solar parallax $\pi = 8\rlap{.}''911 \pm 0\rlap{.}''084$ (the value adopted by the *International Astronomical Union* (IAU) is $\pi = 8\rlap{.}''794$).

5. The whereabouts of Houzeau's instruments

Both sets of large and small half-objectives (the large ones secured on fixed brass mounts), a projection screen, at least one tube and major parts of a mounting, and two eyepiece units with micrometer screws for the small objectives survive at the Royal Observatory of Belgium; the optical items and the screen (with a sketch of a Venus transit as seen with such an instrument) are on display at the Museum of the Royal Observatory. Figure 7 shows the heliometer tube in the Workshop of the Royal Observatory of Belgium. Projection screen and lenses (from the Royal Observatory of Belgium Museum) were already shown in Figs. 3–6.

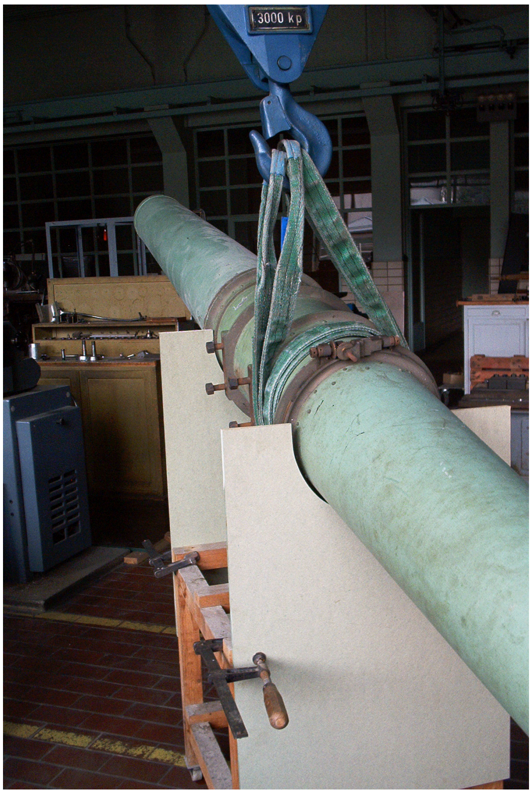


Figure 7. The heliometer tube in the workshop of the Royal Observatory of Belgium. Photo C. Sterken.

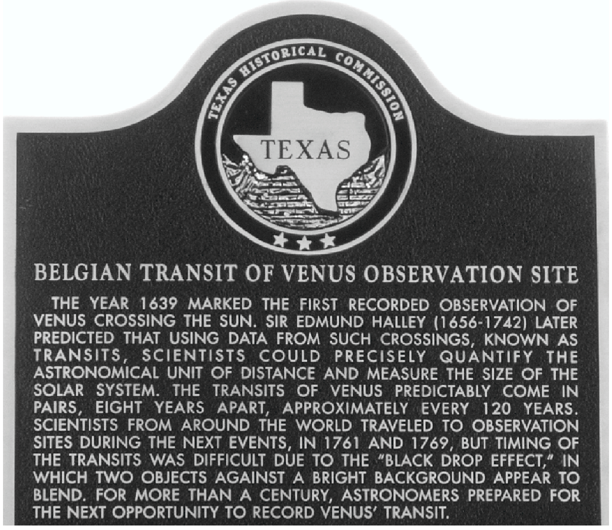
On the occasion of the Venus transit of June 8, 2004, the heliometer tube and the optics were restored, cleaned and put on a primitive mounting. On the day of the transit, the heliometer was installed on a trailer. Personnel and visitors of the Royal Observatory, including many school children, had on the day of the transit the opportunity to observe the (projected) Sun and Venus with the same instrument as more than one century ago. The quality of the images was very bad, maybe because of the ageing of the instrument, or perhaps because the intrinsic optical quality was not that good after all, so it is not surprising that no very precise measurements could be done with this instrument. Nowadays the heliometer is still on exhibit in the hallway of the Royal Observatory.

At the 2000 General Assembly of the International Astronomical Union in Manchester, IAU Commission 41 (History of Astronomy) adopted a Resolution recommending that the sites of previous transit-of-Venus expeditions be inventoried, marked and preserved, as well as instrumentation and documents associated with these expeditions. The safeguarding of these Belgian historical instruments is no doubt a valuable contribution to the archival efforts encouraged by the International Astronomical Union.

6. The San Antonio observing site recovered

In October 2005, the Texas Historical Commission inaugurated a historical marker "Belgian Transit of Venus Observing Site" on the grounds of *Bullis House*, a registered Texas State Historic Landmark located in the Government Hill Historic District on 621 Pierce Avenue, San Antonio (Fig. 8). The unveiling of this marker revealed a very unfortunate inaccuracy, as the text erroneously indicates

> Using a heliometer, a device he had developed for the observation, Houzeau obtained 124 photographic plates of Venus silhouetted against the sun.



BELGIAN TRANSIT OF VENUS OBSERVATION SITE

THE YEAR 1639 MARKED THE FIRST RECORDED OBSERVATION OF VENUS CROSSING THE SUN. SIR EDMUND HALLEY (1656-1742) LATER PREDICTED THAT USING DATA FROM SUCH CROSSINGS, KNOWN AS TRANSITS, SCIENTISTS COULD PRECISELY QUANTIFY THE ASTRONOMICAL UNIT OF DISTANCE AND MEASURE THE SIZE OF THE SOLAR SYSTEM. THE TRANSITS OF VENUS PREDICTABLY COME IN PAIRS, EIGHT YEARS APART, APPROXIMATELY EVERY 120 YEARS. SCIENTISTS FROM AROUND THE WORLD TRAVELED TO OBSERVATION SITES DURING THE NEXT EVENTS, IN 1761 AND 1769, BUT TIMING OF THE TRANSITS WAS DIFFICULT DUE TO THE "BLACK DROP EFFECT," IN WHICH TWO OBJECTS AGAINST A BRIGHT BACKGROUND APPEAR TO BLEND. FOR MORE THAN A CENTURY, ASTRONOMERS PREPARED FOR THE NEXT OPPORTUNITY TO RECORD VENUS' TRANSIT.

Figure 8. Texas Historical Marker (2005, photograph C. Sterken).

But Houzeau's data were time series of calibrated screw revolutions obtained by superimposition of Venus and the "small" solar images projected on a screen. It can only be hoped that the Commission will repair this error, otherwise this story will start a life of its own in a way similar to the text on the commemorative plaque at Paris Observatory that says

> L'astronome Danois Olaus Rømer 1644–1710 a découvert la vitesse de propagation de la lumière á l'Observatoire de Paris en 1676.[8]

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[8] *The Danish astronomer Olaus Rømer 1644–1710 discovered the speed of light at the Observatoire de Paris in 1676.* See Sterken (2007) for a discussion of the propagation of the erroneous vision that Ole Rømer discovered/determined the speed of light.

7. Conclusion

In the history of astronomy, the nineteenth-century transits do not occupy the same rank of importance as those of the eighteenth century. While in the sequel of the eighteenth century transits, there was no immediate way to replace the method by another one. The refinement of other, concurring methods in the second half of the nineteenth century – even when the "transit season" was underway – led to a critical evaluation of different approaches to determine the astronomical unit, which is perhaps best exemplified in Simon Newcomb's varying views how to handle the problem of solar parallax. And when a suitable minor planet – Eros – was discovered, which provided all the advantages, and none of the disadvantages of Venus, the method of Venus transits fell into oblivion. There was no twentieth century Encke[9] who tried to homogenize the nineteenth-century results. But the importance of solar parallax, which was known to be just one mosaic stone in the system of astronomical constants, was clearly recognized by some of the leaders in the field, like Harkness (1891) and Newcomb (1895), who sat down to determine consistently such a system, based on the foundations that Houzeau had laid by compiling the first – and perhaps most extensive and erudite – compilation of "astronomical quantities" in one of his *opera magna*, the *Vade-Mecum de l'Astronome* (Houzeau 1882). So we recognize in Houzeau a unique person, who was both a compiler and a researcher, a republican and a "Royal astronomer", a Belgian and a cosmopolitan.

The history of Houzeau's ordeal comprises all aspects that are commonly present in all transit of Venus enterprises through history. In particular the impact of the weather conditions: Houzeau's Texas expedition almost failed because of bad weather, whereas the complementary expedition – with exactly identical instruments – was a great success thanks to the splendid skies. That is not different today, as the June 2012 transit sky was heavily overcast in Vardø, whereas Tromsø enjoyed splendid weather all night, see the papers in the *Venus in Sole visa* part of these Proceedings.

Acknowledgments

I owe a lot to Hilmar W. Duerbeck (1948–2012) for his continuous help and support in unearthing interesting facts about this most special Belgian colleague.

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MEETING VENUS
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Observation of Venus and Mercury Transits from the Pic-du-Midi Observatory

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Abstract. The Pic-du-Midi, on the French side of the Pyrénées, became a state observatory in the summer of 1882. The first major astronomical event to be observed was the Venus transit of 6 December 1882. Unfortunately this attempt by the well-known Henry brothers was unsuccessful due to bad weather conditions.

During the twentieth century, the Pic-du-Midi became famous for the quality of its solar and planetary observations. In the sixties, Jean Rösch decided to use this experience to monitor the transits of Mercury. The objective was not to measure the parallax, but to determine the diameter of the planet in order to confirm its high density. Observations were made using a photometric method – the Hertzsprung method – during the transits of 1960, 1970 and 1973.

The pioneer work of Ch. Boyer on the rotation of the Venus atmosphere as well as some experiments involving Lyot coronographs are also noteworthy.

A Venus transit was finally observed on 8 June 2004 with a new CCD camera, providing a significant contribution to the model of the Venus mesosphere. This opened the field for new observations in 2012.

1. Early days of the Pic-du-Midi Observatory

The site of the "Pic-du-Midi de Bigorre", on the forefront of the Pyrénées, has been known since ages as an ideal location to carry out astronomical observations.

François de Plantade (1670–1741), a lawyer from Montpellier, who met Jean-Dominique Cassini in 1693 in Paris, showed early interest in astronomical observations.[1] He died at the Sencours pass (elevation 2378 m) at the age of 71 during a mapping mission. At this very location, Dr. Costallat built in 1852 a "Hostellerie", with the intention to attract tourists and scientists. In fact, it is from this "Hostellerie Plantade" that the famous photographer, Maxwell-Lyte, successfully recorded his first photographic images of a solar eclipse, on 18 July 1860.

Thanks to the "Société Ramond" and the enthusiasm of the co-founders Général de Nansouty and C.-X. Vaussenat, there was a growing interest in the scientific community to build an observatory at the Pic-du-Midi. As a trial, it was decided to start regular meteorological observations during the 1873 summer season, from the Plantade station. In view of the success of this first experience, the Général de Nansouty decided in 1874 to perform regular observations, also during winter time.

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[1] During the 1706 solar eclipse, he was the very first to give a description of the solar corona. In 1736, observing the transit of Mercury from Montpellier, he claimed to have detected a possible bright ring around the planet.

Unfortunately, severe weather conditions with huge snow falls and avalanches forced the General to evacuate the Hostellerie Plantade on December 14, 1874.

It was a painful experience. But a lesson was learned, and it was thus decided to build a permanent observatory on the very top of the mountain at 2877 meter. On 20 July 1878, the first stone was laid; but the completion of the project appeared to well exceed the financial resources of the founders.

In August 1882, the ownership of the observatory had to be transferred to the French State, and C.-X. Vaussenat became the first director.

2. The 6 December 1882 Venus transit

There was a huge interest in the scientific community for the observation of the 1882 Venus transit. France organised ten expeditions all over the world.

In France, the Sun was rather low above the horizon, but one can understand that Admiral Mouchez, director of Paris Observatory, decided to send the two Henry brothers to the recently opened Pic-du-Midi observatory. The positive experience made by Maxwell-Lyte during the 1860 eclipse has probably played a role in that decision. Indeed, Prosper and Paul Henry (Fig. 1) were excellent candidates for this task, as they were very well experienced with the set-up of the photographic laboratory in Paris observatory.[2]

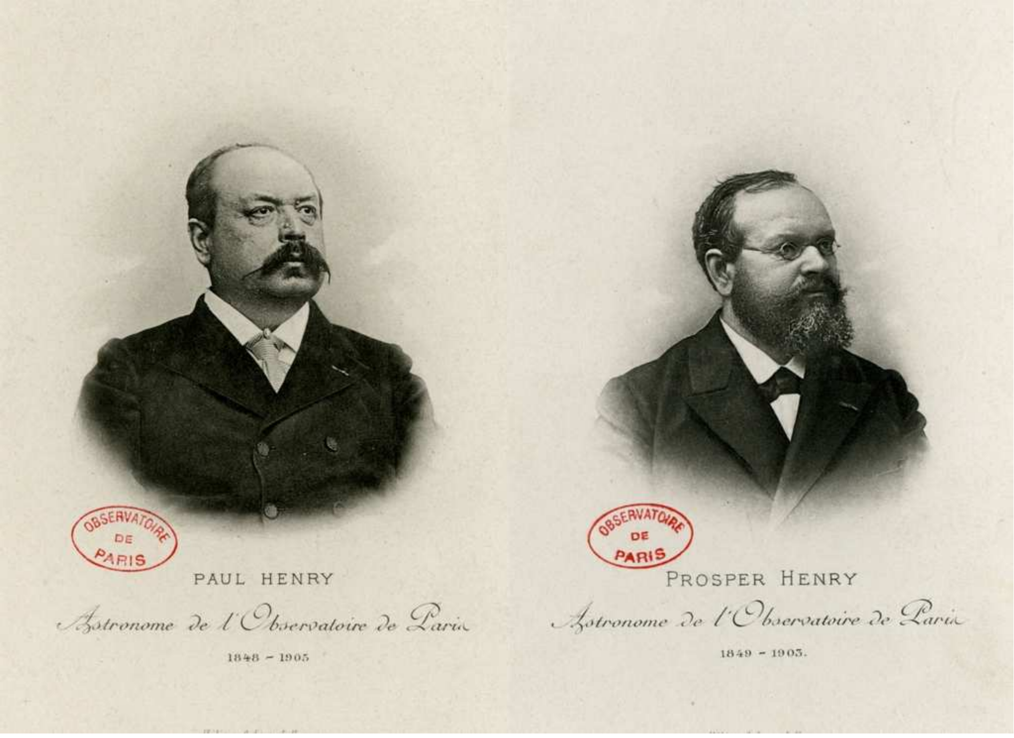

Figure 1. The Henry brothers (Paul & Prosper). Source: Bibliothèque de l'Observatoire de Paris.

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[2] They later provided a key contribution to the success of the "Carte du Ciel" project.

However, snowfall was ahead of schedule that winter in the Pyrénées. The equipment needed by the Henry brothers was brought with huge difficulties to the Hostellerie in Sencours. But it was out of question to hand-carry the 60 boxes (with an average weight of 20 kg) to the summit.

Therefore C.-X. Vaussenat and the Henry brothers decided to install the astronomical equipment in Sencours. A team of porters was to bring the necessary logistic support from the valley to the Sencours pass. Unfortunately, on 2 December, four days before the transit, a snow avalanche caught the porter team shortly after leaving Sencours. Three men were killed in this dramatic mountain accident. It was a bad start for this astronomical mission.

On December 6, in the early morning, after a somewhat stormy night, the Sun was shining again. The Henry brothers took a few preliminary calibration plates. All the equipment was ready at midday to start recording. Unfortunately, half an hour later, clouds came, a strong wind started blowing, and even snow was flying horizontally! During some short periods they could see the Pic-du-Midi summit in the blue sky, but with a sudden fall in atmospheric pressure, the wind increased significantly and the Sencours pass became completely overcast. "*La partie était perdue*" C.-X. Vaussenat recorded sadly in his notebook.

Two days later, on Friday 8 December, the weather conditions became excellent, and the Henry brothers were able to observe the planet, 3 degrees away from the Sun. According to Vaussenat's notes, they saw "a special annular brightness which could originate from the atmosphere of the planet".[3]

In fact, the observation of the 1882 Venus transit from the Pic-du-Midi was a double failure, as no astronomical data were acquired and a fatal accident occurred resulting in three casualties. However, this accident highlighted the need to have permanent observing equipment at the summit. Accordingly, in 1884 two telescopes (likely a heritage from the other Venus transit missions) were erected at the Pic-du-Midi.

3. Paving the road towards the 2004 Venus transit: observation of Mercury transits

After this difficult start, the astronomical activities made a significant step forward when, following an initiative of Benjamin Baillaud, director of the Toulouse observatory, a large dome (8 m diameter) was erected at the summit in 1907. Soon after, the first observations of Mars performed by F. Baldet, an astronomer from Meudon observatory, confirmed the possibility to acquire high quality images at the Pic-du-Midi.

The exceptional quality of the atmosphere at the Pic-du-Midi was further emphasized in the 1930s by Bernard Lyot when he demonstrated the possibility to observe the solar corona outside eclipses with his "coronograph". Bernard Lyot, who was a very skilled astronomer, recorded later high-resolution images of the Moon and the planets. In the Coupole Baillaud, the 38-cm refractor was replaced in 1943 by a 60-cm refractor originally built by the Henry brothers for the "Coudé equatorial"

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[3] *"A midi, MM. Henry observent Vénus à l'œil nu et aussi avec une petite lunette; ils constatent qu'elle n'est qu'à* 3° *du soleil et qu'ils la voient avec autant de netteté qu'on la voit ailleurs avec de puissants instruments. Ils constatent même autour de Vénus un espace presque entièrement annulaire d'une clarté spéciale et qui constituerait l'atmosphère de Vénus".* C.-X. Vaussenat, quoted by J. Rösch, 1951.

at Paris observatory. A team of young astronomers, following the impulse given by Bernard Lyot, was assembled to perform observations as frequently as possible at the summit. Among them, the names of Henri Camichel and Audouin Dollfus have to be quoted.

It was in this context that Jean Rösch became the new director of the observatory from 1947 onwards. He made a lot of efforts to develop a wide spectrum of observations and to improve the necessary logistic support at the Pic-du-Midi.

One of his achievements is undoubtedly the "Coupole Tourelle"[4] dedicated to photography of the solar surface (spots and granules). This dome has a specific design where the refractive doublet is closing the aperture, preventing any heat exchange (and therefore image degradation) from the instrument. This dome, operated by A. Carlier and R. Muller, yielded photographs that were considered to be among the sharpest ones recorded by ground-based solar telescopes.

In this situation, it is no surprise that Jean Rösch took the opportunity to observe the Mercury transits. The aim was not the determination of the solar parallax, but new measurements of Mercury's diameter, a rather controversial subject due to the unusual density found for this planet. Jean Rösch's project was based on the Hertzsprung method: a photometric method in which the diameter of the planet is compared to the size of a calibrated pinhole in the focal plane of a telescope.

A first promising experiment took place during the 7 November 1960 transit at the Pic-du-Midi (as well as in Meudon with J.-L. Leroy). Following the publication, in 1967, of the radar measurements of Mercury's diameter, Jean Rösch considered that it was worth observing the next transit on 9 May 1970. In order to maximise the chance of observing the phenomenon, the experiment was duplicated. Henri Camichel and Guy Ratier would operate the "Coupole Tourelle" at the Pic-du-Midi, whereas Jean Rösch and F. Chauveau would use the refractor available at the Athens National Observatory. Unfortunately, the sky was completely overcast at the Pic-du-Midi, but Jean Rösch managed to record record the event in Athens. In spite of non-optimal atmospheric conditions in Athens, the experiment yielded an upper limit for the diameter of Mercury ($6\overset{\prime\prime}{.}79$), a value slightly higher than the one provided by the radar.

As the following transit was fully visible at the Pic-du-Midi, it was decided to repeat the experiment on 10 November 1973. This time, the atmospheric conditions were excellent and Ratier and Chauveau were ready to operate the "Coupole Tourelle". Unfortunately, soon after the start of the transit, the water tank located in the vicinity of the focal plane started to leak, creating a cloud of water vapour in the instrument. There was no way to repair the faulty equipment "on the spot", and the photometric measurements were meaningless. It was a great disappointment; obviously the "Mercury gods" again failed to cooperate.

4. Charles Boyer and the rotation of the Venus atmosphere

As previously mentioned, in the post-war years a team of young astronomers, following Bernard Lyot's impulse, was operating at the Pic-du-Midi. They recorded, weather permitting, as many photographs as possible of the planets. Venus was indeed a difficult case, as the observations could only take place shortly after sunset or before sunrise. The contrast of the images recorded, in the yellow part of

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[4] This "Tourelle telescope" is now renamed "Lunette Jean Rösch" (LJR).

the spectrum, was rather poor as Audouin Dollfus experienced in 1948 and Henri Camichel in 1953–1954 (Fig. 2).

Figure 2. The "young astronomers" at the Pic-du-Midi in 1956: Henri Camichel, Marcel Hugon, Jean Focas, Audouin Dollfus in front of the 60-cm refractor polished by the Henry brothers. Photo: Henri Camichel Collection: Observatoire Midi-Pyrénées.

Henri Camichel also knew, from the work done by Frank E. Ross at Mount Wilson observatory in 1928, that one way to improve the photographic contrast was to use the near-ultraviolet part of the spectrum. Unfortunately, the equipment available at the Pic-du-Midi during the late 1950s was not optimal: the 60-cm refractor polished by the Henry brothers had a flint glass absorbing UV light, and the 60-cm reflector had a rather poor image quality. In this situation, he suggested to the amateur astronomer Charles Boyer, to try to record Venus pictures in violet light from Brazzaville (Congo). Using a 26-cm reflector, Charles Boyer immediately noted in September 1957 a periodic re-appearance of some spots every 4 days. The same period was also confirmed later by Henri Camichel, when he made a new survey of the plates he took in 1953–1954.

Following additional exposures showing some constant features (like a "tilted Y"), Charles Boyer and Henri Camichel came to the conclusion that the movement of the spots observed on Venus were due to a retrograde rotation of the atmosphere of the planet in 4 days. This was a very controversial hypothesis, as the rotation of the planet itself was found very much slower by radar measurements in 1962.

An international campaign was triggered by Audouin Dollfus (1962) to gather more photographs in sequence. Additional observations were also conducted by Charles Boyer at the Pic-du-Midi with the recently erected 1-meter telescope. He even could record pictures of Venus during daytime, thanks to the high purity of the atmosphere at the Pic-du-Midi. He was supported in this job by new astronomers such as Pierre Guérin and Michel Aurière (Fig. 3).

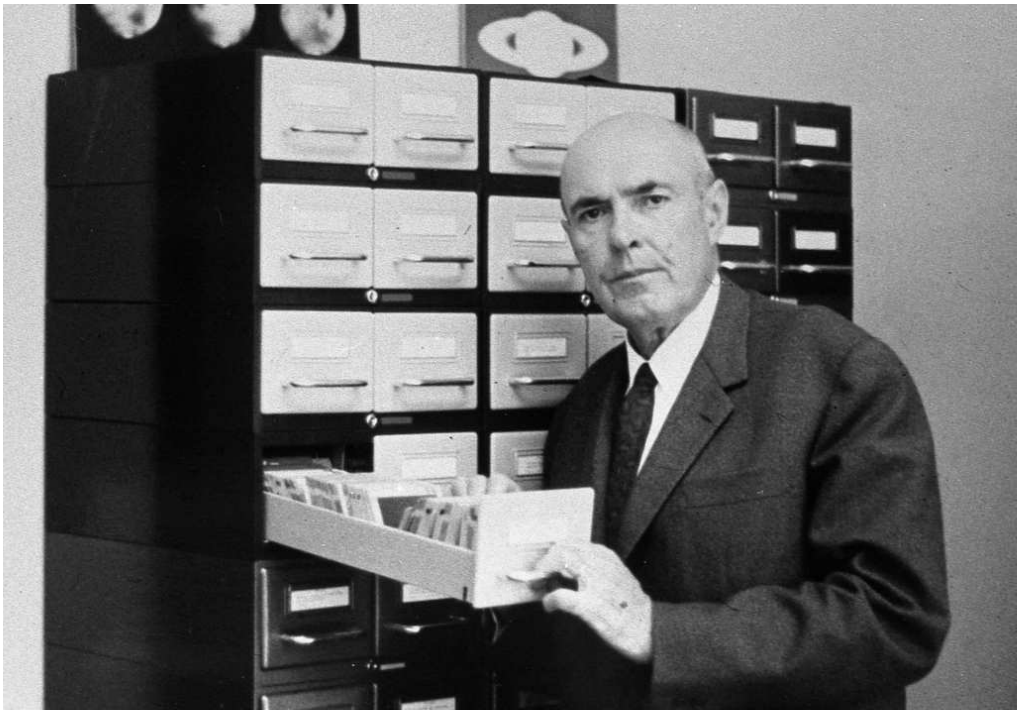

Figure 3. Charles Boyer at the "Centre de photographie planétaire" Meudon. Source: Observatoire Midi-Pyrénées.

In the years 1964–1966, Bernard Guinot and Martine Feissel, using interferometric spectroscopy detected a Doppler shift that was in line with the 4 days retrograde rotation of the atmosphere of Venus.

The controversy ended only with the results provided by various space missions devoted to Venus: Mariner 10, flying by Venus on 5 February 1974, was the first to provide a film in UV light, a brilliant confirmation of the findings of Charles Boyer.

5. Miscellaneous observations performed with coronographs

It is rather unusual to use a coronograph to observe planets, but it can be done when the planet is close to its conjunction and quasi-simultaneously in the ecliptic plane (i.e., near the line of nodes). In case of an inferior conjunction, a "transit" could take place: a fairly exceptional event (2 times every 130 years for Venus, 2 times every 13 years for Mercury). In case of a superior conjunction, the phenomenon is of similar nature, but the planet is "occulted" by the Sun, and due to the Sun's brightness, only a coronograph is then able to record the event.

On 15–16 November 1969, an "occultation" of Mercury was visible from the Pic-du-Midi and recorded successfully with the 20-cm Lyot coronograph by G. Ratier and J.L. Leroy. The aim of this experiment was to check if Mercury's albedo, close to the null phase, had a behaviour similar to that of the Moon.[5] No specific anomaly could be detected within the limited photometric accuracy of the photographic emulsion.

On June 16, 1984 J.-C. Noëns performed, with the same instrument, a similar experiment during the superior conjunction of Venus. Images of the planet were recorded as close as 1 arcminute from the limb in order to evaluate the possibility of detecting the Einstein effect.

Finally, it is worth mentioning the special case of a "Moon transit": on February 25, 1971, a partial solar eclipse took place that was fully visible at the Pic-du-Midi. On the photographs taken by J.-P. Rozelot and G. Ratier in "white light", the Moon is clearly visible outside the solar disk. Following a fine photometric analysis, it has been possible to evaluate the light scattered (by the atmosphere around the Pic-du-Midi and by the instrument itself) and to retrieve brightness values of the "white corona" as far as 10 arcminutes from the limb.

6. Observations of the 2004 Venus transit

The Venus transit of 8 June 2004 was fully visible at the Pic-du-Midi, and a number of observatories were planning to record the event. Obviously, the main objective was not anymore to determine the solar parallax[6] but to investigate this strange "aureole" that was reported by some observers during previous transits[7].

Since the first observations made by J. Rösch during the partial solar eclipse in 1961, the "Tourelle telescope" (LJR) has been significantly improved: the old 38-cm refractor doublet has been replaced by a larger one (50 cm) polished by J. Texereau. The 35-mm cine-camera that enabled A. Carlier and R. Muller to record and select the sharpest images of sunspots and solar granulation has been abandoned, and the project was to replace it by a wide field CCD camera (CALAS). But in June 2004 only a preliminary version of the CCD camera was operational.

Sylvain Rondi operated a CMOS PixeLINK camera from June 5 onward, when the planet elongation was 4.8 degrees. The aureole was clearly visible and its aspect was progressively changing when the planet came closer and closer to the Sun (see Fig. 4). On 8 June, it was still possible to detect the aureole after the first contact and to record the variations up to the second contact. Unfortunately, clouds came later in the day, and the third and fourth contacts were lost.

In parallel, A. Rondi (S. Rondi's father) who had built his own small coronograph (diameter 90 mm) was observing from a different site in the area. He was also able to get a good record of the aureole photometric fluctuations between the first two contacts.

The records made in various observatories of the aureole have been compiled and analysed by Tanga et al. (2012). Thanks to the CCD technology, it was possible to obtain a rather precise photometric description (spatially and timely) of the aureole. Based on these data, a rather elaborate model of the mesosphere of Venus involving

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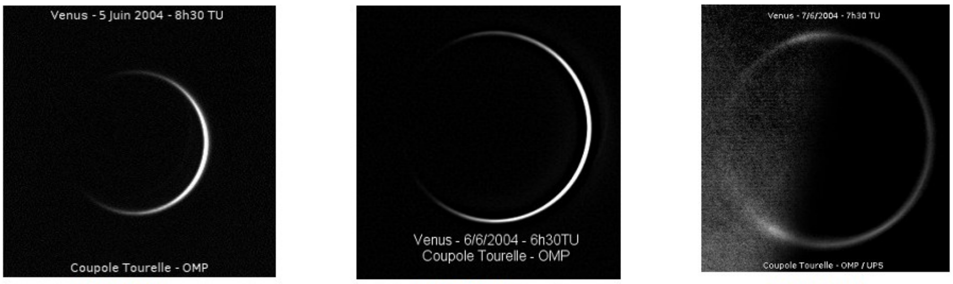
[5] This Moon anomaly was detected during the Apollo 8 and Apollo 10 missions.

[6] However, a joint initiative (by ESO-IMCCE) to promote the 2004 Venus transit among amateur astronomers was able to collect some 3700 time measurements of the contacts and to re-assess transit-based calculations of the Sun–Earth distance.

[7] Mikhail Vasil'evich Lomonosov, who observed the 1761 transit of Venus from St Petersburg, is often reckoned as the discoverer of the atmosphere of Venus. There are, however, numerous candidates to this same discovery, see for example Meadows (1966) or Aspaas (2012, p. 202).



5/6/2004
~69 hrs before transit start

6/6/2004
~49 hrs before transit start

7/6/2004
~24 hrs before transit start

Figure 4. The Venus aureole prior to the 2004 transit as seen from the "Lunette Jean Rösch". Photo: S. Rondi.

the temperature in the South polar region, as well as the latitudinal variation of the cloud-top layer altitude, was derived. Preliminary results from this model are being compared with measurements from space probes (e.g. Venus Express).

7. Conclusions and perspectives for the 2012 Venus transit

In spite of the apparent failure of the observation during the 1882 transit of Venus in Sencours, it appears that the study of the Venus atmosphere has been an almost permanent concern at the Pic-du-Midi. These investigations have been supported by the development of an appropriate instrumentation initiated by B. Lyot and pursued by J. Rösch. Observations performed during the 2004 transit by S. Rondi have confirmed the Henry brothers' intuitive observation of an areola around Venus. Fast photometric recordings of the 2004 transit have opened a new approach for modelling the Venus atmosphere. The Pic-du-Midi staff is proud to have made a significant contribution in this field. The 2004 transit has also revealed the suitability of the coronograph concept to observe the atmosphere of Venus. As a consequence, it has been proposed to deploy some 9 small coronographs (based on A. Rondi's prototype) around the world to monitor the 2012 transit in the frame of the Venus Twilight Experiment (Venustex) project.[8]

Acknowledgments

The authors would like to express their gratitude for the kind support received from their previous colleagues of the Pic-du-Midi Observatory, namely MM. R. Muller, J.C. Noëns, and M. Aurière. Fruitful comments have also been provided by MM. P. Tanga (Nice Observatory) and T. Widemann (Paris-Meudon Observatory).

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[8] Note added after the Tromsø conference: The Venus Twilight Experiment has been successful in 2012, see Tanga et al. (2012). The current status can be found at `https://venustex.oca.eu/`

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VENUS IN SOLE VISA

A SCIENTIFIC expedition may be said to have two histories.

The one treats of the special object of the expedition, the other of the personal adventures of those concerned in it.

It is only the former which finds permanent record in the Transactions of scientific societies: the other too often remains unwritten.

David Gill (1878)

MEETING VENUS
C. Sterken, P. P. Aspaas (Eds.)
The Journal of Astronomical Data 19, 1, 2013

The Transit of Venus on the Midnight Sun Observed from the Tromsø Region

Steinar Thorvaldsen

Abstract. Tromsø, the largest city in Northern Norway, is almost 70° north, and, as luck would have it, a fantastic Midnight Sun shone down from the clear blue arctic sky during the entire night of the June 2012 transit. It was like a dream come true for astronomers in the area! The weather was perfect in most parts of the Tromsø region, and the Norwegian national TV channel, NRK, got the front row for its marathon broadcast that lasted for more than seven hours. Several groups observed the night-long transit that started just after midnight and ended after 7 a.m. One group took the cable car just outside Tromsø city to 420 m above sea level on Fløya mountain, while another group observed from the top of the Auroral Observatory by the lake Prestvannet on Tromsø Island. Both groups had telescopes and cameras to stream video and pictures to the internet and to national TV broadcasts.

1. At the Cable Car Station

The observers at the cable car station had reinforcements by David Wright from the Astronomy club in Oslo. They had an 80-mm telescope with video camera for streaming to the Internet, a 70-mm telescope of the type Ranger with camera dedicated to still photography, a telescope with regular sunscreen and, from Oslo, a Televue 101 with a 90-mm Coronado Solarmax H-alpha filter. Pål Tengesdal operated the 80-mm refractor with video for delivery of images to the Norwegian Science Centre's webcast and television companies. I operated the Ranger telescope.

The group took the cable car up early in the evening to set up and test their equipment, and, not least, the food from the kitchen of the Cable Car restaurant. During the evening, several other groups and observers arrived. This included a school class from Germany, and individuals from Germany, as well as the Netherlands, Denmark, Spain and Brazil. A large group from the University of Madrid

Figure 1. *Left*: The big screen at the football field outside Tromsø Sports Hall. Photo: Øystein Lund. *Right*: Map of three observing sites close to Tromsø city. Based on Google Earth.

had also made the long trip to observe the event. Around midnight a lot of people showed up, primarily to see the Midnight Sun. Some of them were unaware of the upcoming transit and they were delighted to see the little black Venus on the solar disk at the same time. Figure 1 shows a map with the observing sites, and Fig. 2 shows the Cable Car observing site.

The large crowd went back down to Tromsø with the last cable car of the night at 3 a.m., after that fully dedicated observers were the only ones left to witness the transit. Although we had full access to facilities and heating in the cable car station and restaurant, the beautiful weather made the vast majority of us stay outside all night. After the passage was over, we had breakfast and watched the clouds roll back in while we waited for the first trip down at 10:30.

Figure 2. Observers at the Cable Car Station in Tromsø. From left to right: David Wright, Anne Bruvold, Steinar Thorvaldsen and Pål Tengesdal. Photo Anne-Kristin Tengesdal.

2. At the Auroral Observatory

Some ten observers had chosen the observation roof of the Auroral (Northern Lights) Observatory at 89 meter above sea level as their observation site (Fig. 3). Among the observers were: Torsten Aslaksen with a 60-mm refractor and H_α solar filter and video for delivery of images to the Norwegian Science Centre's webcast and to TV stations; Sven Erik Grydeland with a 250-mm Maksutov-Newtonian Skywatcher and camera; Stein Høydalsvik with a 110-mm William Optics refractor with camera and Anders Olsen with an 80-mm William Optics refractor, visually. There were also visitors from Scotland. Three amateur astronomers from Nordjysk astronomy club in Aalborg, Denmark had also made the trip to Tromsø, with Per Rieffestahl and Hans Kristensen observing visually, and Hans Ejler Jørgensen recording the transit with a Phillips SPC 900NC PC camera through his Meade LX200 telescope and an $f/3.3$ focal reducer.

3. Mountain peaks

Northern Norway has many peaks that may be suitable for extreme trips to find the best atmospheric conditions. Erling Nordøy is one of the region's most enthusiastic astrophotographers. To achieve the best possible conditions, he took the trip on skis to the top of Vasstinden, 895 m above sea level on Kvaløya west of Tromsø city, with 20 kg of equipment on his back! Here he caught the entire transit under perfect conditions, with only slight turbulence in the beginning, and took a total of 24 GB of images in raw format through his Swarovski AT 80HD telescope (Fig. 4). This material has been processed, where around 20 images (taken during 56 seconds) are stacked, to optimise image quality and give a fantastic impression of the transit. Furthermore, Ole Anton Haugland and Åge Mellem made the trip up to Gumpe in Sørreisa, over 1000 m above sea level, with clear view in all directions.

Figure 3. Observers at the Auroral (Northern Lights) Observatory in Tromsø. Photo: Per Rieffestahl.

4. All-night National TV Show

The University of Tromsø, Norwegian TV and Knut Jørgen Røed Ødegaard plus several others had invited the public to a Venus transit show at the soccer field outside a Sports Hall on Tromsø Island. A crowd of around 1,000 people showed up, which was beyond most expectations. The area was equipped with a large video screen, many stands and an outdoor TV studio. In fact we could see the big screen with our telescopes from the Cable Car station several kilometers away. Around the football field it was possible to engage in various research activities organized by the University of Tromsø and others (Fig. 1).

Ida Kvissel from the Norwegian national TV (NRK) was responsible for the live broadcast of the transit of Venus, and the program was led by Selda Ekiz and

Per Olav Alvestad. For Kvissel and the science staff at NRK this was the first time they had attempted such a long live broadcast, and it was impressive to keep it going throughout the arctic midsummer night. Although there were a couple of small hitches, they managed quite well thanks to visits by guests like the well-known Norwegian astronomer Knut Jørgen Røed Ødegaard with his wife Anne Mette Sannes, and Truls Lynne Hansen from the University of Tromsø together with Pål Brekke from the Norwegian Space Centre.

According to the Norwegian Broadcasting Corporation, there was an average of 163,000 viewers who followed the program throughout the night, while 892,000 visited the program for at least one minute. In addition to all those that followed the transit on national TV, there were almost 50,000 people who followed it on NRK's live stream on the Internet. The TV images of the transited Sun were recorded by people of the Tromsø astronomy club, located at the Cable Car station and at the Auroral Observatory, and other sites around the country. The live pictures were also shown on the web of the Norwegian newspaper VG, and periodically also by NASA and other international sites. Particularly interesting were the simultaneous videos taken from Hawaii and Tromsø that made it possible to demonstrate the parallax phenomenon live. The Norwegian newspaper Dagbladet also followed the event the whole night via updated pictures displayed on their media sites.

Figure 4. Erling Nordøy's snow observatory built at Vasstinden outside Tromsø, nearly 900 m above sea level.

5. The observations

The transit began with the first contact at 0:04:30 local time in Tromsø, and the second contact, at 0:22:16. But with the Sun in the north and at its lowest at 0:43 and just over two degrees above the horizon at its lowest, the turbulence made it impossible to clearly see the first contact. The second contact was also challenging, with Venus dancing on a crooked solar limb. But later on, it was easy to follow

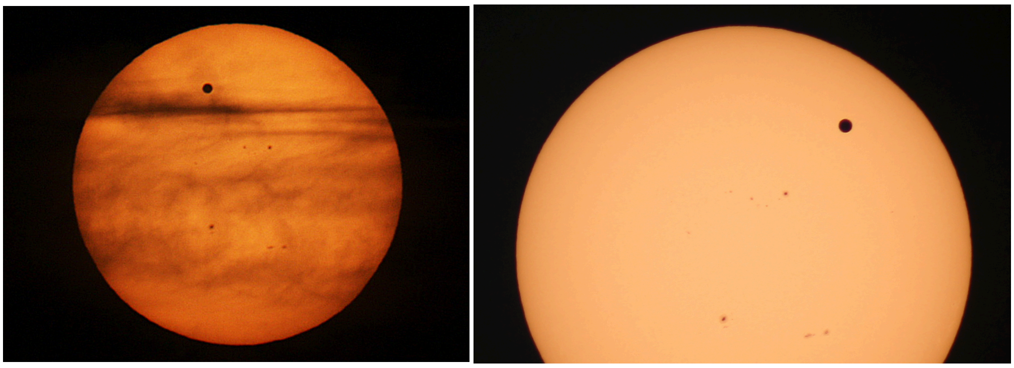

Figure 5. *Left*: The Sun with a black spot at 02:23 local time. A few thin clouds came in and displayed for some short periods Jupiter-like belts on the solar disc. Camera: Canon EOS 450D with 70 mm Ranger telescope. *Right*: transit of Venus at 05:14 local time. Camera: Canon EOS 600D with 70 mm Ranger telescope. Photos by Steinar Thorvaldsen.

the motion of Venus with telescopes and with H_α filters and several sunspots could be observed. In particular, H_α filters made it possible to monitor the protuberances around the solar disc, and structures on the solar disc itself. A few thin clouds came in from the north and displayed for some short periods Jupiter-like belts on the solar disc, without disturbing the black silhouette of Venus (Fig. 5). The clouds just created nice variations in the scenery.

During the night the Sun climbed higher in the sky and seeing conditions improved, making the third and fourth contact much easier to observe. Some contact times are listed in Table 1. Observers using an H_α filter saw the fourth contact about a minute after the white-light observers saw it. This is because H_α telescopes show the solar chromosphere, which is above the photosphere. After fourth contact the clouds came in from the north with full strength, and the well-known coastal rain started to fall later on: how incredibly lucky we had been!

Table 1. Contact times of the Venus 2012 transit as observed from Tromsø (69°39′41″ N, 18°56′26″ E). The observations are given in Central European Time (UT + 2 hours). Observers: Per Rieffestahl (visual with telescope), Hans Jørgensen (visual on screen, and video).

Contact	Calculated Cartes du Ciel	Visually telescope	Visually on screen	On video
1	0:04:30	?	0:05:00 (?)	-
2	0:22:16	0:20:07 (?)	0:21:53	-
3	6:36:02	6:35:43	6:35:49	6:36:07
4	6:53:39	6:53:17	6:53:30	6:53:40

The transit of Venus event has been an undisputed success in the Tromsø area, and we felt as if we had been on another planet, with a strong taste of heaven, the whole night!

Note added by the Editors

Steinar Thorvaldsen, Dr. scient. in mathematics, associate professor at Tromsø University's Department of Education and long-serving head of *Tromsø Astronomiforening* (astronomy club), has for decades devoted himself to the task of organising observations and disseminating astronomical knowledge to the public. With characteristic enthusiasm and diligence, Steinar not only organised the Venus transit observations as recounted in this paper, he also helped to secure funding both for the conference and for its Proceedings. Incidentally, the publication of these Proceedings coincides with his 60th birthday on May 31, 2013, on which we warmly congratulate him.

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A Venus Transit Midnight Flight over Alta

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Abstract. After the Tromsø conference, the author had planned to observe the 2012 Venus transit from a small plane flying over North Cape. This paper provides a summary report from this unusual expedition.

1. Preparing for a midnight flight over North Cape

The organizers of the Tromsø conference had scheduled a voyage on board of a *Hurtigruten* ship with the objective to reach Vardø, the historical site from where Maximilian Hell observed the Venus transit over the Sun in June 1769. The idea to follow the trace of Maximilian Hell and to try to repeat the observations he made 243 years ago was indeed a quite exciting project.

I had a word with Trevor Sanderson, a close friend and former scientist from the European Space Agency (ESA), on the feasibility of such a project. He objected that the probability to get good weather conditions was rather low at those northern latitudes; but, as we were both private pilots, he agreed that an attractive alternative would be to fly above the cloud layer to try to record the transit from the air.

The choice of the plane was rather straightforward: we would use the well-equipped Piper Arrow IV (owned by Satellite Aviation B.V. based in Rotterdam) on which the two of us were approved to be "pilot in-command". As a safety measure, Alberto Boetti, another pilot and former colleague from ESA, offered to accompany us.

The choice of the airfield was less straightforward: of course, the first idea was to fly to and from Vardø Airport at Svartnes to join the group coming from Tromsø with the Hurtigruten. But Vardø airfield has no refuelling facility that is compatible with our plane. So, we investigated the most northern airfields in Norway (see Fig. 1), as we were seeking to get the highest elevation of the Sun above the horizon during the midnight flight, to avoid potential haze effects over the sea.

Figure 1. Locations of potential airfields. North is up. Based on `GoogleEarth`.

Valan by Honningsvåg close to North Cape, had also to be discarded as the operational conditions were too marginal in case of bad weather. Finally Mehamn appeared to be the best compromise, as the airfield has a "straight-in approach", and is located at a walking distance from the town. In addition, the Mehamn airport manager kindly offered to make a special extension of the opening hours of the airport to allow us to perform our "Venus transit midnight flight".

Even though our flight was not part of a solid scientific programme, we had to consider the photographic equipment to be taken on board. In 2004, I was rather successful recording on film the Venus transit from Strasbourg (France) with my old Asahi-Pentax camera, equipped with an $f = 1000$ mm telephoto lens. But this equipment is rather heavy and bulky, so we chose to only keep the coated green filter in combination with Trevor's modern CCD camera.

2. Flying over the Norwegian fjords

The plan was to fly from Rotterdam to Tromsø along a scenic route following the coastal fjords of Norway. It went fine, except that I had to leave my colleagues behind in Kristiansund in order to make it to the Tromsø conference in time, due to a delay caused by some unexpected snow showers along our route around Trondheim. By Monday morning June 4, however, the crew was ready to leave Tromsø for Mehamn, with a planned stop at Honningsvåg Airport Valan. Approaching North Cape, the meteorological situation was changing with pretty strong gusts of wind. Being informed by the Honningsvåg control tower of the rapid deterioration of the landing conditions, we decided to divert to Lakselv Airport Banak. A close look at the last weather reports confirmed that an area of bad weather was drifting from the east to the western part of Finnmark. Predicted winds were rather strong, and operations on Tuesday from Mehamn airport were looking marginal for a single-engine light aircraft. Therefore, we decided to activate plan B and to divert to Alta.

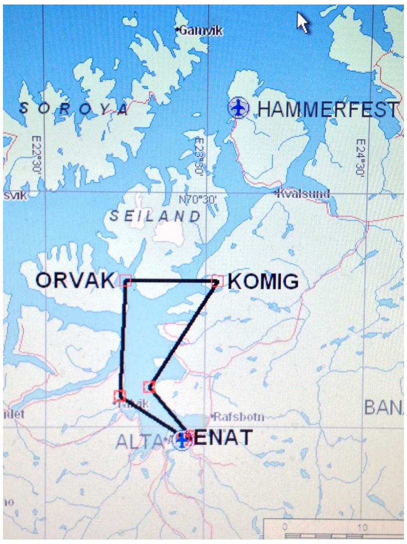

Figure 2. Chart showing the itinerary of the midnight flight. Komig and Orvak have the same geographical latitude and are separated by 12 nautical miles (approximately 20 km). Map Reproduced with permission of Jeppesen Sanderson, Inc. © 2012. NOT FOR NAVIGATIONAL USE.

On Tuesday morning June 5, we woke up with a fantastic blue sky. It was a sunny day in Alta, with excellent visibility. The CCD camera was checked and a special flight plan filed and accepted for our "Venus transit midnight flight". There was no real need to negotiate an extension of the operation times of the airport, as we could easily witness the first and second contacts; then land to have a rest, and take

Figure 3. Guy Ratier (left) and Trevor Sanderson (right) preparing the plane in Alta on the evening of June 5, 2012. Photo: Satellite Aviation B.V.

off again to witness the third and fourth contacts. To ease the navigation in flight, it was planned to make a kind of extended circuit between two reporting points, well known to Air Traffic Control, located along the same parallel (see the chart in Fig. 2.). Doing so, we would be able to see the Venus transit through the windows on the left or right sides. The circuit could be repeated as required, keeping in mind that a 180 degrees turn would induce a one-minute blank in the recording.

Figure 4. The "Venus transit midnight flight" crew relaxing in Alta (from left to right: Trevor Sanderson, Alberto Boetti, Guy Ratier). Photo: Satellite Aviation B.V.

We arrived well in time at the airport (Fig. 3) to prepare the plane. The internal clock of the CCD camera was synchronized with the on-board GPS. We were ready: Alberto was the "pilot in-command", Trevor the camera man, and I was doing the coordination of the operations and the radio with Alta Tower (Fig. 4). We just had to wait for a commercial plane to land, for a wild fox to cross the runway, and soon after we were cleared for take-off.

There are simply no words to describe the incredible beauty of a midnight flight over the Norwegian fjords. There were almost no clouds in the northern direction, whereas towards the east, one could detect the bad weather approaching. At 7000 feet, our selected altitude for operation, the air was calm and the plane was flying smoothly. Unfortunately, it became rapidly clear that we had a problem with the automatic focusing of the camera. We tried various tricks, but none of them were successful. The images recorded between the first and second contact were not exploitable. It was a great disappointment, and we had no other choice than simply to return to Alta and to land.

After landing the controller at the tower, who had no other traffic to monitor, asked us some details about our flight. He was interested to know what we did, as he could follow on his screen the transit broadcasted by the Norwegian TV from a ground station at Tromsø Island (see the paper by Thorvaldsen in these Proceedings). Of course we were a bit sorrowful when hearing this last remark and decided to cancel the flight for the third and fourth contacts.

3. The lesson learned

Back at the hotel in Alta, I had a second thought about the expedition from the Henry brothers at the Pic-du-Midi in December 1882 (Ratier & Rondi 2013). One of the reasons why the Henry brothers were unsuccessful to record the Venus transit has probably its origin in the fact that they were unable to bring their own equipment to the summit of the Pic-du-Midi before the snow came. This was likely due to a shortage of time preparation during the early days of the observatory.

We fell into the same trap, rushed in the preparation of this unusual expedition and missed the need to take along a spare camera. On Wednesday 6 June morning, the sky was fully overcast in Alta. To fly above the cloud layer would have been the only possibility to record the third and fourth contacts. Too bad! The lesson is learned for the next transit... in 2117 !

Acknowledgments

The author expresses his gratitude to the Norwegian Air Traffic Control for authorizing this special midnight flight in the Alta and Hammerfest TMAs. Special thanks also to the ground staff and operators at the various airports in Norway where we landed, for their efficient and very cooperative support.

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A Voyage to Vardø.
A Scientific Account of an Unscientific Expedition

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[7] *University of Jyväskylä, Finland*

[8] *Institut für Astronomie, University of Vienna, Austria*

Abstract. After the "Venus Transit Conference" that took place at the University of Tromsø from June 2 to June 3, 2012, participants were given the opportunity to either stay in Tromsø until the night of June 5–6, or to participate in a voyage to Finnmark, where the historical sites Vardø, Hammerfest, and the North Cape were to be visited. This voyage culminated in the observation of the 2012 transit of Venus at Vardø.

This paper gives a detailed account of this voyage that lasted from June 3 to June 6, and emphasizes the historical, scientific, philosophical, educational and cultural involvement of the participants of the voyage and of the local population.

The paper concludes with reflections on the prime condition for success of any of the Venus transit expeditions of the past: the weather must cooperate in the first place – not only during the quarter of a day of the transit, but also during the preceding weeks and months in order to allow the explorers to rightly determine their geographic positions and correctly set their clocks. The latter factor is no longer an issue nowadays, but the weather aspect remains today a limiting factor as much as it was 250 years ago.

Despite the variable and partly clouded weather at Vardø during the time of the transit, the participants of this expedition were able to observe Venus in front of the Sun – with interruptions due to quickly moving clouds – between 4.30 a.m. and the fourth contact at 06:53:20 a.m. A large number of impressive, partly 'dramatic' photographs have been taken especially in this time interval.

1. Preamble

Sir David Gill (1842–1914), who served as H. M. astronomer at the Cape of Good Hope from 1879 to 1907, remarked that "A scientific expedition may be said to have two histories . . ."[1] Gill made this observation in the introduction of a book written by his wife Isobel Sarah Gill, née Black (–1920), entitled *Six Months in Ascension.*

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[1] Quoted on page 191.

An Unscientific Account of a Scientific Expedition (Black 1878, p. 130). The book deals with her "unscientific" account of her husband's expedition to the island of Ascension to determine the solar parallax by measuring the parallax of Mars at the opposition of 1860.[2]

Gill's thoughts were reformulated almost one century later by McMullin (1970), who distinguishes two principal senses of "science":

1. either a collection of propositions, i.e., theories, data, and interpretations that he calls S_1, or
2. a second body of information S_2 that he considers as the ensemble of the activities that affect the scientific outcome in any way.

S_2 contains S_1, but is far broader and vaguer than S_1. Evidently, scientists are primarily interested in S_1, whereas S_2 is soon forgotten – except by historians of science.

Non-academic factors can influence science in various ways. When a rare event such as a transit of Venus takes place, low-profiled astronomers might find themselves in the limelight of popular media channels. Historians can find funding to host conferences and get books published that otherwise would be considered too narrow. Indeed, entire populations will sometimes be affected by events that are usually in the domain of the more than average interested academic and/or "nerd", bringing new interchanges between academia and the general public. This is exactly what happened when a party of 11 Tromsø-conference participants of very different education, language and background, traveled together to see the 2012 transit on the Midnight Sun at the unique location of Vardø, where Maximilian Hell carried out his successful measurements in 1769.

This article tells the story of our unscientific expedition whose aim it was to commemorate the scientific expedition of Father Hell, who visited the same region nearly 250 years earlier. In the spirit of Sir Gill's statement, we have undertaken to write the "second story" of our voyage. As such, this paper, as well as the two preceding papers in these Proceedings, exactly deals with S_2. Whereas the scientific merit of ground-based observations of a Venus transit is virtually nil today, the present documentation of our voyage in the global context of the commemoration and re-enactment of historically significant observations – including the interest that such events are capable of raising among the general public – certainly has some scholarly value.

History of science can be important for both local and national identity. Three commemorative plaques on Vardø Town Hall, which is located at the site where Father Hell's observatory once stood, illustrate this quite vividly (see Fig. 1). The lowest one, in Norwegian, explains that

> Upon orders from His Majesty King Christian VII, Maximilian Hell built an observatory at this site in order to study the transit of Venus on June 3, 1769.

This plaque was unveiled during a solemn ceremony led by the vice-mayor of Vardø on June 3, 1979, i.e. exactly 210 years after Hell made his observation (there was only a small settlement, a church and a fortress at Vardø Island in 1769, not yet a proper town). Upper left is a plaque that was set up in 2006 by the *Občianske*

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[2] Her "unscientific" account, though, gives an excellent description of the scientific principles that were at the basis of this voyage.

združenie Maximilián Hell (Maximilian Hell Civic Association), a group of Slovaks traveling by car all the way from Slovakia for this purpose.[3] To the right is a plaque added by the *Norvégiai Magyarok Baráti Köre* (Circle of Friends – Hungarians in Norway) on June 5, 2012. The laurel with a band of Hungarian flag colors was attached on the same occasion. From the name forms (Slovak "Maximilián" and Hungarian "Miksa") one notices that the Jesuit Hell[4] – a child of German-speaking parents who wrote all his works in Latin or German and whose loyalties were with his order, the international republic of letters, the Habsburg dynasty, and the multi-ethnic kingdom of Hungary – is now somewhat anachronistically claimed for several national scientific canons.

Figure 1. Commemorative plates on the façade of the Vardø Town Hall. Photo courtesy Knut Ramleth.

2. The cast

Per Pippin Aspaas (PPA) is an academic librarian at the University Library of Tromsø. He received his degree in Classical Philology at the University of Oslo in 2001 and his PhD in History of Science at the University of Tromsø in 2012. PPA is the author (or co-author) of several articles in English, French, German, Swedish, Finnish and Norwegian on various aspects of early modern science. Since 2010 he is a co-editor of *Sjuttonhundratal: Nordic Yearbook for Eighteenth-Century Studies*. He has recently co-edited a thematic issue on the history of research into the Aurora Borealis (in *Acta Borealia* vol. 29, issue 2, 2012) and an anthology on the history of Travels in the North (forthcoming on Wehrhahn Verlag, 2013).

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[3] See `hell.planetarium.sk/expedicia.php` and `hell.planetarium.sk/expedicia02.php`

[4] Baptized Maximilianus Rudolphus Höll, he changed his surname to Hell at the age of 35 (in 1755), and from then on consistently named himself Maximilianus or Maximilian Hell. See also the discussion in Section 5.3 and Kontler's article in these Proceedings.

David Dunér (DD) is associate professor of history of science and ideas at Lund University, Sweden. In 2010–2011 he was research leader for the research project *Astrobiology: Past, Present and Future* at the Pufendorf Institute for Advanced Studies, Lund University. He currently is a team member of *Centre for Cognitive Semiotics* at Lund University. He obtained his PhD in 2004 with a dissertation on the Swedish natural philosopher and theologian Emanuel Swedenborg. A revised English version *The Natural Philosophy of Emanuel Swedenborg*, was published in 2012 by Springer Verlag. He was guest editor for a special issue of *Astrobiology* (October 2012) on the topic *The History and Philosophy of Astrobiology*, and he is Editor-in-chief of *Sjuttonhundratal: Nordic Yearbook for Eighteenth-Century Studies*. Besides his professional interests, David Dunér is an avid bird watcher.

Päivi Koivisto (PK) is a research scientist at the Technical Research Centre of Finland in Espoo. She received her degree of doctor of science in technology in 1995 from Helsinki University of Technology. Her field of interest is engineering applications of electromagnetic field theory and numerical solutions of inverse problems.

László Kontler (LK) is professor of history at Central European University in Budapest, Hungary. His academic interests focus on intellectual history, especially political and historical thought, intercultural communication and reception, and more recently the history of scientific knowledge production in the early modern period and the Enlightenment. He has written extensively (in English and in Hungarian) on Edmund Burke and William Robertson, on European and Hungarian political thought, on the Enlightenment in European and Central European contexts, and he is the author of *A History of Hungary* (Palgrave Macmillan Publishers 2002).

Detlev Lutz (DL) works as a Team Manager at Allianz Global Assistance, and assists worldwide Allianz and car-industry customers in the event of breakdown or malfunction of their vehicle. At Berlin's Freie Universität he obtained a M.A. degree in communication, politics and law. Astronomy first struck him in 1983, when he – as an exchange-student to the USA – joined William Russel Blacke's astronomy course at the Plymouth-Carver High-School Planetarium in Massachusetts. His first encounter with the Venus-transit phenomenon was thanks to the publication of a novel about Le Gentil's unfortunate journey by his former journalistic teammate Lorenz Schröter. Having missed his first chance for observation in 2004, he gladly joined this group for chasing this year's return of this rare cosmic configuration at the historical location of Vardø.

Reinhard Neul (RN) is senior scientist at Corporate Research of Robert Bosch GmbH in the field of microsystem technology, particularly micromechanical sensors for automotive and consumer electronics applications. He studied electrical engineering and obtained his Ph.D. degree in 1992 in technical cybernetics from the University of Stuttgart. Besides his professional occupation, he enjoys amateur astronomy and, specifically, eclipse chasing. He already had the chance to observe and photograph the entire 2004 transit of Venus at optimal weather conditions from Stuttgart.

Osmo Pekonen (OP) is a Finnish author, mathematician and historian of science. Besides his scientific papers, he has published numerous books in Finnish, for instance a popular science book on the history of the study of the planet Venus (Pekonen 2012). A landmark in humanities is his verse translation (the first ever in Finnish) of the Anglo-Saxon epic Beowulf that he accomplished in collaboration with Clive Tolley (Oxford University). OP wrote one doctoral thesis on differential geometry and another one (in French) on the trip of Pierre Louis Moreau de Maupertuis to Lapland to measure the shape of the Earth in 1736–1737. The latter work received Prix Chaix d'Est Ange of Institut de France in 2012. OP is a corresponding member of four scientific academies in France.

Päivi Maria Pihlaja (PMP) holds a PhD in history at the University of Helsinki (2009). Subjects of interest include history of learning and ideas, in particular research targeted at the northern regions in the eighteenth and nineteenth centuries.

Thomas Posch (TP) is an astronomer, historian of science and writer working at the University of Vienna. He holds a PhD in astronomy and a PhD in philosophy, and participated in the expedition from Tromsø to Vardø primarily because of his interest in Maximilian Hell's 1768–1769 expedition.

Johan Stén (JS) is a research scientist at the Technical Research Centre of Finland (VTT) in Espoo. He received his degree of doctor of science in technology in 1995 from Helsinki University of Technology, where he is a docent in electromagnetic theory specializing in boundary value problems in scattering and radiation. He is also working in the field of history and philosophy of science.

Christiaan Sterken (CS) received his MSc in mathematics at the University of Ghent (1969), his PhD in astronomy at the University of Brussels (1976), and his Habilitation degree at the University of Liège (1988). He is Research Director at the Belgian Fund for Scientific Research, and works at the Department of Physics and Astronomy at the University of Brussels. His principal field of research is the photometry of variable stars (luminous blue variables, massive binaries, pulsating main sequence stars, and cataclysmic variables), and comets. He also teaches courses in observational astronomy, and on the history of natural sciences at the University of Brussels. In 2006 he was accorded the 21st *Sarton Chair for the History of Sciences* at the University of Ghent (Belgium). CS is the Editor of *The Journal of Astronomical Data* (JAD), an Open-Access on-line astronomical journal.

3. The voyage

3.1. Leaving Tromsø, en route for Vardø

On June 3, around 5 p.m., the group boarded the Motor Ship *Lofoten*, a 87-m long vessel (see Fig. 2) built in 1964 in Norway and operated by the Norwegian passenger and freight line *Hurtigruten* on voyages along Norway's western and northern coasts.

The MS *Lofoten* is the most traditional ship of the Coastal Voyage fleet, and is Norway's only floating national historic monument.[5] The ship features cosy wood paneling, shining copper staircase grips, and a command bridge that invites for real marine navigation (see Fig. 3). The voyagers were to stay on board for more than 40 hours, a stay though interrupted by two short excursions on shore (see below, and also Figs. 3–5).

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[5] `http://www.hurtigruten.co.uk/norway/Ships/Hurtigrutens-fleet/MS-Lofoten/`

Figure 2. MS *Lofoten* at the Tromsø wharf. Photo DL.

Figure 3. Command Bridge of MS *Lofoten.* Photo CS.

Figure 4. On board of *Lofoten*: Päivi Koivisto and Johan Stén looking at a Venus transit paper in the Swedish amateur astronomy magazine *Populär Astronomi* (photo OP).

3.2. Stopover at Hammerfest

Around 5 a.m. on June 4, the ship called at the port of Hammerfest, from which a short taxi drive took us to the site of the *Struve Geodetic Arc* monument at Fuglenes. The Arc is a chain of geodetic triangulations stretching from Hammerfest to the Black Sea, covering $25^\circ\ 20'$ (2822 km) and linking more than 250 measuring stations. The survey was carried out between 1816 and 1855 under the direction of the German-born Russian astronomer Friedrich Georg Wilhelm Struve (1793–1864) and Carl Friedrich Tenner (1783–1859) in a large Russian–Scandinavian geodetic measurement enterprise. This allowed Struve to determine the oblateness of the Earth with great precision: $1 : 294.73$ (versus the hitherto accepted value $1 : 302.5$, see Viik & Randjärv 2011). In other words: the *Struve Geodetic Arc* yielded the result that one degree of latitude was 359 meters shorter on the Black Sea than on the coast of the Barents Sea. Figure 6 shows the triangulation scheme in Finnmark.

The entire Arc is a *World Heritage Site* comprised of 40 points of measurement between the Barents Sea and the outlet of the Danube. One of its key monuments is located in Estonia, on the grounds of the old Tartu (Dorpat) Observatory, the first point of the Arc (see Fig. 7, where the meridian of Tartu appears as a vertical line in the middle). The Struve Geodetic Arc was added to the UNESCO World Heritage List in 2005, and became the first technical and scientific object to be accorded this prestigious status.

Figure 5. On board of *Lofoten*. *Top*: Reinhard Neul and Detlev Lutz, *bottom*: Thomas Posch and Detlev Lutz examining the geography of Norway. Photos CS.

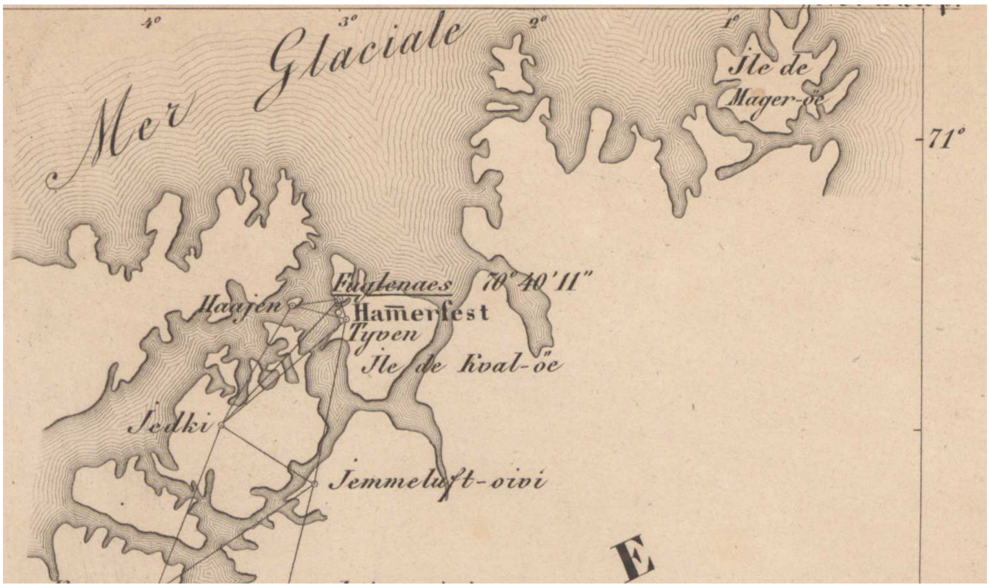

Figure 6. Northernmost triangles of Struve's arc. Source: Struve (1857).

Figure 7. *Left*: the obelisk at Hammerfest is one of the geodetic points of measurement. The inscription reads 70° 40′ 12″ N, 23° 39′ 48″ E (photo CS). *Right*: Geodetic Arc map as displayed on site. Credit: National Land Survey of Finland.

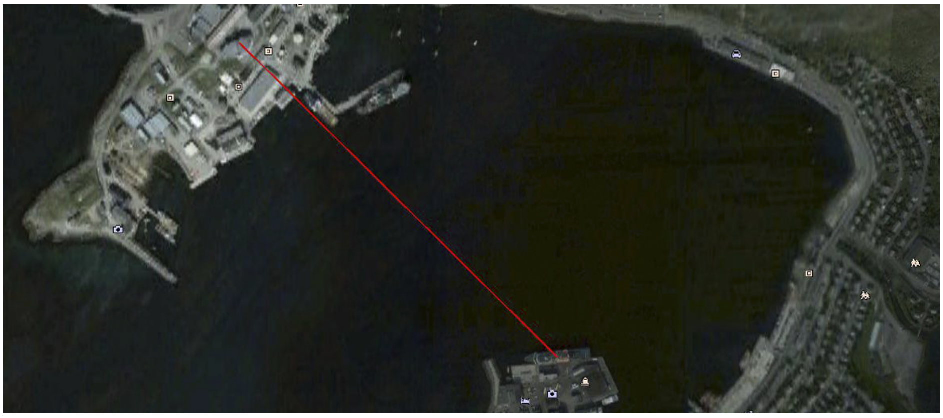

Figure 8. Hammerfest harbor. Location of ship and of obelisk linked by a line of length 840 meter. North is up and East is right. Based on `GoogleEarth`.

The Hammerfest obelisk (Fig. 7) gives the geographic coordinates of the site: 70° 40′ 12″ N, 23° 39′ 48″ E. Figure 8 illustrates the formidable facilities that high-tech navigation puts at our fingertips: the Google-image shows a 123-meter long vessel – probably MS *Nordkapp* or MS *Nordnorge* moored at about the same position as our MS *Lofoten* was that day (70° 39.′899 N, 23° 40.′876 E as recorded from the ship's GPS by CS). Starting from this position on a Google Earth map, the Struve Geodetic Arc monument is located at a distance of 842 m NNW, and its calculated coordinates are 70°40′12.″8 N, 23°39′53.″57 E, thus deviating less than 10 m from the inscription on the obelisk. Early navigators, geodesists and transit of Venus observers, by contrast, needed many days or nights of painstaking observation, calibration, and calculation (hand-based on logarithmic tables), only to determine their geographical position.

Hammerfest has a historical link to Rypeklubben, the site of one of the two northern British Venus transit expeditions (the one led by Jeremiah Dixon), as described by Nils Voje Johansen in these Proceedings.

3.3. Stopover at North Cape (71°10′21″ N)

The North Cape on Magerøya – the northernmost accessible point of the European continent[6] – offers three impressive artistic landmarks, viz.,

1. an array of seven sculptures (Fig. 9) created by boys and girls (aged 8–12 years) from different nations, symbolizing *Peace on Earth*. The nearby monument *Mother and Child* was created by sculptor Eva Rybakken (Oslo),
2. the North Cape *Globe* erected in 1978, to mark this northernmost point,
3. the Obelisk, erected in 1873 by King Oscar II of Norway and Sweden to commemorate his visit to the North Cape (Fig. 10) .

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[6] Actually, the northernmost point is Cape Knivskjellodden; North Cape is located 50″ or about 1.5 km to the south of Knivskjellodden.

We were specially lucky with the weather thanks to a favorable wind. On the guided bus tour, we passed by the area where British observers were stationed in 1769 (see Nils Voje Johansen's paper in these Proceeedings).[7]

Figure 9. *Left*: the *Children of the Earth* monument on the Nordkapp plateau. *Right*: statue of mother and child. Photo CS.

Figure 10. *Left*: Per Pippin Aspaas, Thomas Posch, Reinhard Neul and Detlev Lutz in front of the metallic globe at Nordkapp. *Right*: Reinhard Neul at the hotel window in Vardø, hours before he observed the transit from that location. Photos CS.

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[7] William Bayly's temporary observatory was near Honningsvåg Airport.

Later on the same day we passed by the abandoned settlement Kjelvik, which Father Hell visited twice on his voyage to and from Vardø, on October 3–7, 1768 and July 6–18, 1769, respectively. Thanks to the good weather, we had a very nice view of the village and its surroundings, clearly resembling the perspective on a beautiful copperprint by Maximilian Hell (Fig. 11).

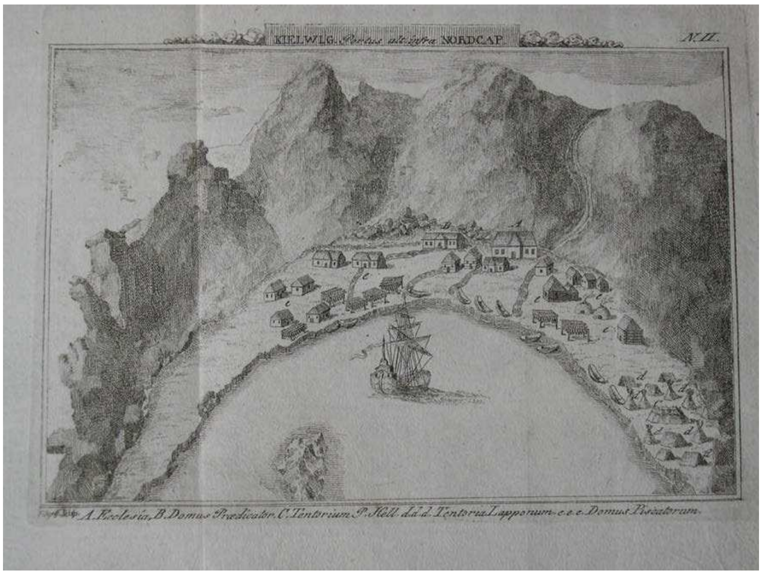

Figure 11. View of Kjelvik. From Hell's *Ephemerides Astronomicae ad Meridianum Vindobonensem Anni 1791* (1790).

4. Vardø

4.1. Arrival at Vardø

According to notes taken by Thomas Posch, our arrival was almost exactly at 4 a.m. on June 5 (i.e., 2 a.m. UT). Our voyage, therefore, had lasted 1.5 days, a duration that may be compared with that of Maximilian Hell and his colleagues from Tromsø to Vardø in 1768 – from September 26 to October 11: 15 days! The sky was completely overcast and there was little evidence for any imminent change of the weather because of the slow motion of the clouds. In fact, it would last almost exactly 24 hours until the Sun would become visible near the end of the transit. The majority of the team shared accommodation at the *Vardø videregående skole*[8], whereas two participants (RN and CS) checked in at the Vardø Hotel.

Norway's easternmost town, now a municipality of approximately 2.200 inhabitants,[9] evolved from a fishing village to a frozen-fish industry after 1945 (Finstad 2004), an industry that replaced traditional home-based fish processing in Vardø.[10] Little is left these days of Vardø's fish-processing industry, and the city's emphasis

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[8] The local high school, see `http://www.vardo.vgs.no/`

[9] The population peaked around 4200 in the 1968–1970, see the population statistics provided by `http://www.ssb.no/folkendrhist`.

[10] Balsvik (1989/2007) pp. 134–136 describes that unmarried daughters, widows and youths prepared the cod for the drying racks, see also Finstad (2004), p. 36.

has shifted towards tourism (in particular attracting birdwatchers to Hornøya and Finnmark County).[11]

4.2. Vardøhus Festning

Vardø is the world's most northern fortress village, and its *Vardøhus Festning* is still in use – although not any more for military purposes: military operational presence is rather concentrated at the nearby US military radar installation operated by the Norwegian army. The first fortress on the site dates back to the early 14th century, and the present fortress dates from 1738. The square compound is surrounded by star shaped fortifications of earth walls, and houses the commander's residence and officer's quarters, powder storehouse, barrack, and prison (see Fig. 12). The fortress also functions as a museum facility, and acts as a flag and salute station.[12]

Figure 12. *Vardøhus Festning.* Photo courtesy Knut Ramleth.

4.3. Witches monument

The late artist Louise Bourgeois (1911–2010) and architect Peter Zumthor designed the *Steilneset Memorial* in Vardø to honor the alleged witches (77 women and 14 men) that were on trial – and even burned at the stake – as a result of the seventeenth-century witch hunts and the ensuing court trials, many of which were conducted at the *Vardøhus Festning*. The monument consists of two parts, of which

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[11] See `www.gonorway.no/norway/counties/finnmark/vardoe/76378bfebb2bf20/index.html`

[12] Historical details and diverse maps and drawings are available at `www.verneplaner.no/?f=vardohus&id=107826&a=4`.

the 100-m Zumthor wood-frame pavilion hides more history-of-science symbolism than any tourist leaflet dares to suggest. Inside the structure, visitors walk through a long corridor with 91 windows, each lit by a dim bulb that shines day and night (see Fig. 13).

Figure 13. Peter Zumthor's *Steilneset Memorial* pavilion, and one of the framed filament bulbs. Photos CS.

Besides the windows are texts displayed on black linen that document, for each individual woman and man, the details of the trial. These texts read as contemporary scientific posters – complete with date, value of the estate of the accused, the accusations, confessions, convictions and outcome of each case. The legal documents recording all the witch trials that took place in seventeenth-century Finnmark have recently been edited and published by Liv Helene Willumsen (2010), see also Willumsen (2011).

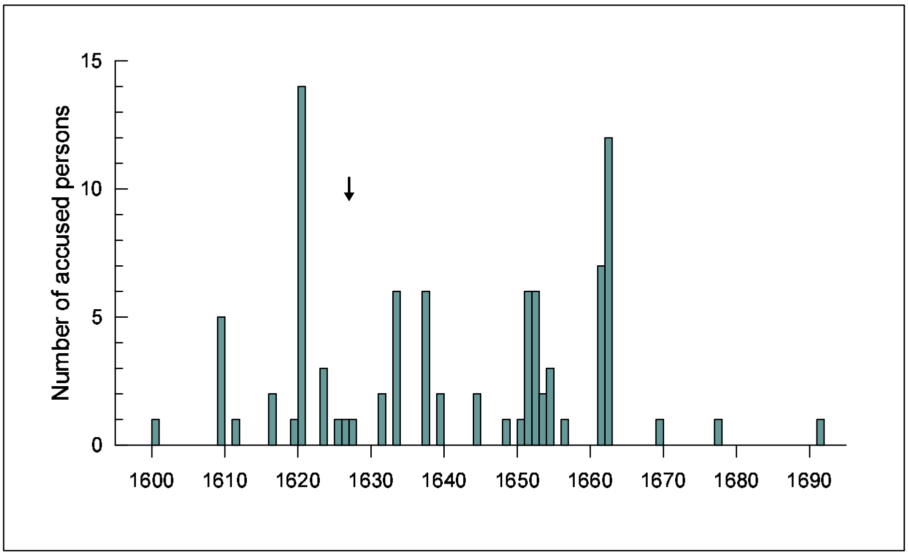

Figure 14. Histogram of number of persons accused of witchcraft as a function of time. The arrow represents the moment of Kepler's predicted first transit of Venus in 1631. Based on data collected at the Vardø *Steilneset Memorial*.

The first point to consider here is that the outcome of each case was very often based on "evidence" that came forth from a water ordeal, i.e., a *Judicium Dei* – a procedure based on the premise that God would help the innocent by performing a miracle on his behalf. Some of the cases are really telling: Anne, Laurits Pedersen's wife, was brought before the court in July 1610, a couple of months after Galileo published his *Sidereus Nuncius*. And Quiwe Baarsen, brought before the court in

May 1627, the year that Kepler published his *Tabulae Rudolphinae* that led to the very first prediction of a transit of Venus.

Figure 14 shows a histogram of the number of persons accused of witchcraft over the time period covered. The arrow represents the moment of Kepler's predicted first transit of Venus in 1631. The distribution is quite uneven, with irregular spells of several years, but also with peaks caused by series of linked witchcraft trials. Also Kepler's mother, Katharina Guldenmann (1546–1622), was accused of witchcraft in 1619 and put to prison one year later.[13]

The lesson to be learned from these facts is that at all times from Antiquity through the Age of Reason and into modern times, a bewildering conjugation of advanced scientific thought can coexist with retarded and brutal beliefs and convictions, and that such lack of insight and education always brings harm to many innocent people. This is true of all times and of all places, and this thought is perhaps the prime essence of the Vardø *Steilneset* monument. The close geographical link with an early-modern successful scientific expedition only illustrates the permanent need for ongoing teaching of the sciences and of their historiography.

Figure 15. Disembarkation at Vardø: David Dunér, Per Pippin Aspaas, Thomas Posch, Christiaan Sterken, Päivi Maria Pihlaja, Osmo Pekonen, Reinhard Neul, László Kontler, Päivi Koivisto and Johan Stén.

5. Living the transit

The Venus Transit Event in Vardø was a huge undertaking, the city being a *lieu de mémoire* for several groups, viz., Finno-Ugrianists, astronomers, historians of science, Catholics (and Jesuits in particular), Slovaks, Hungarians and Austrians, plus the Vardø population themselves.

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[13] Voelkel (1999).

Figure 16. Per Pippin Aspaas (*right*) interviewed by the Norwegian Broadcasting Corporation reporter Per Olav Alvestad (*left*). Photo DL.

Members of the group (the Norwegian-speaking Per Pippin Aspaas and the Swedish-speaking Johan Stén) gave lectures at the local *Kulturhus*. Per Pippin Aspaas also made his debut on National TV for 900 000 spectators during the live program of NRK (Norwegian Broadcasting Corporation), see Fig. 16. Local school teachers explained the transit event to the public, see Fig. 17.

Figure 17. Vardø teacher Steinar Kristiansen explains the transit event to the local populace. The white circular disks are plastic fastfood plates: the rightmost one serves as a projection screen, the left ones are meant to prevent exposing the eye to direct sunlight. Note the low water level: at 00:51 a.m., when this photo was taken, the water level observed at Vardø was 22 cm above the tidal datum to which soundings on a chart are referred, i.e., just above the 2012 minimum of 19 cm (the 2012 maximum was 375 cm, see `http://vannstand.no/`). Photo RN.

Quite a number of official people traveled to Vardø for the transit celebration: several representatives of the churches, of the Norwegian army, and deputy heads of mission of the Austrian and Hungarian Embassies in Oslo (Fig. 18). The transit event was hosted against the background of a series of impressive cultural events.

Figure 18. Mr. Georg Schnetzer (*left*) of the Austrian Embassy in Oslo, and Mr. Tamás Vörös (*right*) of the Embassy of Hungary in Oslo in the lobby of Hotel Vardø. Photo CS.

Figure 19. Elisabeth Eikeland, Commander at Vardøhus Fortress poses in front of the gallery of her predecessors. Photo OP.

5.1. Concert at Vardøhus Fortress

On Tuesday June 5 we were offered a Baroque concert at Vardøhus Fortress under the motto *Where is Venus? A journey into the Habsburg dynasty music*, featuring compositions from the 1750–1830 timeframe. The arias were from Joseph Haydn's opera *Il mondo della luna*[14] (1777). The soprano was Felicia Kaijser, the cembalo was played by Lars Henrik Johansen, and the presentation was by Anne-Lise Berntsen.

5.2. Dinner ceremony

The Mayor of Vardø, Lasse Haughom, hosted a dinner at the Vardø Hotel. The dinner was attended by several dignitaries, among whom Elisabeth Eikeland (Commander Vardøhus Fortress, Fig. 19) and Brigadier John Einar Hynaas (Commander of the History and Tradition Division of the Norwegian Armed Forces),[15] who drank a toast to the health of King Harald V of Norway. The Mayor offered to each country representative a copy of Randi Rønning Balsvik's *Vardø – Grensepost og fiskevær*,[16] a memorial book about the history of Vardø over the time span 1307–2007.

5.3. Religious service

A divine Service of ecumenical character comprising elements of Lutheran and Catholic eucharistic liturgy was conducted at the Vardø church. One of the participating priests was of Hungarian origin: Reverend János Kona is a Lutheran priest who settled in Northern Norway at Tana, a neighboring parish. The priest who gave the sermon was Catholic, and of Polish origin: Pater Dariuz Banasiak, O. Cist., superior of the Cistercian Monastery of Our Lady Queen of the Fjords, based in the Lofoten islands in Northern Norway. Rev. Cato Torsvik, the local Norwegian Lutheran priest, presided the service, which appropriately included a *Te Deum*, just as in 1769.

The music was mainly performed by *Vardø Bymusikk*, the local orchestra. Some of the music was profane, including *Bunch o'bones, Twinkling Flutes* and *Bugler's Holiday*. During the night, the same band played many other pieces, and marched in the street playing the *Transit of Venus March* by John Philip Sousa (Fig. 20).

The service emphasized the Hungarian origin of János Sajnovics and possibly also of Maximilian Hell. The Hungarian deputy head of mission Tamás Vörös spoke nicely, recalling the information from Sajnovics' work *Demonstratio Idioma Ungarorum et Lapponum idem esse*,[17] that the two Jesuits were able to recognize the Finno-Ugrian language relationship when hearing one of the local inhabitants reciting the Lord's Prayer. Besides astronomy, Hell and Sajnovics also engaged in the empirical study of the Lappish (Sami) language and confirmed earlier theories of its relationship with Hungarian, thereby seriously contributing to the development of

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[14] *The World on the Moon*, which features "the star Hesperus": in Greek mythology, Hesperus (in Ancient Greek Hesperos) is the Evening Star, the planet Venus in the evening.

[15] *Forsvarets avdeling for kultur og tradisjon.*

[16] *Vardø, borderpost or fishing village*, (1989/2007).

[17] Sajnovics (1770), pp. 14–15. This quotation actually refers to Maursund in present-day Troms County, and Sajnovics explicitly categorizes the reciter of the *Pater Noster* as a Carelian (i.e. Finnish) immigrant, not as a Sami native. Moreover, the episode is not even mentioned in the diary or in any of the numerous letters that Hell and Sajnovics wrote while in Vardø. It is only recorded in Sajnovics' treatise, which was written in Copenhagen about a year and a half after the visit to Maursund.

Figure 20. *Left*: *Vardø Bymusikk* performing. *Right*: Thomas Posch setting up his equipment. Vardø church in the background. Photos OP.

comparative Finno-Ugric linguistics. For linguists, Sajnovics is mainly known for his *Demonstratio* in which he addressed the topic (see the text on the white plaque in Fig. 1). He even launched a language reform, trying to introduce Sami words into Hungarian (see Kontler, in these Proceedings).

Venuspassasjen 6. juni 2012

Venuspassasjen
VARDØ 6.6.2012

Norges første astronomiske observatorium,
bygget i Vardø og brukt av
Pater Maximilian Hell
under Venuspassasjen i 1769

VARDØ FRIMERKEKLUBB

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Figure 21. First day of issue cover commemorating the 2012 transit. Courtesy Steinar Borch Jensen.

5.4. The transit proper

A party tent had been erected on the place where Hell carried out his observations, i.e., the location of the present town hall, 70°22′15″ N, 31°06′26″ E.[18] Artillery

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[18] These GPS coordinates should not be directly compared to Hell's coordinates, because the latter refer to the plumb line and the local meridian, whereas the GPS data refer to the geoid model.

salutes were fired from Vardøhus Fortress at the beginning (and at the end) of the transit,[19] but the main problem was that the sky was totally overcast, with not even a glimpse of the Midnight Sun. Fortunately, the weather in Tromsø was splendid (see Thorvaldsen's paper in these Proceedings) and we could enjoy the view on a giant TV screen (Fig. 22). The bad weather persisted for several hours, and when the majority of local inhabitants had chosen to return home, only a dozen of hard-core Venus-watchers kept vigil. Between 04:30 and 04:40, the Sun and Venus became visible through the heavy clouds, but to our disappointment, this short phase was followed by total obscuration, and even light rainfall at 05:04 a.m.

Figure 22. László Kontler, Päivi Maria Pihlaja, Reinhard Neul, David Dunér, Detlev Lutz, Osmo Pekonen and Per Pippin Aspaas looking in awe at the beautiful transit pictures broadcasted from Tromsø. Photo CS.

To illustrate the intensity of desperation, the following anecdote is worth telling. Around 03:30, Thomas Posch and Chris Sterken were looking for the other team members who had somehow disappeared, when the latter said that, from his life-long experience as an observer, it would just suffice to go to bed in order to see clear skies at wakeup. Thomas begged "Chris, you are the oldest, thus you should sacrifice yourself, please go to bed". CS thus went for an alarm-clock assisted nap, and his belief system worked wonderfully well: the weather slightly improved around 5:30 – about 1.5 hours before egress – and Osmo Pekonen alerted the team lodged at the school (Fig. 23) and the positions indicated in Fig. 24 were taken. Osmo and Thomas walked from location O2 to place O3 between 05:04 and 05:25 a.m., and observed from there until the transit was entirely over. Thomas used viewing and imaging equipment, viz., a Canon EOS 550D digital camera (crop factor 1.6), a Canon EF 70-300mm 1:4.0–5.6 IS USM (used at $f = 300$ mm, corresponding to $f = 480$ mm due to crop factor) telelens, and a Carl Zeiss Mirotar T* 500 mm 1:8.0 (corresponding to $f = 800$ mm due to crop factor).

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[19] That is, at $00^{\rm h}04^{\rm m}51^{\rm h}$ and $06^{\rm s}53^{\rm m}20^{\rm s}$ (GMT +2), respectively.

Figure 23. The very first minutes of actual observations of the transit: Per Pippin Aspaas, Päivi Maria Pihlaja, Osmo Pekonen, Johan Stén, Thomas Posch, and David Dunér. Per Pippin Aspaas and Osmo Pekonen are wearing the official T-shirts created for the event. Photo LK.

The most comfortable observing position, no doubt, was Reinhard Neul's (Figs. 10 and 25). As there were only thick clouds and no Sun visible from the beginning of the transit at midnight until 4 a.m., he decided to go to bed and set up the alarm clock at 5 and at 6. At 5 the sky was still completely covered, but before the alarm clock rang at 6, he woke up due to sunrays breaking through the windows. The sudden clearing of the patch of sky around the Sun confronted him with a dilemma: either move the equipment outside, and risk that viewing would be over by the time that the equipment was set up, or just "shoot" Venus from the hotel window. The latter option proved to be the better, and in so doing the situation already experienced in 1761 at the Copenhagen Rundetårn by the brothers Christian and Peder Horrebow – when "the phenomenon was already over"[20] by the time Peder Horrebow had finished the setup, was avoided.

Reinhard Neul used a telescope from William Optics, USA, with an apochromatic triplet lens made of SD glass by Lomo in Russia (aperture 80 mm and focal length 600 mm). The focal length was extended with an apochromatic Barlow lens: the Flat Field Converter from Baader Planetarium in Germany, which uses fluorite (CaF_2) as optical elements. As such, the effective focal length reaches about 1450 mm, large enough to fill the frame of the used DLSR Canon 1000D APS-C size sensor. For observing the Sun, he mostly applied a self-made filter using Baader AstroSolar film with density ND 5. He had tested the whole setup of the telescope in the hotel room the evening before the transit. The time recorded by his camera clock[21] had been synchronized in Stuttgart with a radio controlled clock just before his departure, and was verified after returning home: the clock ran one second late in about one week.

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[20] Translation taken from Aspaas (2012), p. 273.

[21] Central European Summer Time MESZ = UTC + 2.

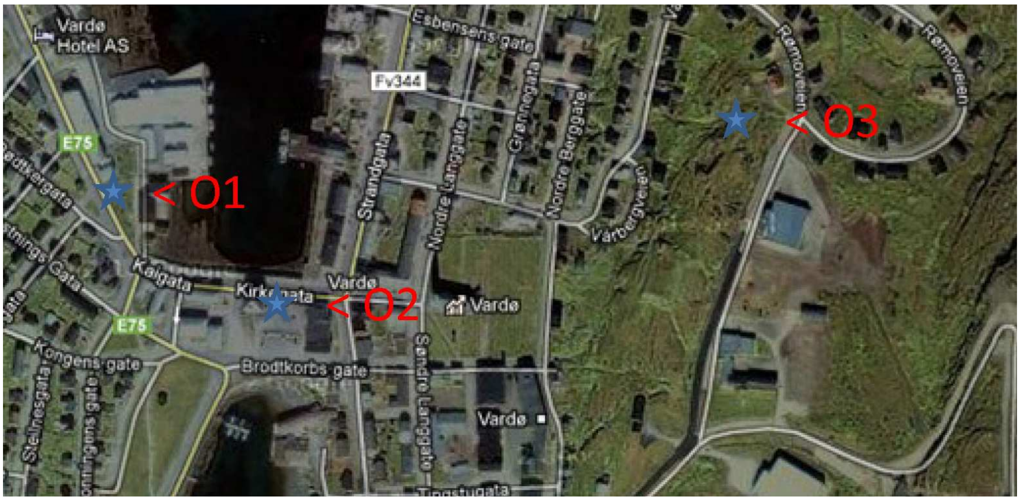

Figure 24. Map with observing locations prepared by TP. O1: PPA, DD, PK, LK, OP, PMP, TP and JS from 04:30 local (summer) time to 05:03. This position is very close to Hotel Vardø where RN and CS observed from around 5 a.m. till the end of the transit. O2: Original observing place of Maximilian Hell in 1769, and observing place of the successful and patient local observer Kai-Egil Evjen. O3: OP and TP from 05:25 until the end of the transit, location ~ 560 m East of Hotel Vardø.

Figure 25. Reinhard Neul's observing room at Hotel Vardø. Note the heavy books (Balsvik 1989/2007) that helped to stabilize the telescope mount. Photo RN.

Figure 26 shows the Venus trajectory across the solar disk in equatorial coordinates[22] and in altazimuth coordinates (azimuth and elevation)[23]. The calculated

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[22] Geocentric right ascension and declination – a coordinate system that refers to the celestial equator – derived from the orbital elements of the Sun and Venus at intervals of 1 minute in time.

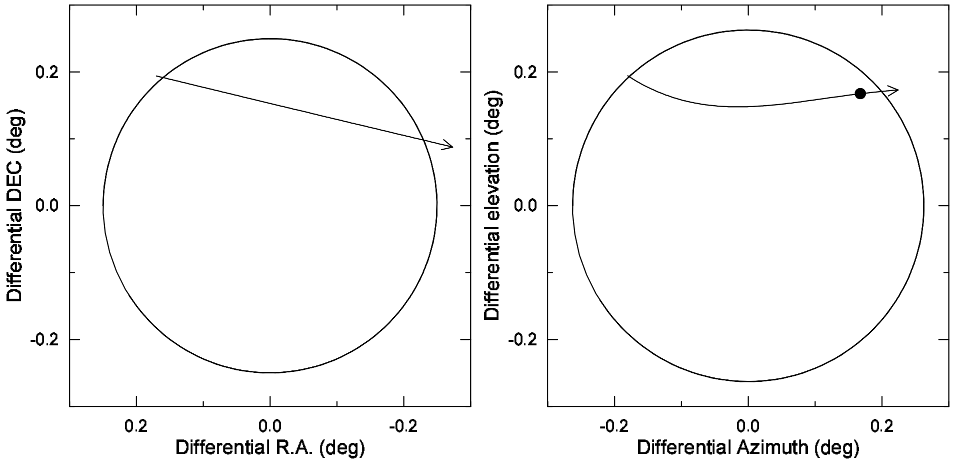

Figure 26. Venus trajectory across the solar disk. *Left*: trajectory in right ascension – declination (North is up and East is left). *Right*: the curved line is the trajectory as was to be seen in Vardø (North is up and West is left); the black dot represents Venus at 06:05:45 local time when Reinhard Neul took the picture shown in Fig. 28.

angular diameter of the Sun on June 6 was 31′.5, and Venus had an apparent diameter of 57″.8, and also the path of Venus as it was to be seen in Vardø. Figure 27 is a polar diagram showing azimuth and height (elevation above horizon) of the Sun on June 5–6. The thick segment represents that part of the trajectory during which Venus was on the solar disk for an observer at Vardø.

The Vardø observers missed the crucial stages of exterior and interior contacts at ingress, and also the exterior contact at egress, the Alta observers saw both ingress contacts, but entirely missed the egress, whereas the Tromsø observers got it all. The worst off was Detlev Lutz, who saw the clearing around the Sun when boarding the delayed *Hurtigruten* vessel *Midnattsol*. Once on deck, the Sun disappeared again only to reappear for one rare moment when he was looking from the inside of the upper deck, but the automatic window-cleaning destroyed all hopes for him to really spot the transit: Detlev's bad luck was almost worse than Le Gentil's in 1769.

Not to mention the Dutch visitor Steven van Roode,[24] who traveled from Vardø to Vadsø during the night, hoping for better weather because webcams had indicated partly blue skies over Vadsø during the time when we had bad weather in Vardø. Therefore, Thomas Posch even considered to leave Vardø for Vadsø together with Steven, but in the end he decided not to pursue that idea. As it turned out, it did clear up a bit in Vadsø towards the morning, but not enough to see the last phase of the transit, so van Roode deeply regretted having left Vardø.[25]

Figure 28 shows two images taken by Reinhard Neul (at 06:05:45 MESZ) and by Thomas Posch. A keen observer will notice the basic difference between the

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[23] Azimuth and height were derived from right ascension and declination using transformation formulae from spherical astronomy.

[24] Editor of the website `www.transitofvenus.nl`

[25] van Roode (2012).

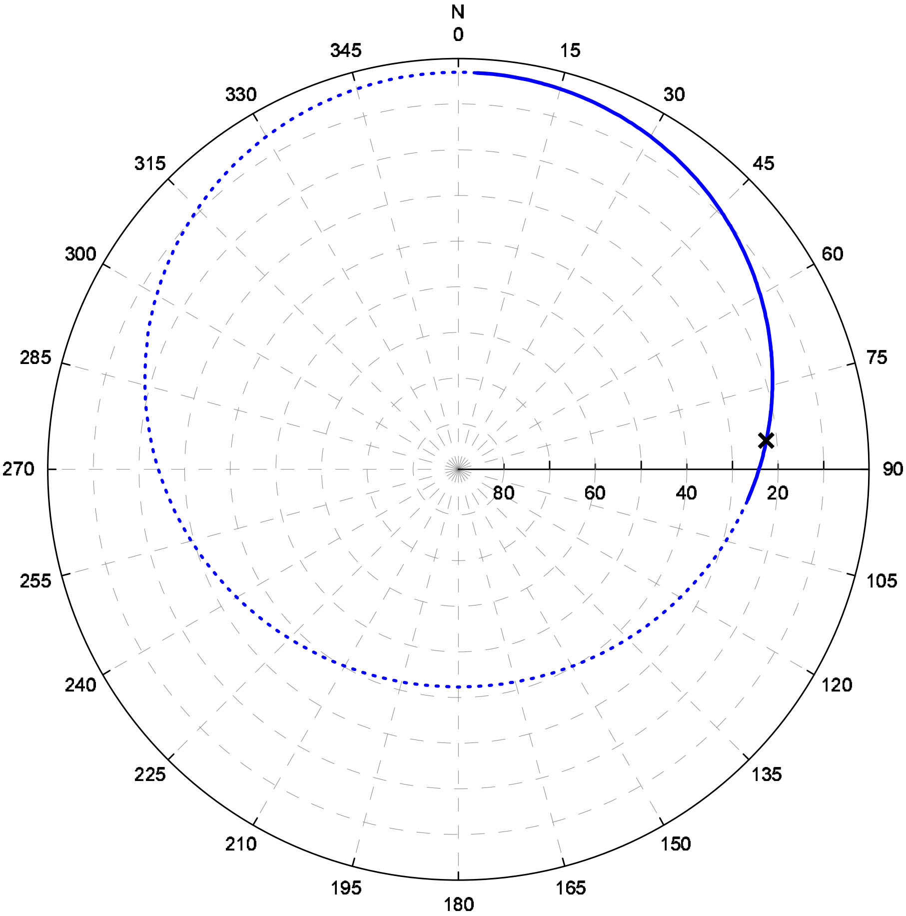

Figure 27. Venus trajectory across the solar disk: polar diagram with azimuth 0–360° (north is at top, the azimuth circle represents the local horizon), and height (elevation above horizon) is indicated along the radius axis. The dashed curve represents the trajectory of the Sun from 5:00 p.m. on June 5 till 5:00 p.m. on June 6. The thick segment represents that part of the trajectory during which Venus was on the solar disk for an observer at Vardø. The × symbol corresponds to the position of Venus at 06:05:45 MESZ (Fig. 28).

two pictures (except for the clouds): Neul used an equatorial mount,[26] whereas Posch used an altazimuth telescope mount (see Fig. 20). Comparison of both photographs using the positions of the sunspots reveals a rotation around the center of the field of view. This phenomenon, known as *Field Rotation*, arises from the fact that altazimuth telescope mounts are always aligned with respect to the local horizon with the camera always in the same position during a sequence of exposures. Human vision is also affected by this rotation, although we are not aware of this. The effect is dramatically illustrated in the movie of Misch & Sheehan (2004), that is based on photographic plates collected with a photoheliograph by David P. Todd at the 1882 Venus transit.

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[26] He aligned the polar axis as well as possible considering the local facilities, i.e., the axis of the mount was not star-adjusted but was aligned only by using a compass and an inclinometer, hence this photograph may also reveal an absolutely minor rotation effect.

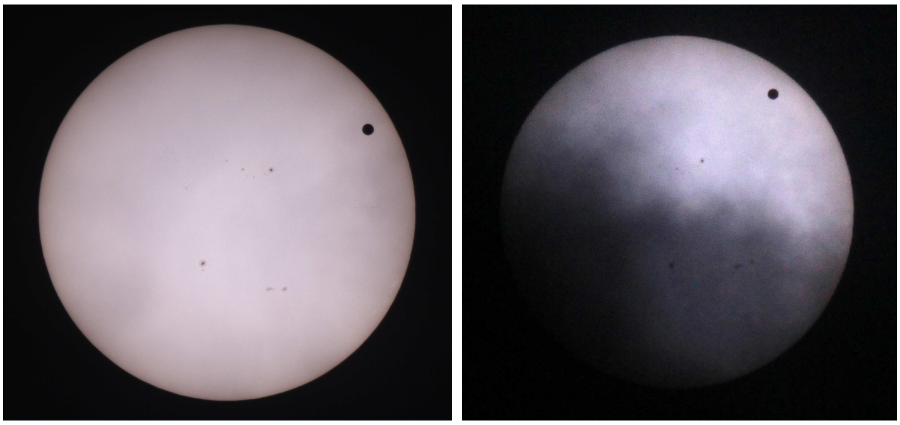

Figure 28. Venus in transit. *Left*: photo Reinhard Neul. *Right*: photo Thomas Posch.

But even if weather had been cooperative, the differences in latitude and longitude between Tromsø and Vardø (a distance less than 500 km as the crow flies) would of course never yield an acceptable estimate of the solar parallax.

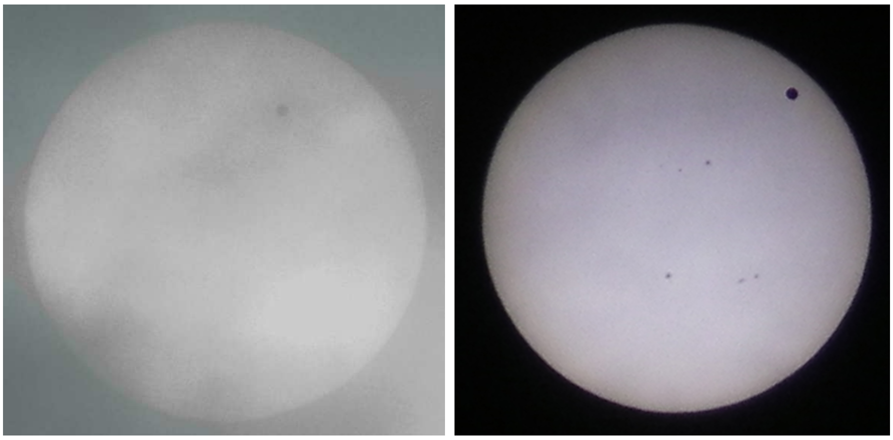

Figure 29. Venus in transit. *Left*: very first glimpse of the transit at 04:32:02, photo courtesy Kai-Egil Evjen (taken with a Sony A350 camera and a Minolta 300-mm APO/f2.8 lens). *Right*: photo courtesy François Moreau (taken at 06:10 a.m. through a density 5.0 filter with a Sanyo VPC-HD2000 digital camera mounted on an altazimuth tripod.

6. Departure from Vardø

In the early afternoon of June 6 the entire party left Vardø by plane and traveled back to Tromsø, where some of the participants continued their trip home the next morning (Figs. 30 and 31).

7. Closing remarks

The description of the Vardø weather conditions, in combination with the descriptions in the papers by Ratier and by Thorvaldsen in these Proceedings, vividly illus-

Figure 30. David Dunér and Chris Sterken board a Widerøe plane at Vardø airport. Photo RN.

Figure 31. Suzanne Débarbat admiring Reinhard Neul's imaging equipment at Tromsø airport. Photo CS.

trates the extreme impact of the weather on the outcome of a scientific enterprise of the magnitude of a Venus transit expedition today – despite our real-time weather evolution reports – and even more so in the past. The history of the pursuit of the Earth–Sun distance by the transit method is littered by laments of numerous desperate observers. One of Maximilian Hell's letters, for example, contains a telling note on the weather at Vardø in particular:

> [. . .] I got my observatory ready to the extent that if the weather permits it, I will be able to make the necessary observations; however, the sky here at Vardø is truly not suitable for any astronomer. [. . .] Since the 19th of November, when we saw the Sun for the last time, I could see the Moon and the stars only twice, and only through clouds, while during all the other days and nights, the sky looked so dark that one should believe the Sun, Moon, Planets and Stars to be no longer in the sky at all, or else ourselves not to be on the Earth any longer.[27]

Sajnovics' travel diary gives an idea of the suspense felt during the crucial moments of observation (here referring to the solar eclipse occurring the day after the transit):

> *4th [June], Sunday the 3rd after Pentecost.* After mass for the Holy Trinity, the corresponding altitudes were recorded in the clearest of skies, with some wind from the North. During these operations, at 10:09 [a.m.] according to the Copenhagen clock, the eclipse of the Sun was noted to begin. Honourable Father Hell observed this moment; and I too observed the end. Then the meridian was recorded, and after lunch the corresponding altitudes of the Sun. As I take down the last of these altitudes, suddenly the entire sky is completely filled by the thickest of fog, falling down to the ground like dew or drizzle, covering everything in a darkness that is likely to last for a very long time. How bad if it had been like this yesterday![28]

It appears that really a miracle is needed, and this is what Sajnovics literally expressed to Father Splényi[29] in Tyrnavia, dated Vardø June 6, 1769, and quoted by Aspaas (2012) p. 306:

> I for my part will cherish the magnitude of this miracle for as long as I live.

In 1769 Jacques-André Mallet and Jean-Louis Pictet also experienced overcast skies at their sites on the Kola Peninsula: Pictet could not see anything at all, whereas Mallet could observe part of the ingress. They shared this fate with other observers in northern Europe (Aspaas 2012, and references therein).[30] In the same

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[27] *mein observatorium habe ich so weit in stande, daß wenn es der him[m]el zu lassen wird, meine [nöthige] observationes [werde] machen können, allein der him[m]el, der [hiesige] Wardöer him[m]el, dieser ist in wahrheit für keinen Astronom. [. . .] in wahrheit seit dem 19ten November da wir die Sonne das letztemahl sahen, sahe ich den Mond und [die] Sterne nur zwei mahl, und diese nur durch die wolken, alle übrige täge und nächte sichet der him[m]el so finster aus, das mann glauben sollte Sonne, Monde, Planeten und Sterne seyen nicht mehr am him[m]el, oder wir selbsten wären nicht mehr auf Erden [. . .]* Translated by Thomas Posch, from a letter from Maximilian Hell to the County Prefect of Finnmark Eiler Hagerup in Talvik, dated Vardø 27 December 1768.

[28] Translation from Aspaas (2012) p. 305.

[29] Probably Ferenc Xavér Splényi (1731–1795), Bishop of Vác 1787–1795.

[30] It should be mentioned, however, that Anders Planman got excellent observations of both contacts at ingress in Kajaani. He also recorded the exterior contact at egress, though during less favorable weather conditions. Furthermore Stepan Rumovskii, along with two assistants, got quite accurate observations from Kola town. However, they made these observations through a thin layer of cloud, a circumstance which seems to have made Rumovskii doubtful regarding the accuracy of his observations. A Danish team led by Peder Horrebow at Dønnes in Nord-

year 1769, the secretary of the Danish Society of Sciences Henrik Hielmstierne wrote to his colleague Johann Albrecht Euler in Saint Petersburg that Danish efforts to observe the transit of Venus from the Round Tower in Copenhagen, from the nearby Frederiksberg Palace, as well as from Trondheim and Nordland County in Norway

> [. . .] have met with the same fate as that of the Englishmen situated at Nordkapp, as well as the Dutchmen, Germans, etc: either the sky has been cloudy or the light of the Sun has been too feeble for one to expect much from their observations; but, on the other hand, Professor Hill [sic] has had the best sunshine one could have hoped for; the acknowledged talents of this observer will guarantee the exactitude of his observations; we expect him to arrive here in two or three weeks, he will not hesitate to publish his findings and I shall not neglect to send them to You, in the meantime I have the honor to remain [etc.][31]

Lomb (2011) gives multiple examples of failures of nineteenth-century British and French expeditions. And Jean-Charles Houzeau also had his share of bad-weather luck in 1882 when he lost about half of the transit at "his" Texas observing station, whereas his colleagues in Santiago de Chile had splendid weather (see Sterken in these Proceedings).

Mrs Gill concludes in her book (Black 1878) that

> If any one desires to form an adequate idea of the difficulties of measuring the Sun's distance to a million of miles, *let him try to measure the thickness of a florin-piece, looked at, edge on, a mile off.*

This is a fair statement about the cutting-edge technology that is needed to succeed. That is, when the weather cooperates – not only during the quarter of the day of a transit, but in the preceding weeks and months so that the explorers could rightly determine their geographic positions and correctly set their clocks. The latter factor is no longer an issue today, but the weather aspect, as Fig. 32 vividly shows, remains a limiting factor as much as it was 250 years ago.

Nothing of this is surprising of course: in 1764 Nevil Maskelyne wrote of his experiences on Saint Helena in the southern Atlantic (Maskelyne 1764):

> The almost continual cloudiness of the skies, at the Island of St. Helena, renders it a very inconvenient place for the making of astronomical observations, which I had the mortification to experience in losing the fight of the exit of the planet Venus, from the sun's disc, on the 6th of June 1761, to observe which was the primary motive of my going thither.

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land Country only caught glimpses of the phenomenon; the Sun was totally covered by clouds during both ingress and egress. Swedish observers stationed at Pello (Fr. Mallet) and Torneå (Hellant) could not record any of the contacts of Venus with the limb of the Sun due to bad weather (see Widmalm and Pekonen, these Proceedings). Finally, the British observers Bayly and Dixon had similar problems in Honningsvåg and Hammerfest (see Voje Johansen, these Proceedings). No wonder Hell and Sajnovics considered their luck a miracle!

[31] Hielmstierne to Euler, dated Copenhagen September 23, 1769, Translation from Aspaas (2012) pp. 260–261.

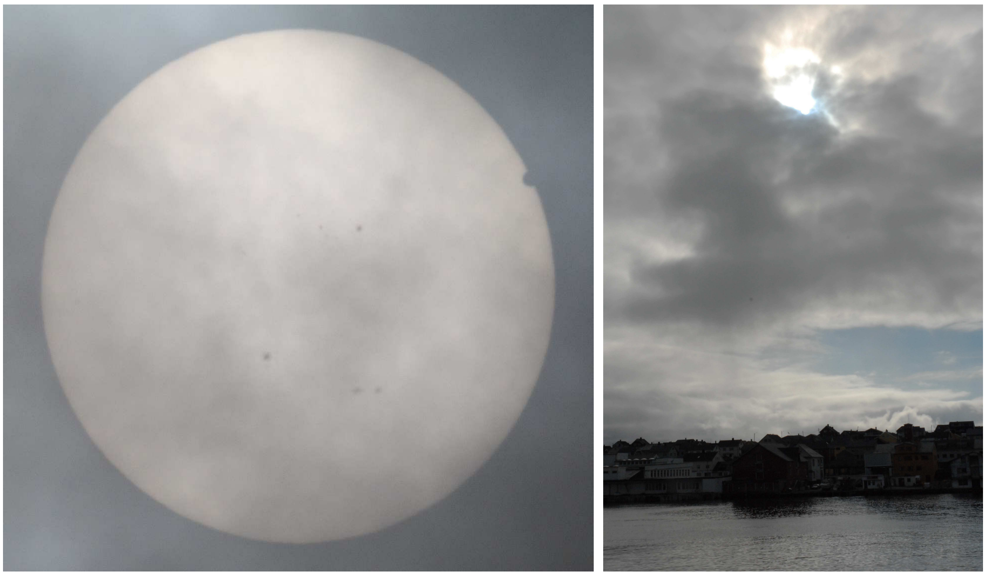

Figure 32. *Left*: last view of Venus on the Sun for more than a century to come. Photo RN. *Right*: simultaneously acquired view of the Sun above Vardø harbor. Photo CS.

Acknowledgments

The authors thank co-voyagers Päivi Koivisto, Detlev Lutz, Päivi Maria Pihlaja, Johan Carl-Erik Stén for interesting company during the entire trip. We thank Steven van Roode, Steinar Kristiansen and François Moreau for interesting discussions.

We express gratitude to Steinar Borch Jensen, librarian of the *Vardø videregående skole*, for donating a first-day of issue cover commemorating the 2012 transit, to former archivist of Vardø Municipality Oddfrid Heen for unearthing evidence on the plaques commemorating Maximilian Hell's expedition, and to Kai-Egil Evjen, François Moreau and Knut Ramleth for permission to reproduce their photographs. Last but not least, we thank the organizing committee, in particular Commander Elisabeth Eikeland, for inviting us to participate in the memorable festivities in Vardø.

We dedicate this account of our voyage to the people of Vardø.

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LEAVES OF MEMORY

Were a star quench’d on high,
For ages would its light,
Still travelling downward from the sky
Shine on our mortal sight.

So when a great man dies,
For years beyond our ken,
The light he leaves behind him lies
Upon the paths of men.

Henry Wadsworth Longfellow
American poet, 1874

MEETING VENUS
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Hilmar W. Duerbeck: Leaves of Memory

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Abstract. This paper pays tribute to the memory of Hilmar W. Duerbeck, who was scheduled as one of the conference keynote speakers, but unexpectedly passed away in January 2012. The eulogy is set in the context of Hilmar's profound interest in the history of the transit of Venus expeditions.

Preamble

It is my sad duty to record here a few of my memories of a very lovely person who should have been with us in Tromsø and Vardø, but who passed away suddenly and unexpectedly on January 5, 2012. This short paper is meant to evoke the memory to the very special person and scientist that Hilmar Duerbeck was.

The title of this paper directly refers to the paper *Some notes on Leaves of Memory* by Vollmer, Vollmer & Duerbeck (2004) that briefly describes and illustrates the life of the blind astronomer Hermann Kobold (1858–1942) as it was published in his autobiography (Kobold 2004), the edition of which heavily profited from Hilmar's able capacities as a proofreader and Editor. Kobold, before he went blind, did work for the German Venus Transit Commission in Berlin (1883–1886), and he was one of the four expedition members of the 1882 Venus transit expedition to Aiken, South Carolina (see Fig. 1). He also used the heliometer of the Venus transit expeditions to measure the solar diameter over many years.

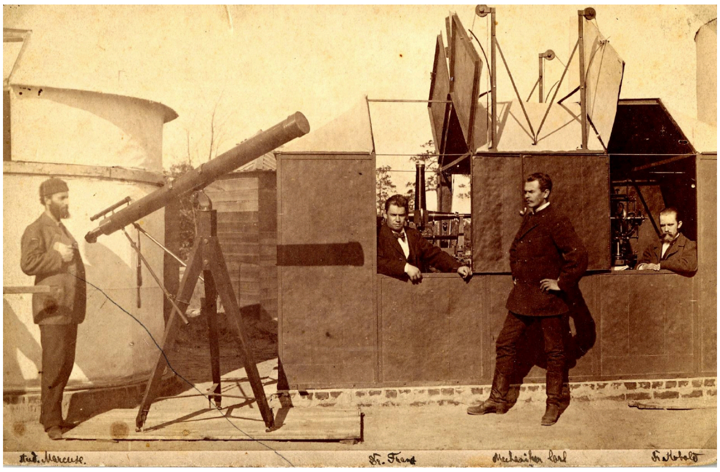

Figure 1. The observing station of the German expedition to observe the Venus transit in Aiken, South Carolina, 1882. Kobold is the rightmost person in the picture. Source: Vollmer, Vollmer & Duerbeck (2004).

The title of Kobold's paper reminisces of two lines in Henry Wadsworth Longfellow's seashore poem *The Fire of Drift-wood*, viz., *"The leaves of memory seemed to make // A mournful rustling in the dark"*. The allegory for burning driftwood – wood that has been washed onto a shore or beach, often from shipwreck – here refers to Hilmar's lost scientific heritage, see the closing sentences of this paper.

The next Section offers a short obituary (based on Sterken et al. 2012), and the rest of this paper gives some historical information about Hilmar Duerbeck and his commitment to Venus and her transits over the solar disk.

1. Obituary

Born in 1948 in Klarenthal (near Saarbrücken in Germany), Hilmar Duerbeck studied physics from 1966 to 1969 at the Universität des Saarlandes (University of the Saarland) in Saarbrücken. He then moved to study astronomy and physics at Bonn University, where he graduated in 1972 with a thesis entitled *Astronomical observations with a photoelectric area photometer*. In 1974 he obtained his Ph.D. with a dissertation on *The eclipsing binary VV Orionis*. From 1975 to 1985 he served as a Scientific Assistant at the Hoher List Observatory in Germany, and during the same period he was astronomy Lecturer for the European Division of the University of Maryland in Germany. During that period he obtained his Habilitation in astronomy from Bonn University with a dissertation entitled *Eruptive variables – observations, analyses, models*.

From 1985 to 1991 he was a Lecturer in astronomy at the University of Münster, Germany, and from 1996 on he was an honorary Professor at the same university. From 1994 Hilmar occupied various educational and research positions abroad: Exchange Professor at the Universidad Católica de Chile in Santiago and at the Universidad Católica del Norte in Antofagasta (Chile). He was repeatedly Senior Visiting Scientist at the European Southern Observatory in Chile, and at the Space Telescope Science Institute in Baltimore, USA. For more than a decade he was Senior Scientific Collaborator at the Vrije Universiteit in Brussels Belgium, and a couple of years ago he was appointed as an Adjunct Professor at James Cook University in Australia.

Hilmar was a member of several international organisations, including the International Astronomical Union and the Historical Astronomy Division of the American Astronomical Society. He served on numerous panels and commissions (e.g., the Hubble Space Telescope and the International Ultraviolet Explorer), and he served on scientific organizing committees of IAU Colloquia and other meetings. From 2003 on he also was Secretary of the *Arbeitskreis für Astronomiegeschichte* of the *Astronomische Gesellschaft* in Germany.

He was an expert on novae, nova remnants and supernovae, and on cataclysmic variables and flare stars. His best-known papers are catalogues and atlases of eruptive stars. He was also a keen observer: for example, in 1975 he visually noticed Nova Cygni (V 1500 Cyg) at declination $+48^\circ$ from ESO La Silla Observatory located at -30° latitude, and promptly secured sequences of crucial spectrograms.

Hilmar was a highly prolific writer (the SAO/NASA Astrophysics Data System[1] lists more than 450 entries), and a very active editor: he was a member of the Editorial Board of the *Information Bulletin on Variable Stars* (Budapest, Hungary) and of the Editorial Board of the book series *Acta Historica Astronomiae* (Frankfurt,

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[1] `http://adsabs.harvard.edu/abstract_service.html`

Germany). As Associate Editor of the *Journal of Astronomical History and Heritage* (James Cook University, Australia), and as Co-Editor of the *Journal of Astronomical Data* (University of Brussels, Belgium), he helped and coached many authors.

From 1975 until her death in 2007 Hilmar was married to astronomer Waltraut Carola Seitter. Hilmar died suddenly and unexpectedly on Thursday, January 5, 2012 at his home in Schalkenmehren, Germany.

2. The IAU Transits of Venus Working Group

At the 2000 General Assembly of the International Astronomical Union in Manchester, the following Resolution was adopted at the Commission 41 Business Meeting:

> Recognizing the historical importance of previous transits of Venus and the numerous transit of Venus expeditions mounted by various countries, and
>
> Noting the rarity of the upcoming transits in 2004 and 2012,
>
> Commission 41 Recommends that the sites of previous transit of Venus expeditions be inventoried, marked and preserved, as well as instrumentation and documents associated with these expeditions.

In order to take this Resolution forward, a *Transits of Venus Working Group* was formed, with the additional aims of assembling a bibliography of existing publications relating to all transits of Venus, and encouraging colleagues to carry out further research and to publish their results. Hilmar Duerbeck has been Chair of this Working Group from 2009 till his untimely death.

3. The place of Venus in Hilmar Duerbeck's life

Venus had become a standard in his daily life, which had become quite stressful because of the health situation of his wife Waltraut Seitter. On April 2, 2004 he wrote to me:

> If you permit some personal note, ...I really cannot concentrate too much. So I don't know exactly how to handle all these trips and talks that are piling up before June 8...[2]

On July 19, 2004, the day after he had been urged to depart from a workshop that we organised in Brussels (see Sterken 2005) because of Waltraut's health condition, he wrote

> I don't know when you will have a chance to read this; I just want to say that we arrived home safely this morning at around 5 am, with some fog between Verviers and Schalkenmehren, but also a nice view of Venus (first time after the transit).

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[2] i.e., the June 8, 2004 Transit of Venus

My response the next day was very telegraphic "I am in Vienna observatory enjoying Hell's original notes on the infamous ToV data 'handling'. Frankly, I will need more time before understanding Newcomb's arguments."

Hilmar took a keen professional interest in two particular aspects of the Venus transits, viz.,

1. compiling the ultimate transit of Venus bibliography, and
2. documenting the German transit expeditions of 1874 and 1882 (see, for example, Duerbeck 2003a, 2003b, 2003c), for which he did not restrict himself to researching archives in Germany (mostly Berlin and Leipzig), but he also actively guided people overseas to recover architectural remains of these expeditions.

About the latter point, he sent me some interesting information via forwarded email. On June 2, 2004 he wrote to Pouria Nazmei[3]:

> I looked at your photos and it could be that this is the bench or foundations of the largest instrument, the photoheliograph. According to the description in the German records, on the surface of the bench was the writing "Deutsche Venus-Expedition" (or German Venus expedition). Do you think that this inscription can be hidden below the sand and stones that cover the bench?
>
> If you find this inscription, or at least parts of it, it would really be a "Cultural Place", and I would also try to persuade the German Ministry that is in charge of Foreign Affairs to offer some money to keep this place in good shape as a historic scientific place.
>
> Concerning the expedition member Stolze, he stayed in Persia for a few years to do photography and photogrammetry of architecture: the Friday-Mosque in Shiraz and the buildings in Persepolis. I have a copy of a paper of a Berlin professor who wrote about Stolze's activities, also with a few pictures (I will make a copy for you). Stolze himself published a book *Persepolis. Die achaemenidischen und sasanidischen Denkmaeler und Inschriften von Persepolis, Isthakr, Pasargadae, Shapur*, Berlin 1882, with 150 photos. It is a very rare large book which I have not yet seen – the Berlin library has a copy, and I will look at it when I am in Berlin next time. Stolze also wrote this popular article about Persia which I can send you.
>
> Please provide me with your mailing address, so I can send you the xerox copies.

One week later he received the following reply from Pouria Nazmei[4]:

> I have very good news for you. We found an inscription with exactly that sentence on it: "Deutsche Venus-Expedition". I shall receive the photos from Isfahan tonight or tomorrow, and I will send them to you as soon as possible. I talked to the Ministry of Science and Technology and

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[3] Free-lance Science Journalist, Iran.

[4] Reproduced after minor copy editing.

> asked them to write a letter to an organization for the Cultural Heritage of Iran for protecting the place, but I need some other evidence. Can we find the original report of this expedition from Berlin University? And another question: is there any governmental or non-governmental organization or university in Germany that is interested in this subject? If the answer is yes and if you can ask them to write a letter to the Iranian Cultural Heritage Organization and Iranian Ministry of Science and Technology, we may be able to protect this place very soon.

Also privately he always had Venus in mind, for example during a cruise voyage along the Norwegian coast – with visits to the places that several of us also cherished after the Tromsø meeting – he sent me a postcard of *Vardøhus Festning* postmarked April 3, 2010 from aboard *MS Kong Harald* of the Hurtigruten Line:

> ...yesterday we reached Kirkenes where the ship turned back southwest, passing Vardø where M. Hell was in 1768 or 9. Today we visited in Hammerfest the column marking the northernmost point of Struve's meridian arc. The weather is quite nice, but no observation of semi-forbidden oxygen lines yet ...

Postscript

Besides his professional dedication, and his legendary encyclopedic knowledge, Hilmar will be best remembered as a quiet and caring personality and as a very helpful and friendly person, who was always kind and generous to his colleagues. In addition, he was most encouraging to students – his own students as well as others' – for whom he was always ready with good advice, always topped with a big smile (Fig. 2) and a deep sense of fine humour – see the last sentence of previous quote, referring to the Aurora Borealis.

His untimely death confronted his immediate astronomical entourage with a totally unexpected problem: he left no direct heirs, and in the absence of a will, his entire estate passed to a distant relative who is too remote from our trade to properly oversee the great wealth of astronomical information that is buried in his more-than-100-meter-long archives, in addition to over ten thousand books on astronomy.

At the Tromsø meeting, a couple of colleagues who had in the past received Venus-related information from Hilmar, or had been one of the many guests at his house, expressed to me their deep sorrow about this state of affairs. But haven't we seen such deplorable situation before? Indeed, Franciscus de Paula Triesnecker (1745–1817), Hell's successor at the Vienna University Observatory, wrote to Lalande that he had "been unable to even look at the manuscripts", for

> the inheritors have denied him this satisfaction: this is another reason to regret the loss of Father Hell. Perhaps Curiosity, which publishes what Jealousy has been able to hide away, will one day supply us with the publication of these manuscripts.[5]

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[5] Lalande (1803), p. 722: "M. Triesnecker, habile astronome de Vienne, m'écrit qu'il n'a pu parvenir à voir même les manuscrits; les héritiers lui ont refusé cette satisfaction: c'est un nouveau motif de regrets sur la perte du P. Hell. Peut-être que l'intérêt, qui publie ce que la jalousie aurait pu recéler, nous procurera la publication de ces manuscrits." Translation taken from Aspaas (2012) p. 41.

Jealousy, definitely, does not play here, and, most fortunately, part of Hilmar's work had already been dispersed to some colleagues around the globe in a small number of modest digital files which, like driftwood, certainly will surface during the coming years.

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Figure 2. Hilmar Duerbeck, photographed at a Bollendorf (Germany) restaurant during the 2001 Christmas holidays.

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