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The 1882 Transit of Venus — as Seen from Chile

Hilmar W. Duerbeck

The forthcoming transit of Venus in front of the solar disk of June 8, 2004, serves as an opportunity to review the activities carried out by several astronomical expeditions to Chile during the most recent Venus transit of December 6, 1882. Astronomers from five nations set up stations in Santiago or Punta Arenas, and returned with data to determine new values for the solar parallax.

On April 28, 1883, a few months after the latest Venus transit, the illustrated newspaper *Harper's Review* published a picture showing a few youngsters watching the sun through a piece of blackened glass (Janiczek 1983). Its caption was taken from an article in the scientific journal *Nature*: «What will be the state of science when the next transit season arrives, God only knows. Not even our childrens' children will live to take part in the astronomy of that day» (Harkness 1882).

We, the great-grandchildren of these youngsters, are privileged to use fancy telescopes on earth and in the sky, many of them built and operated by international organizations, to take part in the astronomy of today. Furthermore, we also have the privilege to see the next transit of Venus: this year, on June 8, Venus will pass in front of the solar disk. The complete transit, which will take 7 1/3 hours, can be seen from Europe. Only 8 years later, on June 5, 2012, another Venus transit will be visible from Chile. We take the opportunity of the 2004 transit to recall the previous one of December 6, 1882, which was completely visible in the western hemisphere, and to focus our attention to a single country – Chile – where astronomers of many nations met, without, however, joining forces to carry out an international project.

Why are Venus transits interesting?

One of the goals of astronomers of the 18th and 19th centuries was to determine the distance from the earth to the sun (the astronomical unit), or, alternatively, the solar parallax, being the angular diameter of the earth's semi-major equatorial axis as seen from the sun's center. The astronomical unit is the baseline for stellar parallax determinations, and is thus the first step of the cosmic distance scale. Following a suggestion of the famous astronomer Edmund Halley to determine this unit, the transit of Venus had to be observed from widely distant locations on earth (Halley 1716). He proposed to measure the time of duration of the transit; others suggested to determine ingress or egress times, or to carry out precise measurements of the location of Venus on the solar disk, in order to calculate the value of the solar parallax.

Halley's suggestion fell on fertile ground. Accounts of many expeditions, mainly carried out by astronomers from France and England, to observe the Venus transits of 1761 and 1769 in the southern seas, Siberia or North America make fascinating reading (e.g. Woolf 1959, Fernie 2002), and have even entered modern fiction: *Mason & Dixon* by Thomas Pynchon, or *Venuspassage* by Lorenz Schröter. The huge amount of data collected during the 18th century transits was analyzed, among others, by Encke (1824) and Newcomb (1890).

References to expeditions to observe the 19th century transits are less frequently found in present-day literature, since the results actually not lead to major improvements of the value of the astronomical unit. Reasons of this failure are manifold: the methods employed were either too new to be reliable (photography), or too old-fashioned to supersede earlier data (like timings of contact moments). At the time of the 19th century transits, planet or asteroid observations, either simultaneous from various points from earth, or evening-morning measurements from one observing station, also became accurate enough to obtain reliable parallaxes and distances from earth. The knowledge of the earth's distance of any – major or minor – planet, as well as its time of revolution around the sun, by means of the application of Kepler's third law, yields

Fig. 1. Portraits of the leaders of the Belgian, French and U.S. expeditions (Upper left: Louis Niesten; upper right: Octave de Bernardières; lower left: Lewis Boss) and of the director of the Chilean National Observatory, José Vergara, lower right (from Zegers 1883).

the distance between the earth and the sun. A favorable opposition of the earth-approaching asteroid *Eros* in 1900 gave a fresh impetus to the determination of the astronomical unit.

The 19th century Venus transits were not only monitored by expeditions from the established astronomical «super-powers» France and England, but by a bunch of «newcomers», like Austria, Belgium, Brazil, Denmark, Germany, Italy, Mexico, the Netherlands, Portugal, Russia, and the United States. And when it came to observe the 1882 transit from a good site in the southern hemisphere, Chile turned out to be an excellent choice. Word on this was spread during an international conference on Venus transits held in Paris in early October, 1881. Among its participants was also the former director of the Chilean National Observatory, CARLOS MOESTA, who had retired to Germany. There was a proposal to establish, after the return of the expeditions, an international commission of Venus transits, that should collect all observational data and produce a general result for the solar parallax, but this early plan for an international cooperation came to nothing. It was only agreed to exchange the observations among the participating parties (anonymous, 1882). But even this resolution left no mark on subsequent research on the solar parallax: methods were too disparate, and publication progressed too slowly.

Observations of the Venus transit in Chile

Astronomers from Belgium, Brazil, France, Germany and the United States spent a few weeks in or near Santiago de Chile, or in Punta Arenas, the capital of the southern 12th (Magallanes) region to observe the transit. We will briefly review the various groups and places, and tell about their achievements (Fig. 1).

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. 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 and SALAZAR 1896).

Let us briefly mention that ZEGERS' book does not inform us about the activity of the Chilean National Observatory on 1882 December 6, since this was obviously restricted to the «authorized word of its director», JOSÉ 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 at the observatory («debemos estos datos a la benevolencia del señor Director del Observatorio Nacional»). And this remained, according to my knowledge, the only printed result of the Venus transit observed by the Chilean National Observatory staff.

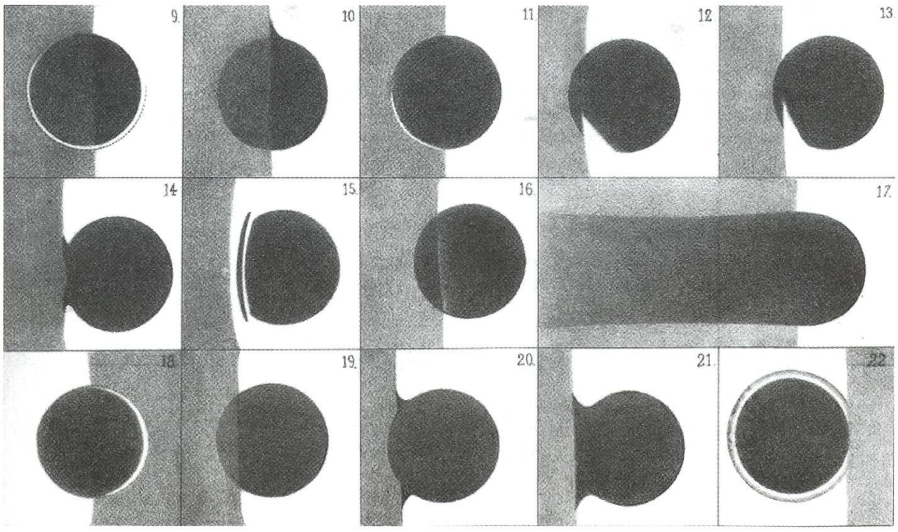
The expeditions of the Belgian, Brazilian, French and German expeditions are described in bulky books, issued by the observatories and commissions in charge of the projects, while the U.S. activities are less well documented. In addition to the published sources, a lot of official documents survive: the German ones in the Archiv der Berlin-Brandenburgischen Akademie der Wissenschaften, the French ones in the Archive de l'Académie des Sciences, the U.S. ones in the National Archives and the U.S. Naval Observatory, Washington, DC.

The Belgian Group

Two Belgian expeditions observed the Venus transit of 1882: the first went to Chile, the second to San Antonio, Texas, to observe the transit from both southern and northern sites, in order to determine the parallactic displacement of Venus on the solar disk. Both parties were equipped with identical instruments, so-called heliometers with unequal objectives. This special arrangement, invented by JEAN-CHARLES HOUZEAU, director of the Brussels Royal Observatory, consists of two semi-circle-shaped lenses of different diameters and focal lengths, which could be moved relative to each other by means of a micrometer. They produced a large and a small image of the sun, plus a large and a small image of Venus. The trick was to shift the two lenses of such a heliometer in such a way that the small image of the sun, produced by the short-focus lens, coincided with the dark large image of Venus projected on the very large image of the sun, and to read and record the heliometer setting.

The Chilean party consisted of LOUIS NIESTEN, astronomer at the Royal Observatory of Brussels, CHARLES LAGRANGE, adjunct astronomer at the same institution, and LOUIS' brother JOSEPH NIESTEN, an artillery captain on leave from the War Ministry. A 45-day trip on the steamer *Denderah* brought them from Antwerp to Valparaiso. After a railway trip of five hours, they arrived in Santiago on September 2, 1882, and set up their observing station in the garden of the Chilean National Observatory, which at that time was situated at the Quinta Normal in downtown Santiago. 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. 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 18th century observers: the black spot that appears at second and third contacts (Fig. 2), which makes accurate timings of the moments of internal contacts virtually impossible. After finishing the observations, the party went by railway to Santa-Rosa, crossed the Cor-

Fig. 2. Disturbing effects at second contact, among them the famous «black drop effect», as observed by the Belgian observers (from HOUZEAU 1884).



dillera on muleback, and returned by train and ship via Buenos-Aires to Belgium, happily finishing «the first scientific expedition organized by Belgium» (NIESTEN 1883).

JEAN-CHARLES HOUZEAU himself headed the Texas party, which suffered from clouds. Only about half of the transit could be observed, and 124 measures were taken. Two years after the transit, HOUZEAU (1884) published the report of the campaign, and his final result was: 8.911±0.084 arc seconds. He blamed the large error on the poor sky conditions in San Antonio and remarked that at least this had been, after all the inconclusive observations of the 1874 event, a novel method to observe a Venus transit.

The French Group

The French Academy of Sciences had organized ten expeditions, comprising 35 persons, to observe the transit from various places on earth: Haiti, Mexico, Martinique, Florida, Santa Cruz (Patagonia), Chile, Chubut, Rio-Negro, Cap Hoorn, Bragado and Montevideo. The head of the Chilean party was the naval lieutenant OCTAVE DE BERNARDIÈRES, accompanied by two members, lieutenant LEON BARNAUD and watchman CARLES FAVEREAU, and five assistants (so unimportant that they are not listed in the French official reports, but only in ZEGERS' book): the mates SIMOM [sic!], LALANDE, MERCIER, RAMEL and DEFFES.

The French party chose a region somewhat removed from Santiago, as recommended by the international conference, «in order not to double the observation of the National Observatory». They settled at the «hacienda de Cerro Negro», a farm owned at that time by Señor VALENTIN MARCOLETA, located 20 kilometers south of Santiago and two kilometers from the town of San Bernardo, «which takes a culminating point of the immense central valley of our territory», as ZEGERS proudly remarks.

It took the French the longest time to publish a final report, written by the hydrographer and astronomer JEAN-JACQUES ANATOLE BOUQUET DE LA GRYE (1905). Positional measurements of Venus on the solar disc and photographs were basically put aside, and only the contact observations were evaluated. BOUQUET DE LA GRYE arrived at a value of 8.80 for the solar parallax – close to the modern value, but he fails to give any indication of its error.

The U.S. Group

The United States expedition was one out of eight that was to follow the transit by means of the then «modern» method of photography (DICK 2003). The main instrument was a horizontal telescope, a photoheliograph, with a focal length of 11.7 m. The light of the sun was fed into the system by means of a mirror, a so-called heliostat (Fig. 3).

The expedition arrived on October 30 in Valparaiso after a four-week-long trip, and arrived in Santiago the next day. The general MARCOS MATURANA offered a spacious backyard belonging to the cartridge factory («Fábrica de Cartouchos») which was situated to the south of the Parque BERNARDO O'HIGGINS in downtown Santiago. The head of the U.S. group was LEWIS BOSS (Dudley Observatory, Albany), who was accompanied by a second astronomer, MILES ROCK (U.S. Naval Observatory), and two photographers, THEODORE C. MARCEAU and CHARLES S. CUDLIP.

Fig. 3. The setup of the U.S. Nagasaki station in 1874 with a photoheliograph (no photographs of the 1882 observing stations are available at U.S.N.O.): On the left side, a pillar carries the heliostat; the solar rays are deflected by a mirror and pass through a lens and a small tube into a hut (at right) where the photographic plates are exposed (U.S. Naval Observatory photograph; courtesy of CHUCK BUETER).

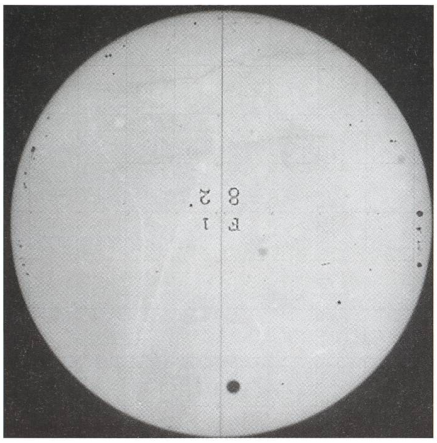


Fig. 4. One of the few surviving Venus transit photographs of the 1882 U.S. expeditions; north is at the top. It is unknown at what station this plate was taken (U.S. Naval Observatory photograph).

On November 21, the photoheliograph was set up, and on the day of the transit, 240 dry collodium plates were taken (Fig. 4). Owners of digital cameras who are curious how to do such a job may consult ZEGERS' report; recipes how to prepare the emulsion, how to develop, and how to fixate are given there: *take 1 ounce egg-white, 15 ounces water and 15 drops of concentrated ammonia...*

The director of the U.S. Naval Observatory, SIMON NEWCOMB, while having initiated the U.S. Venus transit project, by 1882 had reached a very critical opinion about its scientific value, and preferred other methods to determine the solar parallax. Thus it fell to his colleague, WILLIAM HARKNESS, to organize the expeditions and to analyze the observa-

Fig. 5. L. CRULS, head of the Brazilian expedition to Punta Arenas (Observatorio Nacional, Rio de Janeiro).

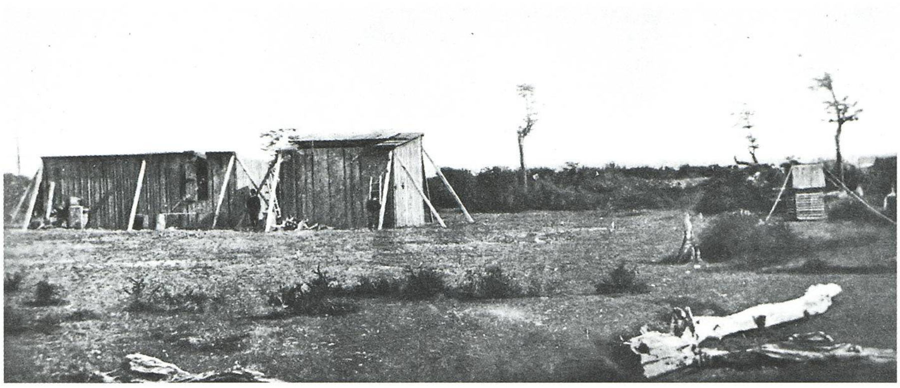


Fig. 6. The observing huts of the Brazilian expedition (from Annales de l'Observatoire impérial de Rio de Janeiro, tome 3, 1887).

tions. In 1889, he presented a more or less final result, 8.842±0.0118 arc seconds, based on 1475 plates of the 1882 transit (Harkness 1891). Although it had been planned to publish the details of the observations, this was never done due to lack of funds – even of the projected 4-volume report of the 1874 U.S. observations, only one volume was published, and the single copy of the proofs of a second volume can nowadays be downloaded from ADS.

The Brazilian Group

Three Brazilian groups observed the transit: one on the island of San Thomas (Antilles), another one in Pernambuco (Olinda, Brazil) and a third one in Punta Arenas, Chile. The Punta Arenas party consisted of the director of Rio de Janeiro Observatory, Belgian-born Luis Cruls (Fig. 5), and his mechanic, Moreira de Assis.

The Brazilian party was brought to Punta Arenas (Fig. 6) by the frigate Parnahyba of the Brazilian Navy, under the command of captain Luiz Philippe de Saldanha da Gama (1887), who wrote extensive «travel notes» for the astronomical report. He later became admiral and director of the naval school, took part in a revolt, and died in 1895 during a federalist revolution in Brazil. Saldanha da Gama's quite refreshing notes describe the trip from Rio via Montevideo (where they met ships of French and U.S. expeditions) to Punta Arenas. On the day of the transit, the Parnahyba was sent off to another observing place, Quartermaster Island, to carry out independent observations, which could only be carried out imperfectly due to poor weather. When Saldanha da Gama and his crew returned the night after the transit, they found Cruls asleep and woke him up. The report reads: *Two short words, rapidly spoken, were exchanged, they said everything. – «Então?» (How was it?) asked the commander anxiously. – «Completo» (Achieved) replied the astronomer and smiled. And then both men shook hands, quietly and with emotion.*

While the Brazilian Groups only used the timings of second and third contacts (second only from Punta Arenas, third from all three stations), their final discussion (Cruls 1887), which just runs over five pages of the Annals, and is based only on a handful of measurements, yields a result, remarkably close to the modern value, but a very uncertain one: 8.808 arc seconds (no error given).

The German Group

A German commission, established in 1869, had set up a very detailed scheme of observing the Venus transits of 1874 and 1882 by means of heliometers and photoheliographs. Because the latter had produced very inaccurate results for the first transit, the 1882 expeditions to Hartford (Connecticut), Aiken (South Carolina), Bahia Blanca (Argentina) and Punta Arenas (Chile) were restricted to visual, and almost exclusively to heliometer observations. The employed heliometers were relatively small instruments, designed by Fraunhofer, with an aperture of 75 mm and a focal length of about 1 m.

The expedition to Punta Arenas (Fig. 7) was led by Friedrich Küstner (who would later establish the reality of the Earth's polar motion). He was accompanied by astronomer Paul Kempf (a pioneer of stellar photometry), geologist Gustav Steinmann, and mechanic Friedrich Schwab, who was also an amateur astronomer. On short notice, the head of the German Venus transit commission, Arthur Auwers, astronomer at the Berlin Academy of Sciences, accompanied by his servant, joined the party (Fig. 8).

Let us quote some (abridged) notes from Auwers' official diary to learn some details of the expedition to Chile: «1882 August 29. Dr. Küstner received the written instructions for the expedition and its cash-box, containing 1200 mark and 100 pounds in cash and a letter of credit for Montevideo on another 100 pounds, and travelled from Berlin to Hamburg in the evening (Küstner and Steinmann used the steamer *Rio* to travel to Montevideo where they would join the rest of the party). On September 5, 117 boxes were stored in the steamer *Ramses* of the Kosmos company. The ship left Hamburg on September 10 with the participants Kempf, Schwab and Bohne, while Auwers joined the group during a stop in Antwerp. The *Ramses*, a steamer of 1166 tons, and a crew of 38, left Antwerp on 1882 September 14.»

In the morning of October 11, the *Ramses* anchored on the roads of Montevideo, and the passengers met their companions who had travelled with the *Rio*. In the afternoon, the *Ramses* con-

Fig. 7. Photograph of the German station in Punta Arenas. Left, wooden lighthouse of Punta Arenas, center, «tea house» and meteorological station, right, two observing domes made from iron and canvas (Archiv, Berlin-Brandenburgische Akademie der Wissenschaften).

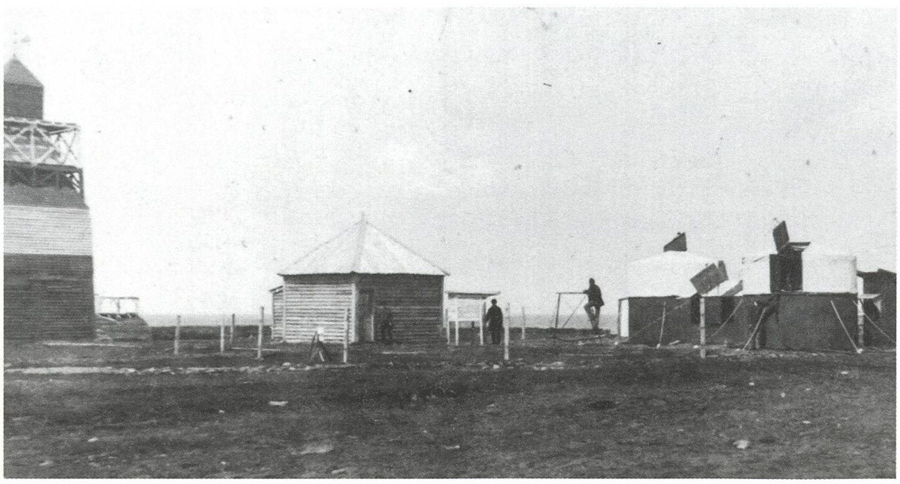


Fig. 8. The German party in front of the «tea house». From left to right, first row: G. STEINMANN, geologist; A. AUWERS, head of the transit project; F. KÜSTNER, astronomer; second row: F. SCHWAB, mechanic, P. KEMPF, astronomer, BOHNE, servant (Archiv, Berlin-Brandenburgische Akademie der Wissenschaften).

tinued her trip to Punta Arenas, where she arrived on October 17. The trade house SCHRÖDER & Co. took care of the passengers; but the journal says «because we arrived three days early, nothing had been prepared, and we had to stay on board during the first night. Then we were located in unfinished rooms, surrounded by workers. In the evening of October 18, a party with the *Gobernator* (governor) took place, and in the next morning, foundations of the observing towers were prepared. First observations, hampered by poor weather, began on October 29.» – «1882 October 31 – The collimator house is being erected. At 11 1/2 a.m. the *nobilities* of the town are invited to tour the almost finished observatory; this was followed by an official breakfast, which lasted till 6 p.m.» – «In the middle of November, the governor gave us a small wooden house, built by Chilean soldiers between the observatory and the lighthouse, which comprised a comfortable living room and a kitchen. This house very much facilitated the nightwatch on location and offered the possibility to carry out paperwork near the instruments.»

And here are some quotations from AUWERS' notes of the transit observations: «After multiple rain showers in the evening of December 5 and in the overcast night of December 5/6, the sky was clear on early December 6, and the air was very transparent... When the time of the transit came, the sky was partly covered with numerous large cumulus clouds. I used a 6-foot refractor. Before the first contact, I tried to find Venus outside the solar disk; the moving clouds were very disturbing. Shortly before the calculated first contact, the clouds left the sun, and the region remained clear for more than 5 minutes, and the image quality became very good. The first [outer] contact of the planet with the solar limb was seen at 21 hours, 8 minutes, 31 seconds of the chronometer [showing Greenwich time]... From 21 h 26 m I left the telescope exposed in order to observe the inner contact, at 21 h 27 m 4 s I guessed that the border of Venus' black disk touched the solar limb, while the [bright] circle belonging to the planet [caused by Venus' extended atmosphere] was still outside the sun; in the same moment the sun was completely obscured by a cloud» (AUWERS 1898).

At 1 h 51 m local time, a thick cloud covered the sun for more than half an hour; the observers noticed that it was raining in the mountains, and almost gave up their expectations for further observations; but the sun reappeared and only thin cirrus remained in the sky. AUWERS could observe the third and fourth contacts, although the seeing was not optimal. After Venus had left the solar disk, both SCHWAB and AUWERS believed to be able to see Venus: «It was a round spot of somewhat stronger brightness than the sky background, with a bluish shine, without a well-defined limb, having a somewhat larger diameter than the planet in front of the sun.»

After Christmas, when more observations to accurately determine the time and the geographical location had been made, the telescopes were disassembled and packed. On the last day of 1882, the meteorological station was closed, and on 1883 Januar 3, the *Theben* arrived to pick up AUWERS, his servant and the mechanic. STEINMANN and KÜSTNER were officially released to carry out other projects in Chile, KEMPF in Montevideo. On 1883 February 21, AUWERS returned home to Berlin – after a trip of 4 months.

AUWERS was also the one who, after his return, sat down and completed his 6-volume report on the expeditions (AUWERS 1898). A lot of performance tests of

Coordinates of observing stations

Belgian station and Observatorio Nacional de Chile (Quinta Normal, Santiago)
latitude = –33° 26' 42"; longitude = –70° 41' 30"

U.S. station «Fábrica de Municiones» (also called «Fábrica de Cartuchos») in the Parque (= Parque B. O'Higgins)
latitude = –33° 28' 04"; longitude = –70° 39' 09"

French station «Cerro Negro», San Bernardo
latitude = –33° 36' 30"; longitude = –70° 41' 21"

Brazilian station in Punta Arenas
latitude = –53° 10' 03"; longitude = –70° 54' 00"

German station in Punta Arenas
latitude = –53° 09' 39"; longitude = –70° 54' 10.5"

the employed heliometers at different temperatures had to be carried out and reduced, and is documented on many hundreds of pages. His best result, based on the heliometer observations, was 8.8796±0.0373 arcseconds (an incredibly poor result, taking into account the year-long calibration observations and the practicing with «artificial Venus transit» models); it is an irony of fate that in 1898, around the time when AUWERS finished writing his work in his Berlin office, two astronomers at Berlin's popular Urania Observatory, GUSTAV WITT and FELIX LINKE, discovered the minor planet *Eros* that would revolutionize the determination of the astronomical unit. Two years later, in 1900, an opposition was observed, and another very favorable one, in 1930. The first one led to a solar parallax of 8.7966±0.0047 (HINKS 1904), a very good result when compared with the present-day value of 8.794148 are seconds.

A Summary

The previous transit of Venus took place when many smaller and younger nations became interested in astronomical research, and arranged for expeditions to observe the event. But time was not yet ripe to establish international cooperation in instrumentation and data reduction, as the 1882 international Venus conference had indicated – the differences in observational methods applied by the various groups were too large. And even the first major international astronomical project, the *Carte du Ciel*, launched in 1887 and carried out with instruments of similar construction, became a tiresome and eventually doomed enterprise.

International cooperation in space science, nuclear physics, etc., is in present times an obvious choice, if not a necessity. In the 1950s European countries agreed to establish ESO, and almost all astronomical projects in Chile are nowadays multi-national enterprises, culminating in the construction of ALMA. WILLIAM HARKNESS would be surprised to learn how much astronomical matters have changed since the (half)-shadow of Venus previously fell on earth...

Acknowledgments

Many colleagues have supported my research on Venus transit expeditions; here I want to express my particular gratitude to Dr. CHRIS STERKEN (Vrije Universiteit Brussel), to Dr. WOLFGANG KNOBLOCH and his staff (Berlin-Brandenburg Academy of Sciences Archive), as well as to the librarians of the Staatsbibliothek zu Berlin, the Observatorio Nacional, Rio de Janeiro, the European Southern Observatory, Santiago, the Royal Observatory of Belgium, Ukkel, and the U.S. Naval Observatory, Washington, D.C.

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Hubble Ultra Deep Field

NASA, ESA, S. Beckwith (STScI) and the HUDF Team STScI-PRC04-07a

This view of nearly 10,000 galaxies is the deepest visible-light image of the cosmos. Called the Hubble Ultra Deep Field, this galaxy-studded view represents a «deep» core sample of the universe, cutting across billions of light-years.

The snapshot includes galaxies of various ages, sizes, shapes, and colours. The smallest, reddest galaxies, about 100, may be among the most distant known, existing when the universe was just 800 million years old. The nearest galaxies - the larger, brighter, well-defined spirals and ellipticals - thrived about 1 billion years ago, when the cosmos was 13 billion years old. In vibrant contrast to the rich harvest of classic spiral and elliptical galaxies, there is a zoo of peculiar galaxies littering the field. Some look like toothpicks; others like links on a bracelet. A few appear to be interacting. These peculiar galaxies chronicle a period when the universe was younger and more chaotic. Order and structure were just beginning to emerge. The Ultra Deep Field observations, taken by the Advanced Camera for Surveys, represent a very narrow, deep view of the cosmos. In ground-based photographs, the patch of sky in which the galaxies reside (just one-tenth the diameter of the full Moon) is largely empty. Located in the constellation Fornax, the region is so empty that only a handful of stars within the Milky Way galaxy can be seen in the image.In this image, blue and green correspond to colours that can be seen by the human eye, such as hot, young, blue stars and the glow of Sun-like stars in the disks of galaxies. Red represents near-infrared light, which is invisible to the human eye, such as the red glow of dust-enshrouded galaxies.

The image required 800 exposures taken over the course of 400 Hubble orbits around Earth. The total amount of exposure time was 11.3 days, taken between Sept. 24, 2003 and Jan. 16, 2004.