

The 1882 Belgian transit of Venus expeditions to Texas and Chile – a reappraisal

Christiaan Sterken and Hilmar W Duerbeck

Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium

E-mails: csterken@vub.ac.be, hduerbec@vub.ac.be

Abstract

In 1871, the Belgian astronomer Houzeau suggested applying a new heliometric device to measure the position of Venus transiting the solar disc. This "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 would yield a measure of the distance of the centres of both objects. Two separate stations equipped with similar instruments may provide a value for the solar parallax. After being appointed Director of the Royal Observatory of Belgium in 1876, Houzeau obtained support to organize two Belgian expeditions to observe the 1882 December 6 transit of Venus: one to San Antonio (Texas) and the other to Santiago (Chile). The observations were quite successful, but it took some time to take into account the effects that influenced the measurements, in order to determine the parallactic displacement. While the result was not overwhelmingly convincing, the experiment nevertheless was a fresh approach to determining the solar parallax. This enterprise was the first major expedition in the history of Belgian science.

Keywords: *Transit of Venus, Belgian expeditions, heliometer with unequal focal lengths, solar parallax, Houzeau, Niesten, Vergara*

"It is fortunate for humanity that the greatness and power of nations is not measured by the extent of the regions that constitute it; just like the talent and the energy of people is not measured by the number of feet of their height ..." (Zegers 1883).

1 THE DRIVING FORCE BEHIND THE EXPEDITIONS: J-C HOUZEAU

The above words of Luis Zegers, the self-appointed historiographer of the activities in and around Santiago de Chile to observe the 1882 Venus transit, form the beginning of his chapter on the Belgian activities. Clearly, however, the project was started through the initiative of just one person, Jean-Charles Houzeau. In 1871, the *Bulletin* of the Belgian Academy of Sciences included a note by him, dated Kingston (Jamaica) 1871, titled "On a method to measure in a direct way the distance between the centres of the Sun and of Venus, during the transits of that planet." Houzeau was an eminent astronomer, arduous topographer, fervent writer and newspaper editor, and at that time the owner of a banana plantation, and in this note he drew attention to a novel and ingenious way of determining the solar parallax. That his note did not pass unnoticed is proven by another one, published just one year later, where he tries to refute some objections put forward by George Airy (Houzeau 1872). Houzeau's drive to turn his project into reality was certainly one of the reasons he later accepted the offer to become Director of the Royal Observatory in Brussels. During the six years of his Directorship "... the activity of the Observatory was truly prodigious. Stimulated by the example of its chief, the personnel worked with a veritable enthusiasm ..." (Lancaster 1889). And it was certainly his feeling of accomplishment, but also the problems with the administration of the Royal Observatory and his aggravating sickness, that led to his resignation soon after the project was carried out.

Extensive biographies of Houzeau are available, including a monumental one by Houzeau's collaborator, Lancaster (1889), others by Rankin (1984) and Evans (1990), and a very recent detailed study by Verhas (2002), so we can restrict ourselves to a short sketch of his life. Jean-Charles Houzeau de Lehaie (Figure 1), who was born in Mons in 1820, was

a prodigious writer on scientific and social topics from an early age. For a while, he lived and studied in Paris, but in 1848, Adolphe Quételet, 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, leave Belgium, and range about Europe, working in various libraries and writing books on geography. In 1854 he was recalled to Belgium to work on the triangulation of the Kingdom, but when this project was interrupted in 1857 he left on the sailing ship *Metropolis* for New Orleans, arriving there in late 1857.

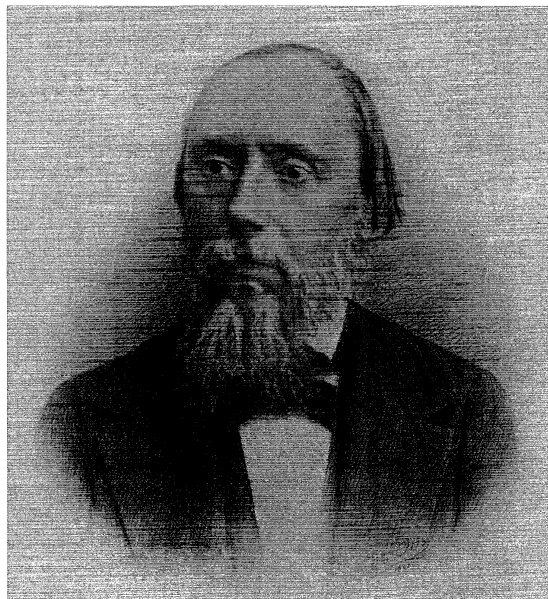


Figure 1. Portrait of Houzeau (from Lancaster 1887)

He first visited San Antonio, Texas, in 1858 May,

and stayed there till 1862, apart from almost a year that he spent surveying in a region to the south of Dallas. When the Civil War broke out, he crossed the Mexican border in 1862 March. 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. In 1868 March he left New Orleans, and in June settled in Jamaica. There he cultivated a plantation, founded a school for young natives, and carried out studies in natural sciences and astronomy, mainly for his *Uranographie Générale* (which also involved a trip to Panama, in 1875). When Adolphe Quételet died in 1874, King Leopold II overrode objections of his ministers and appointed Houzeau as Director of the Royal Observatory. Houzeau took up his post in 1876 June, and was deeply involved in the reorganization and relocation of the Observatory to the suburb of Uccle/Ukkel. He resigned from the Directorship at the end of 1883, but continued to work on his voluminous astronomical bibliography. In 1888 July, he died from the consequences of malaria that he had contracted more than twelve years earlier.

2 THE OUTLINE OF THE PRINCIPAL INSTRUMENTS

Two examples of Houzeau's heliometer with unequal focal lengths (Figure 2) were built by Grubb of Dublin at the initiative of Houzeau and according to plans outlined by Louis Niesten (see Houzeau, 1871). Descriptions are given in Anonymous (1898), Houzeau (1884b), and Van Boxmeer (1996).

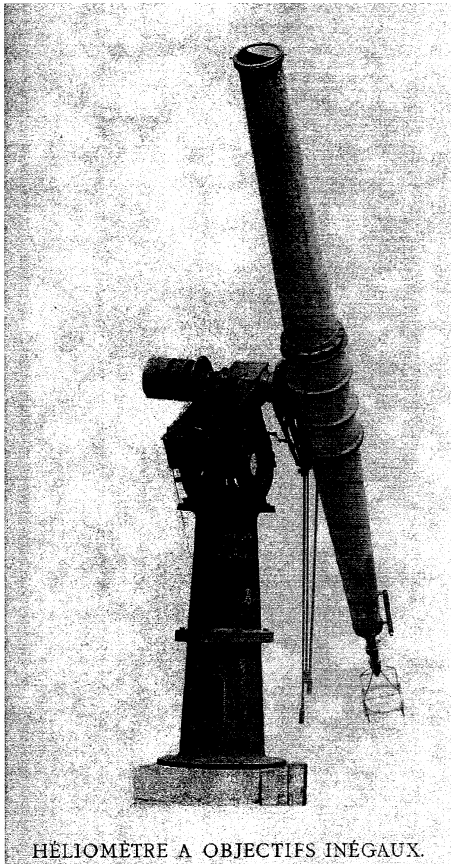


Figure 2. The heliometer with its projection screen on its parallactic mounting (from Houzeau 1884)

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 0.14 m focal length, which actually forms part of the eyepiece unit of the telescope (Figures 3 and 4). The pair of objective lenses was acquired by Quételet in 1844 from the lens-maker Cauchois in Paris. The eyepiece projects a solar image on a screen (Figure 5), which was made in 1882 at the Observatory. The projected large solar image has a diameter of 160 mm on the screen, while the diameter of Venus is about 5 millimetres. The short-focus objective produces a solar image a little bit 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 one to produce a precise coincidence of the small image of the Sun and that of Venus (Figure 6). The difference in micrometer reading between the positions 'small Sun centred on crosshairs, being the centre of the large Sun' and 'small Sun centred on large Venus', properly calibrated, gives a measure of the distance between the centres of both objects during the transit.



Figure 3. Two large and one small half-objectives. Photograph by C Sterken

Fig 3. Micromètre. Coupe Suivant C.D.

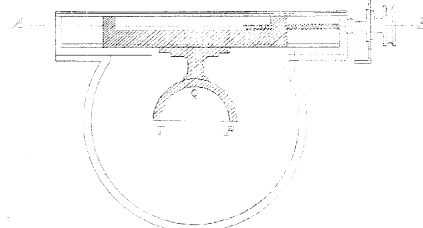


Fig 4. Micromètre. Coupe Suivant A.B.

Figure 4. The small half-objective on its micrometer sledge (construction plan by L Niesten; from Houzeau 1884)

The measurements were done in such a way that one observer centred the 'large Sun' on the screen by

fine motion of the telescope, a second one centred 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).

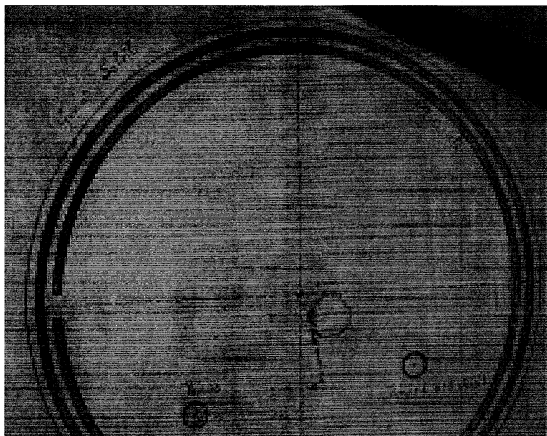


Figure 5. A close-up of the surviving projection screen surface, showing the centring circles for the large solar image ("Grand Soleil"), the silhouette of the dark "Vénus", and the appearance of the small Sun centred on the dark Venus ("Vénus et petit Soleil"). Furthermore, the smallest distance of the centres of both objects is marked ("distance minima" [sic]). Photograph by C. Sterken

Both of the 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.

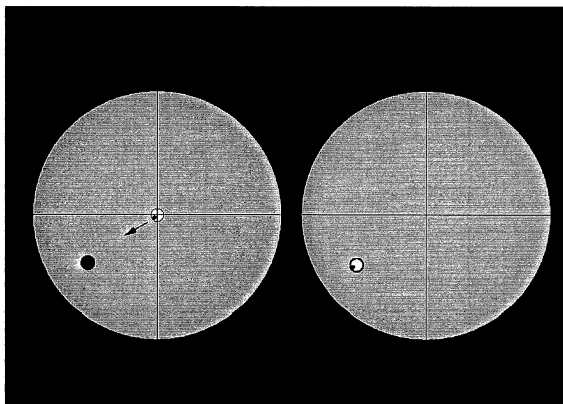


Figure 6. The principle of measurements with the heliometer with unequal focal lengths (adapted from sketches given by Houzeau 1871)

3 AN OVERVIEW OF THE BELGIAN EXPEDITIONS

Two expeditions of the Royal Observatory of Belgium (ROB) were carried out, one to San Antonio, Texas, and the other to Santiago in Chile. We give here a brief overview of the expedition members and the equipment, as well as biographical sketches of the expedition members.

3.1 Texas Mission

3.1.1 Members

J C Houzeau, Director of the ROB, mission leader.

A Lancaster, Meteorologist-inspector, ROB.
E Stuyvaert, Adjunct Astronomer, ROB.

3.1.2 Telescopes

Heliometer with unequal focal lengths (AL).

Merz refractor, 110 mm aperture, 125× (JCH).

Fraunhofer refractor, 75 mm aperture, 90× (ES).

The initials in brackets indicate the observers who used the instruments for contact observations; during the actual transit, all members were working with the heliometer.

3.1.3 Biographical notes

Albert Lancaster (1849–1908) (Figure 7) reorganized the climatological network of stations in Belgium and in 1898 was appointed Scientific Director of the Meteorological Service, a post that he retained until the end of his life. Together with Houzeau, he wrote *Traité Élémentaire de Météorologie*, and the legendary *Bibliographie Générale de l'Astronomie* (Anonymous 1980; Moulon 1908).

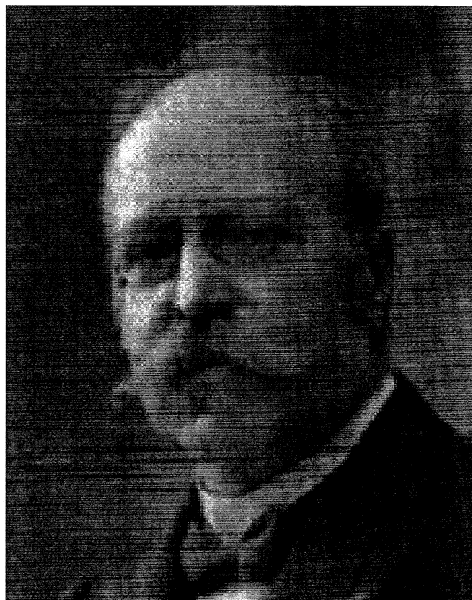


Figure 7. Albert Lancaster (from Lagrange 1908)

Charles-Emile Stuyvaert (1851–1908) entered the Royal Observatory in 1879 as a voluntary, and became Astronomer in 1881. He did surface studies of Venus, Mars, Jupiter, and Saturn, determined cometary positions, observed lunar occultations, and was especially interested in lunar surface studies; in the process, he made drawings and prepared a lunar globe (Stroobant 1909).

3.2 Chile Mission

3.2.1 Members

Louis Niesten, Astronomer, ROB, mission leader.

Charles Lagrange, Adjunct Astronomer, ROB.

Joseph Niesten, Lieutenant of Artillery.

3.2.2 Telescopes

Heliometer with unequal focal lengths (JN).

Dollond refractor, 110 mm aperture, 140× (LN).

Troughton & Simms refractor, 90 mm aperture, 160× (CL).

The initials in brackets indicate the observers who used the instruments for contact observations; during the

actual transit, all members were working with the heliometer.

3.2.3 Biographical notes

The following biographical data are taken from Zegers (1883) and supplemented by Anonymous (1932, 1980).

Louis Niesten (1844–1920) (Figure 8) was born in Visé near Liège, and made his first studies in the Military Academy; he rose to the rank of Artillery Captain, but left military service in 1877 to work as a scientist. Zegers mentions many papers by Niesten on the physical properties of Jupiter and Mars, on comets, asteroids, and double stars, as well as of a transit of Mercury. In 1884 he became Astronomer and Chief of the Service of Mathematical Astronomy. In 1898, he succeeded Charles Lagrange as Scientific Director of the Astronomical Service, a post that he retained until 1900.



Figure 8. Louis Niesten; drawing at the time of his Chilean mission (from Zegers 1883).

Charles Lagrange (1851–1932) (Figure 9) was born in St. Josse-ten-Noode/Brussels. He also took first studies in the Military Academy, became an Artillery Lieutenant in 1874, but moved to the Observatory in 1878. Zegers also mentions theoretical and observational studies, as well as a history of the physical sciences in Belgium between 1830 and 1880. In 1897, he became Director of the Astronomical Service, a post that he left a year later to dedicate his life to historical research, mainly on the chronology of the biblical prophets. He was also a notable Professor at the École Militaire, and wrote several works on the philosophy of science.

Joseph Niesten, born in Visé near Liège in 1847, entered military school in 1867, and became a Lieutenant of Artillery in 1870. Since he also took part in astronomical projects at the Royal Observatory, and because of his practical and theoretical knowledge of astronomy, the War Ministry agreed that he should join the astronomical expedition led by his brother.

A map of the topography of the San Antonio Station is given in Houzeau (1884b), Résultats, Plate 2, and this is reproduced here as Figure 10.

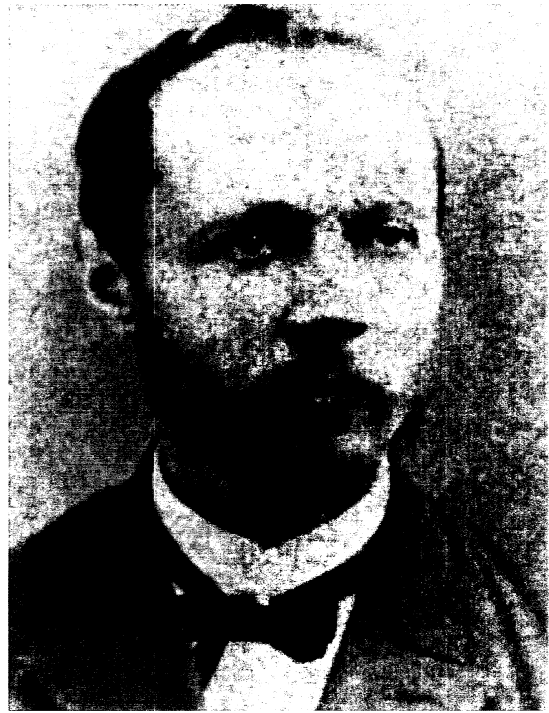


Figure 9. Charles Lagrange, undated photograph (from Anonymous 1980)

4 THE BELGIAN EXPEDITION TO SAN ANTONIO, TEXAS

Houzeau departed for the United States on 1882 June 30, while Lancaster left Antwerp on July 22 on the steamer *Waesland* (of the Belgian Red Star Line), along with the equipment of the expedition. The Atlantic crossing to New York took 11 days and 22 hours. There he found instructions from Houzeau and the New York Belgian consul on how to proceed. On August 12 the instruments were loaded on the steamer *San Marcos*, destination Galveston, and from that port they were transported by railroad to San Antonio, where they arrived on August 30 in perfect condition.

While in Washington, Lancaster (1882) visited the Naval Observatory and the Signal Office (telemetry and meteorological observations), and the Smithsonian Institution. Then he travelled by rail through Kansas and Colorado to San Antonio, where he arrived on September 2.

The Belgian transit observatory was located in the back garden of a rented wooden house "... in an isolated situation ..." (Houzeau 1884b) that faced the Staff Post and the Quadrangle of 'Government Hill' (its present-day name, Fort Sam Houston, was only assigned in 1890). Evans and 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 telescope piers were approximately 640 feet south and 950 feet west of the clock tower in the Quadrangle."

Houzeau (1884b) was an experienced topographer, and he published a list of measurements of buildings and other features of San Antonio in his final report, while a copy of a hand-drawn map giving a bird's eye view of San Antonio is found in the archive of the Royal Observatory of Belgium.

We owe the most detailed description of the Texas observations to Lancaster (1882):

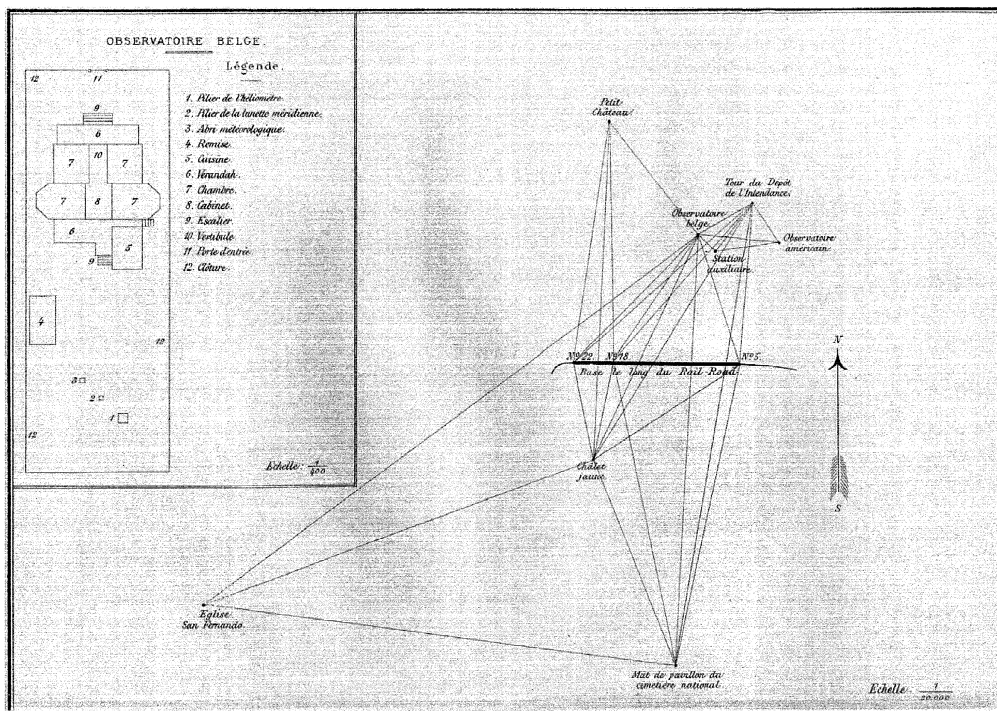


Figure 10. Outline of the house of the Belgian mission in San Antonio, and visual bearings (from Houzeau 1884)

San Antonio is the headquarter of the troops 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. [Lancaster then gives a few details about the city, the inhabitants, and the evening dinners outside on the Plaza de las Armas.]

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 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 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 a.m.; 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 disc through a thin cloud; but another one covers it immediately, and this hope and anguish goes on for 30 minutes. At around 9 1/2, a brightening which is larger than the previous ones permit to point at Venus between the clouds, 12 minutes before the moment of the minimum distance of centres. 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!

But in his extensive obituary, Lancaster (1889) provides information about Houzeau's state of mind on the morning of the transit when the sky was overcast: "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 obituary (ibid.) relating to the Texas expedition that merits citing 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 B Discry, who accompanied him 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."

5 THE BELGIAN 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 accessed a lot of correspondence and newspaper clippings, talked with Belgian and US scientists, and actively took part in the French transit expedition as an assistant. 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' (1883) book does not inform us about the activities 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, deploras 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, according to our knowledge, the only printed result of the transit of Venus observed by the Chilean National Observatory staff. For a detailed history of the Chilean National Observatory, the reader is referred to Keenan *et al.* (1985).

The Belgian project started with an exchange of letters, transmitted by Zegers (1883:168) between Houzeau and the Director of the Chilean National Observatory, José Ignacio Vergara (Figure 11):



Figure 11. The director of the Chilean National Observatory, José Vergara (from Zegers 1883)

Brussels, October 16, 1881

To the Director of Santiago Observatory.

Mr. Director:

Since the Belgian government has decided to send a scientific commission to Chile for the observation of the next transit of Venus in December 1882, I take the honour to recur to your kindness in order to obtain some information with respect to the installation of our instruments.

They comprise a large equatorial of 0.18 m aperture and 4.30 m focal length, which is especially designed for the observation of the transit, and a meridian telescope for supplementary observations. Under which conditions can we easily find in the surroundings of Santiago a convenient place to build shelters, and to put up the instruments?

The Belgian commission will depart from Europe in about August 1882, and consequently will arrive in the month of October.

I hope, Mr. Director, that you excuse the liberty by which I request your benevolence, and I beseech you to accept my anticipated thankfulness, and the expression of all my consideration.

J.C. Houzeau
Director of the Royal Observatory in Brussels.

This was answered as follows:

December 24, 1881

To Mr. J.C. Houzeau, Director of the Royal Observatory in Brussels.

Mr. Director:

I have received your important letter of October 16 of this year, in which you communicated that the Belgian Government has decided to send to Chile a scientific commission with the aim to observe the next transit of Venus, and in which you ask me about the possibility to find a convenient place in the surroundings of Santiago for the instruments that this commission will bring along.

In answering with true joy to your mentioned letter, it is especially pleasant, Mr. Director, to be able to signal to you that the said commission will find in this capital all the facilities which it can expect for the performance of its duty in this important mission, both from the side of the government as well as from that of the single inhabitants, and that consequently it will therefore not encounter any difficulty to establish its observatory in the place which it considers most advantageous.

Being authorized by the Minister of Public Education, I can immediately offer you in the same place that is occupied by the Observatory in whose charge I am, not only the necessary space for this purpose, but also the use of the offices, that of one of the three equatorials, and that of the meridian circles of this institute. If you accept this offer, the Commission does not need to bring the meridian telescope that you have announced.

The equatorials of this observatory are made by Fraunhofer, by Würdeman and by Repsold, and measure, respectively, 0.11, 0.16 and 0.23 m in aperture and 1.40 m, 2.60 m, and 4.25 m in focal length. The lenses of the last one are the work of Mr. Merz.

I have seen in some correspondence that the Belgian commission will not be the only one arriving from Europe in order to observe that phenomenon, and since I must assume that these commissions will chose special points to establish their observatories, not only the purpose of these should be considered, but also, in order to prevent the possible case that the atmospheric condition prevents work in a given location, I take the liberty to announce in addition that whatever point will be chosen by [the commission] of that Republic, the same facilities will be found that I have indicated to you with respect to Santiago. I hope that, if you have the opportunity, that you can use to communicate the previous facts to the above-mentioned commissions.

With the sentiments of my distinguished consideration, I take the honour to offer myself to you, Mr. Director, as your zealous and certain servant.

José Ignacio Vergara.

In fact, other researchers from abroad did come to Chile: the French would establish their observing station at Cerro Negro, an area near the town of San Bernardino, a few kilometres south of Santiago; the Americans in the park (now called Parque O'Higgins) in Santiago; and the Germans and Brazilians in Punta

Arenas, the (then) only major settlement in the southernmost twelfth region of Chile. Details are found in Duerbeck (2004a,b).

The Belgian 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 and Niesten (1883) and in Houzeau (1884b). A forty-five day trip on the steamer *Denderah* (of the German *Kosmos* line) brought them from Antwerp to Valparaiso, and following a five hour railway trip they arrived in Santiago on 1882 September 2.

A few days after arrival, the Belgian commission began to install its instruments in an annex of the National Observatory (Figure 12) "... somewhat to the south and facing the large tower that contains the new equatorial ..." (Zegers 1883:173). In the name of the Sociedad Nacional de Agricultura, the Director of the Quinta Normal, René F. Le-Feuve, offered the Belgian astronomers living quarters near the Observatory grounds.

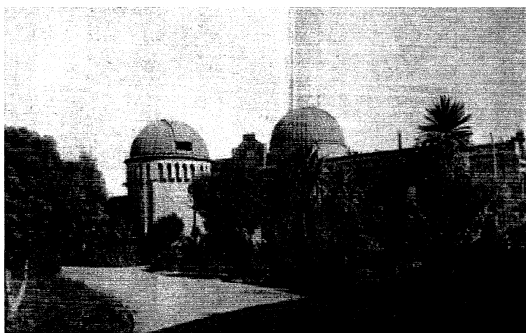


Figure 12. The Chilean National Observatory in the suburb of Quinta Normal in Santiago (provided by H Alvarez)

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 1884b). Indeed, 606 measurements of the position of Venus were taken with Houzeau's heliometer, and additional observations were made with refractors. The latter ones showed the phenomenon that had already plagued the eighteenth century observers, the notorious 'black drop effect' that appears at second and third contacts (Figure 13) and makes accurate timings of internal contacts virtually impossible. Nonetheless, Louis Niesten wrote Zegers (1883:177) that "The measurements were carried out with the utmost easiness, and with a great precision ...", and Zegers added: "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."

After completing their observations, the party went by railway to Santa-Rosa, crossed the Cordillera on muleback, and again by train to Rosario, where a steamer took them to Buenos-Aires. After short stays in Montevideo, Rio de Janeiro and Petropolis, they returned on the steamer *Sénégal* (of the Messageries Maritimes) via France to Belgium, happily ending "... the first scientific expedition organized by Belgium ..." (Houzeau and Niesten 1883).

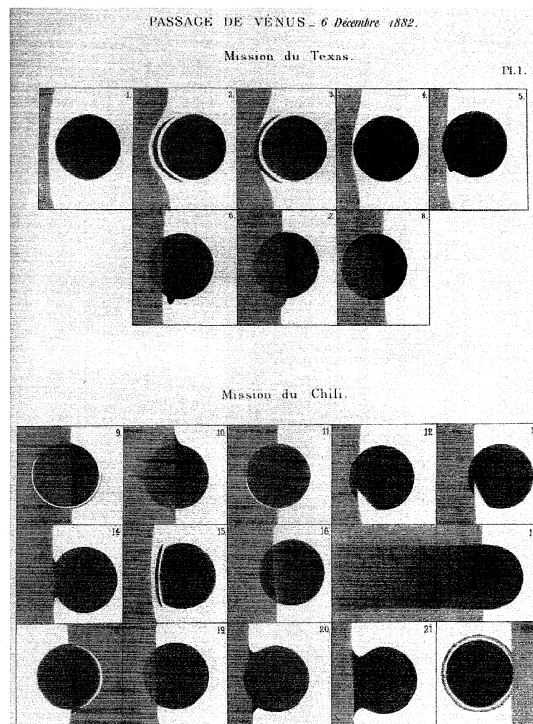


Figure 13. Visual black drop observations, recorded by E Stuyvaert in San Antonio and by C Lagrange in Santiago de Chile (from Houzeau 1884).

6 RESULTS

Two years after the transit, Houzeau (1884a,b) published reports on 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 did 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 $8''.911 \pm 0.084$ 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.

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 Newcomb's varying views on how to handle the problem of solar parallax (see Dick *et al.*, 1998). And when a suitable minor planet—Eros—was discovered, which provided all the advantages and none of the disadvantages, the method of Venus transits fell into oblivion. There was no twentieth century Encke who tried to homogenize the nineteenth century results. But the importance of the solar parallax, which was seen as just one element in the system of astronomical constants, was clearly recognized by some leaders in the field. Astronomers like Harkness (1891) and Newcomb (1895) set out to determine such a system, built on foundations that Houzeau had earlier laid when he compiled the first—and perhaps the 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, someone who was both a compiler and a researcher, a Republican and a 'Royal astronomer', a Belgian and a cosmopolitan.

8 ACKNOWLEDGMENTS

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APPENDIX I GEOGRAPHICAL INFORMATION ABOUT THE BELGIAN OBSERVING STATIONS

Station	Longitude	Latitude	Elevation	Location
San Antonio, Texas	98°27'45" W	+29°26'33"	228 m	Fort Sam Houston
Santiago de Chile	70°41'45" W	-33°26'42"		Garden, Obs. Nac.

Dr Christiaan Sterken is a Research Director at the Belgian Fund for Scientific Research (FWO), and a Guest Professor at the Vrije Universiteit Brussel, Belgium where he teaches courses in observational astronomy and the history of physics. His principal field of research is photometry of pulsating variables (S Dor stars, β Cephei stars, δ Scuti stars) and comets. He has edited several Proceedings of Workshops on the history of astronomy.

Dr Hilmar W. Duerbeck is honorary professor at the University of Münster, Germany, and a research associate at the Vrije Universiteit

Brussel, Belgium. His research interest is focussed on observational studies of binary stars and cataclysmic variables, and on late stages of stellar evolution. In collaboration with Daniel Fischer, he has written two popular books on the Hubble Space Telescope. He is interested in the history of cosmology and the history of astronomy in Germany. He serves as one of the secretaries of the History of Astronomy Working Group in the Astronomische Gesellschaft, and is a member of the Transits of Venus Working Group of Commission 41 of the International Astronomical Union.