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The German transit of Venus expeditions of 1874 and 1882: organization, methods, stations, results

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Abstract
The first major Government-funded German scientific enterprise was triggered by a smaller one to observe the total solar eclipse of 1868. The photoheliograph built for this occasion was later used for transit of Venus observations, together with three similar instruments. Furthermore, five small Fraunhofer heliometers were used to visually measure the position of Venus on the solar disc. The 1874 expeditions went to Tschifu in China, Kerguelen, Auckland and Mauritius Islands, to Isfahan (Persia) and to Luxor (Egypt). The low accuracy achieved from the photographic observations led to the abandonment of such studies in the next transit. The 1882 transit expeditions went to Hartford (Connecticut), Aiken (South Carolina), Bahia Blanca (Argentina), Punta Arenas (Chile), and Royal Sound (South Georgia Island). Meticulous calibrations of the heliometers were carried out before and after the transits, and final results of contact timings, photographic and heliometric observations were only published in 1896.

Keywords: *Venus transits 1874 and 1882, German expeditions, photographic observations, heliometric observations*

1 INTRODUCTION

In 1868, the science writer Aaron Bernstein, whose popular books on the natural sciences would later inspire young Albert Einstein, sent a petition to the parliament [Reichstag] of the North German Federation (the German Empire would only come into existence 3 years later). His suggestion was to organize and support a German expedition to observe the total solar eclipse of August 18. After a feasibility study by Wilhelm Foerster, the Director of the Berlin Observatory, referees' comments from various observatory directors and astronomy professors, and some discussion in parliament, the project was granted 16,000 thalers (equivalent to 48,000 marks after the 1873 currency change), and expeditions were sent to Aden (South Arabia) and to Mulwar, a village near Bijapur (India). The recently-founded Astronomische Gesellschaft served as the controlling authority, and the (somewhat scarce) results were later published in its *Vierteljahrsschrift* (Bruhns, 1872). Nevertheless, this activity carried the seed of the next major project: an attempt to observe transits of Venus from various places on Earth. When this application was filed with the Federal Council, a detailed outline was requested, and scientists were nominated to carry out this task. Thus the *Commission für die Beobachtung des Venusdurchgangs* came into existence in 1869, and would cease its activities about 30 years later, when only two out of the original nine members were still alive, after having organized about ten expeditions, published six volumes totalling 3600 pages, and spent about 780.000 marks—an equivalent of about 12 million present-day dollars.

2 INSTRUMENTATION AND METHODS OF OBSERVATION

It seems that August Winnecke and Arthur Auwers (Figure 1) developed first plans in 1869. They had become friends in 1854, when Winnecke was studying in Göttingen, and Auwers was not yet 16 years old, but already an active observer. Now Winnecke had left his job in Pulkovo (Russia) for health reasons and was carrying out private research in Karlsruhe (he would later become the first Director of Strassburg Observatory), while Auwers was an Astronomer at the Prussian Academy of Sciences. Carl Christian Bruhns, Director of Leipzig Observatory, who had organized the 1868 solar eclipse project, soon joined the team. Bruhns and Auwers planned to file simultaneously—through the Prussian and Saxonian academies—applications to the respective Ministries that would pass them on to the Council of the North-German Federation [Bundesrath des Norddeutschen Bundes], asking for support. Although Auwers' application was delayed, the Council reacted favourably, but required a detailed research plan and a cost estimate, and requested that State Governments should suggest names of scientists to carry out these tasks to the Office of the Federal Chancellor. In this way, a 'Commission' was established, which was composed of the three initiators, and in addition the Directors of Bonn, Berlin, Gotha, and Hamburg Observatories (Friedrich Argelander, Wilhelm Foerster, Peter Andreas Hansen, and George Rümker) as well as the great-ducal Chancellery Officer Friedrich Paschen of Schwerin (Mecklenburg). The latter, a student of Gauß, was well-known for his geodetic work. After the foundation of the German Empire in 1871 January, two astronomers from southern states were added: Eduard Schönfeld from Mannheim Observatory and Ludwig Seidel from Munich Observatory.

Two methods could be applied to determine the solar parallax. The visual method involved measuring the motion of Venus across the solar disc by means of heliometers. Since the instruments should be comparable in size, a series of quite old-fashioned Fraunhofer heliometers (and those produced by his successor Utzschneider) of 3½ feet focal length was slightly modernized to facilitate the reading of the settings by the Repsold company. The photographic method was based on taking a series of momentary exposures of Venus transiting the Sun by means of a photoheliograph; the plate analysis would be carried out after the return in Schwerin (later Leipzig), where measuring facilities were available. The instrument used for the solar eclipse at the Aden station was thought to be suitable, although the image scale was increased by about a factor six by means of an optical device made by Schröder (Hamburg). Three more instruments were ordered, to be used at different stations. In addition, the expeditions carried conventional refractors for the observations of

contacts, chronometers, transit and universal instruments for the determination of longitude and latitude, models for training contact timings and heliometer settings, and various meteorological instruments.

Figure 1. The president of the German Venus Transit Commission, Arthur Auwers (Shane Archives, University of California, Santa Cruz).

The Fraunhofer heliometers had apertures of 34 lines (75 mm) and focal lengths of 3½ feet (1067 mm). Heliometer A of Breslau (Wroclaw) Observatory was used at Tschifu and Aiken, heliometer B of Gotha (later Strassburg) Observatory was used at Betsy Cove and Bahia Blanca, heliometer C of Göttingen Observatory at Port Ross and Punta Arenas, and heliometer D of Berlin Observatory at Mauritius and Hartford. A slightly-different heliometer E, built for Wilhelm Olbers and kept at Hamburg Observatory, was used in Luxor and South Georgia. Heliometers B and C still survive in the respective Observatories, while E is now in the Deutsches Museum Munich.

The Steinheil photoheliographs had slightly different apertures, focal lengths, and focal magnifications. Heliograph A is the original Astronomische Gesellschaft instrument (two-lens aperture: 161.6 mm, 1905 mm focal length, magnification 6.1×) and was used at Betsy Cove; heliograph B (two-lens, 163 mm, 1905 mm, 6.25×) was used at Tschifu; heliograph C (four-lens, 106.8 mm, 1981 mm, 5.5×) was used at Port Ross, and heliograph D (four-lens, 106.8 mm, 1981 mm, 5.4×) was used at Ispahan. Heliograph C is kept at the Dr Remeis Observatory in Bamberg; heliograph A (minus its objective lens, but with a special mounting designed for it by P A Hansen) still survives, and is in the Astrophysikalisches Institut Potsdam.

The photographic observations were straightforward: after a plate was inserted, the shutter was released and a very short exposure of the Sun was taken (the instruments had, except in the case of the Hansen mounting, no equatorial mounting and no tracking provision). More effort was taken concerning the preparation, development and fixing of the photographic plates, and both dry and wet plates were employed.

3 THE EXPEDITIONS OF 1874

Members of expedition I (Tschifu) were astronomers Wilhelm Valentiner (Leiden, Netherlands), Carl Adolph (Elberfeld, today Wuppertal), Eugen Reimann (Ratibor, Upper Silesia) and photographer Carl Kardaetz from Französisch-Buchholz (a village near Berlin). Assistants were the mechanic Friedrich Deichmüller (Leipzig) and painter Oskar Eschke (Berlin). Besides the passengers, there were 107 boxes, with a total weight of 14 tons. The two-month trip from Southampton to Shanghai with a stopover in Bombay was made by British steamers, and the remaining distance was travelled on a small US ship. Tschifu was reached on October 27.

The station was erected on a piece of land enclosed on three sides by a wall, while on the fourth side there was a steep slope (Figure 2). The crew of the corvette SMS *Arcona*, which was stationed in East Asian waters, assisted with the setup.

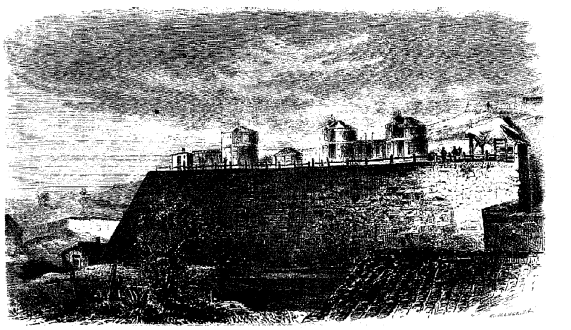

Figure 2. The observing station in Tschifu (Jahrbuch der Illustrirten Deutschen Monatshefte).

A letter from Kardaetz (1874) describes the decisive time at the Tschifu station as follows:

> The day before we were thoroughly frightened because of the weather. No one could sleep during this night. We were lucky, at 3 a.m. the wind changed direction, chased the clouds away, and we had the most marvellous sunrise. At 7 a.m. everyone was on the spot. Baron von Reibnitz, commander of SMS Arcona, said: "This spot looks like the deck of an armoured frigate which is cleared for action." All ships in the harbour were dressed, all consulates and many private houses flew flags, the Chinese in town burned fireworks since morning, therefore begging for clear skies. The requests have been granted, since we had quite clear skies for about two hours. At the end of the phenomenon, with the last photographic plate, it was like cut off, the sky was completely covered with clouds. In the morning of the following day, we had snow and hail.

Members of expedition II (Betsy Cove, Kerguelen Island) were Carl Börgen, Director of the Naval Observatory in Wilhelmshaven, Arthur Wittstein (Munich), Ladislaus Weinek (Budapest, on temporary leave at the photographic test station in Schwerin), zoologist and photographer Theophil Studer (Berne, Switzerland), photographer H Bobzin, and mechanic Carl Krille (both from Schwerin).

Since British and US astronomers had also established stations on Kerguelen, different locations were chosen to minimize the chance of a clouding out:

the British were in Christmas Harbour to the North, the US scientists in Royal Sound to the South, and the Germans chose Betsy Cove within Accessible Bay on the eastern side of the Island. The Kerguelen expedition was part of a two-year research voyage of the steamer corvette SMS *Gazelle*, which also carried out oceanographical, geographical, botanical, and zoological studies. The *Gazelle* left Kiel harbour on June 21, sailed to Cape Town, and anchored in Betsy Cove on October 26 (Figure 3). One day later, the search for a suitable place began, and Börgen (1898) noted that

> At the southern side of the Cove the ground slowly rises to a hill, which piles up in steep rocks in the last 40 feet. At half-way we noted a number of crosses painted in white, which indicate the graves of the whalers who lost their life here. The only somewhat dry spot which was flat as well was found above the graves on the foot of the above-mentioned rocks, and we decided to choose this point.

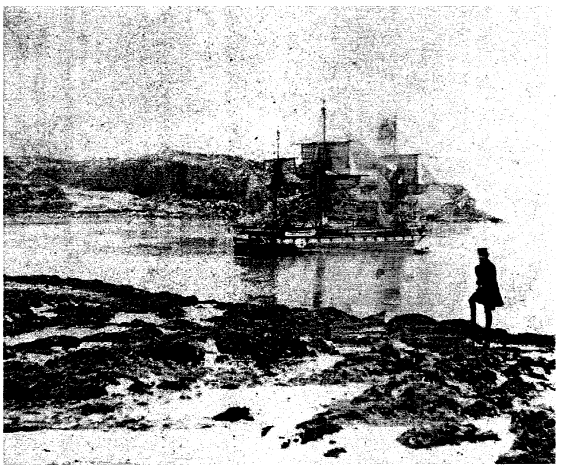

Figure 3. Kerguelen Island. Corvette SMS. *Gazelle* in Betsy Cove, Weinek in the foreground (Universitäts-Sternwarte Göttingen).

Construction was carried out with the help of the *Gazelle's* crew (Figure 4), and two of the naval officers also participated in the observations (Figure 5). Weinek (1911) noted his impressions of the voyage and the transit in a lengthy manuscript. His report of the activities at the time of the transit are quite illustrative:

> In the evening of December 8, it was still raining; on the 9th, the day of the phenomenon, the sun rose in a clear and pleasant sky. The ingress should occur shortly after 6 ½ a.m., the egress at 11 a.m. A few minutes before the event, everybody hastened to his place, the astronomers to their telescopes, the photographer to the darkroom. Börgen stood at the heliometer, Weinek at the refractor, and Wittstein at a 3 ½ foot telescope. ... In the meantime, the sky became covered with a quite thick white veil; above the snow-covered mountains in the west darker clouds were looming. Venus, a small black disc 1/30th of the sun's diameter, slowly started to move into the sun. We waited with tension for the inner contact of the two rims, since if we succeeded in observing it we could say that we did not come in vain to these barren regions. The critical moment is approaching, another glance at the ticking chronometer to verify the second which is counted in thought. Venus seems to intend to detach from the solar rim, a bridge is forming still, it becomes thinner, and finally it breaks in two. This was the moment to be observed, and we were joyful to have established it. ... While Venus is now standing freely inside the sun, the astronomer's work changes; distance measurements of Venus from the solar centre, or more correctly, distance measurements of both rims, first by eye with the heliometer, and second, with the photographic telescope, where the light records the positions of Venus again and again. Börgen stayed at the eyepiece of the heliometer, while Wittstein continuously read the scale of the objective; whereas Weinek and Crille rushed to the photoheliograph, where the first carried out the exposure, while the second took care of the changing of plates, which were prepared by Bobzin and Studer in the darkroom. We were pleased with the work achieved, especially since the observation of the inner and outer egress of Venus succeeded completely. After December 9, muddy and stormy weather prevailed, and we had to wait until December 19 to photograph the sun again.

Figure 4. The station on Kerguelen Island. Domes of refractor and heliometer on the left side, darkroom cabin and photoheliograph dome on the right (Universitäts-Sternwarte Göttingen).

At the end of January, the station was dismantled and the return trip was begun. On February 26, Port Louis on Mauritius was reached, where the astronomers took a mail-steamer, while the *Gazelle* continued her trip around the world (together with zoologist Theophil Studer), finally reaching Kiel in 1876 April.

Figure 5. The scientists and two officers of the Kerguelen expedition. Front row, sitting, from left: sea officer, Krille, Bobzin; standing, second row: sea officer, Studer, Börgen, Wittstein, Weinek (Estate of H Buchwald, made available by W Fuchs, Hamburg).

Expedition III (Port Ross, Auckland Island)

consisted of two astronomers, Hugo Seeliger (Bonn) and Wilhelm Schur (Strassburg), two photographers, Hermann Krone and Guido Wolfram (both from Dresden), and two assistants, mechanic Hermann Leyser Jr. (Leipzig) and Johannes Krone (Dresden).

Most of the participants travelled in a British steamer from London, which took fifty-three days to reach Melbourne, where they were already expected by Seeliger and two officers from the Imperial Admiralty. Five days later, the chartered French barque *Alexandrine* transported the expedition members, boxes and a wooden house (that was made in Australia) to Auckland Island. The station was built on the beach at Terror Cove, near the settlement of Port Ross. One Krone photograph (Figure 6) shows the house and domes, another the photoheliograph inside its dome (Figure 7), and a third is a paper copy of an Auckland Island plate of the Venus transit (Figure 8). Since all original plates of the German expeditions were destroyed during an air raid in World War II, this is possibly the only record of such a photographic observation made by German expeditions.

Figure 6. The station on Auckland Island (Agfa Photo-Historama).

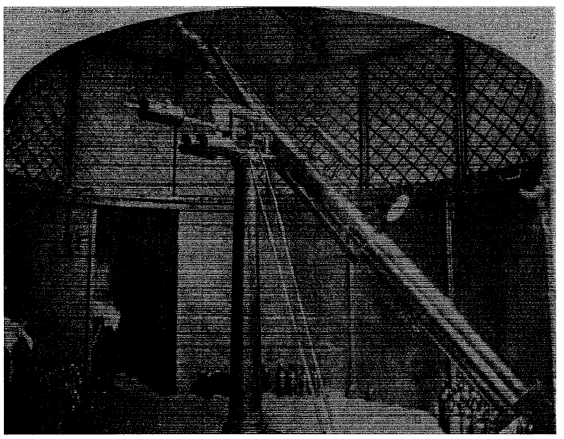

Figure 7. The photoheliograph in its dome on Auckland Island (Krone-Sammlung, Dresden).

The Auckland Island station remained active from 1874 October 18 to 1875 March 6. One of Seeliger's (1898) last entries in the official diary states:

> March 5. The last things belonging to the lodge are brought on board. During our last visit to the island, the pillar of the passage instrument, on whose stone plate Mr. Krone Jr. has incised the words *German Expedition 1874*, was recommended to the special protection of the shepherd who lives on the island.

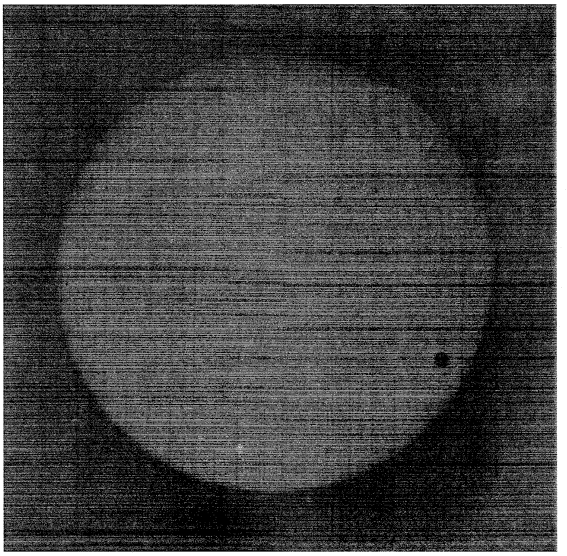

Figure 8. An Auckland photograph of the Venus transit (Krone-Sammlung, Dresden).

The best look into the activities of this expedition (Figure 9) is provided by the photographs, reports, and poems of Hermann Krone, one of the pioneers of photography in Germany. He wrote for various newspapers and journals, produced and sold three photographic series *Die Auckland Inseln*, and around the turn of the century wrote several volumes of poems. Two of these, properly entitled *Father and Son on a Trip Around the World*, deal with the events that were twenty-five years in the past, and in their rhyming emulate the Odyssey.

Figure 9. The members of the Auckland expedition. Front row, from the left: Seeliger, Schur, Krone jr., Leyser, back row: Wolfram, Siegel, Becks, Krone sr. (Agfa Photo-Historama).

The purely visual expedition IV (Solitude, Mauritius) consisted of two astronomers, Moritz Löw (Berlin) and Carl Frederick Pechüle (Hamburg), and two assistants, mechanic Hermann Dölter (Strassburg) and castellan Dietrich Heidorn of Göttingen Observatory. Mauritius had been chosen to have at least one 'meteorological reliable' observing place in the Southern Hemisphere, in case the expeditions to Kerguelen and Auckland Islands—which were prone to storm, rain and snow—would fail. The party went

by train and ship to Aden, and then by mail-steamer to Port Louis. A free area with an uninhabited country house, 'Solitude' (Figure 10), was chosen in the south-east of the island near the railway to Mahébourg, since Lord Lindsay had installed his private expedition at Belmont in the north-east. Contrary to expectations, the weather was bad, but a few heliometer measurements were obtained.

Figure 10. Mauritius expedition members and natives in front of the dwelling-house Solitude. Between the central pillars, from left to right: Heidorn, Löw, Pechüle, Dölter (Universitäts-Sternwarte Göttingen).

The purely photographic expedition V (Ispahan, Persia) comprised four persons, photographer Gustav Fritsch, Assistant at the Anatomical Institute of Berlin University, astronomer Ernst Becker (Berlin), and two more photographers, Franz Stolze (Berlin) and Hugo Buchwald (Breslau – now Wroclaw). The party went by train through the Baltic provinces to Zarizyn (now Wolgograd), took a steamer down the Volga to Astrakhan, across the Caspic Sea to the Persian port of Rescht, and then a caravan of fifty-eight animals to Teheran. After an audience with the Shah, the scientists continued their trip to Isfahan, where a 'Garden palace' outside the city was used as a lodge, and the instruments were set up in the vicinity (Figure 11). An extract from a somewhat sarcastic report by Fritsch (1875) for an illustrated newspaper runs as follows:

> Soon a building was raised on the western part of the platform which excelled through its simplicity, when compared with the nearby castles of Shah Abbas, of a weird architectural style, resembling most closely a shielded battery. A person looking into the open space above the rampart with poor illumination may have thought to discover the muzzle of a heavy gun – the objective of the heliograph, which, however, aimed at the sun in a harmless way. A look inside in bright sunlight showed how the expedition members served the gun [see Figure 12], and how on command "Fire" the momentous shutter was released, which exposed the sensitized plate. Humour did not leave the expedition, except on that fateful day, when unfaithful Venus during its suspect approach to the sun threatened to veil herself completely. Sombre distress prevailed in the small room, until, using the rare light moments twenty useful photographic plates of the phenomenon were taken. The plates will hopefully form a valuable contribution to the material of the expedition, and we will therefore remember with some satisfaction the place near Ispahan, which carries on a base, not unlike a gigantic gravestone, the engraving: Deutsche Venus-Expedition 1874. May the stone soon be considered as a holy grave among the Muhammadans, and may remain unmoved for times to come.

Figure. 11 The station of the Persian expedition at the garden palace Baugh-i-Zerescht near Isfahan (After *Illustrirte Zeitung*, Leipzig).

Auwers himself went to an expedition to Luxor near Thebes in Egypt, financed by the Berlin Academy of Sciences. Here he observed the transit in company with the Pulkovo astronomer Wilhelm Döllen. The 'German-Russian' station was near the stations of the two British parties (Auwers 1878). The heliometer used by Auwers was the one made by Fraunhofer for Wilhelm Olbers, and was borrowed from Hamburg Observatory.

Figure 12. Members of the Persian expedition at the photoheliograph, from left to right: Stolze, unknown person, Fritsch, Buchwald, Becker (After *Illustrirte Zeitung*, Leipzig).

4 THE TIME BETWEEN THE TRANSITS

The photographic observations, into which some committee members had put much hope, turned out to

be disappointing. With one exception, the heliographs did not have a parallactic mounting, since the exposure times had been chosen so short that the Sun was imaged sharply also with a stationary telescope. It had been ignored that the air turbulence would cause a strong deformation of the images. Foerster precisely describes the matter in his memoirs (Foerster 1911):

> During the preparations, we had to try hard to restrict the effects of sunlight on the photographic plate to the most minute time, and we succeeded not to overstep the exposure time of a plate of one ten-thousandth of a second. Only in this way could we obtain sharply limited images of the solar disc and the details on it. When we proceeded to the exact measuring of the photographic solar images of our Venus expeditions of 1874, it was found that the photographic momentous exposures of the sun images are completely unsuitable for the finest measuring results, and this is because of the enormous fluctuations, which had not been known until then, which the propagation direction of the light rays suffers because of the continuous variations of the states of the different atmospheric layers.

The solar limb was poorly defined, and the image of Venus appeared deformed, sometimes five-sided. Commission President Auwers, as a 'classical' astronomer suspicious of the 'modern' technique of photography, decided without much protest from his Commission colleagues to cancel photographic observations during the 1882 transits. This would also save a lot of money (the 1874 expeditions—five to often remote sites, versus four in 1882—cost almost four times as much as the latter ones).

5 THE EXPEDITIONS OF 1882

Favourable places for the 1882 Venus transit were found in the Western Hemisphere, and it was decided to have two northern and two southern stations, two in the United States (at Hartford, Connecticut, and Aiken, South Carolina), and two in South America (at Bahia Blanca in Argentina, and Punta Arenas in Chile). In addition, the German Polar Expedition of the First International Polar Exploration Year was on the island of South Georgia (south of the Falkland Islands), and was also equipped with a dome and the Hamburg heliometer.

Expedition I (Hartford) consisted of astronomers Gustav Müller (Potsdam) and Friedrich Deichmüller (Bonn), astronomy student Julius Bauschinger (Munich) and technical assistant Hermann Dölter (Diedenhofen – now Thionville). The Secretary of State for Connecticut had offered "... the southern part of the Capitol grounds..." for the station, but because of a restricted horizon and possible disturbance by a curious public this was politely declined. Instead, an offer by Trinity College professors was accepted to erect the station on the campus grounds outside the city, and the observers also found a place there where they could stay. A long official report by Müller (1898) describes the activities at the station, and illustrations give a very good impression of what it looked like (Figure 13) and the activity during the transit (Figure 14). After a time of heavy frost, it was thawing the day before the transit. It then rained during the night, and in the morning the sky was overcast. One hour after ingress, the first heliometer measurements could be made, but clouds also disturbed the egress.

Expedition II (Aiken) consisted also of four persons, astronomers Julius Franz (Königsberg, now Kaliningrad), Hermann Kobold (Konkoly Observatory, Hungary), astronomy student Adolf Marcuse (Berlin), and mechanical assistant F Carl (Würzburg). Franz (1884) has provided a detailed report. The party went by steamer to New York and then by train to Aiken, South Carolina. "This little town with only 2000 inhabitants is rapidly growing and, since it is considered as a health resort, is visited by many foreigners because of its mild climate." The station was built on the northern edge of the city (Figure 15). A long period of clear weather ended on December 5, and the night before the transit it was raining. In the morning, the sky was covered, but the clouds became thinner. Three sets of measurements were made, and the station was closed on December 22. The sea trip back to Hamburg was made on the steamer *Cimbria*, which sank on its next Atlantic crossing!

Members of expedition III (Bahia Blanca) were Ernst Hartwig, Assistant at Strassburg Observatory, Bruno Peter, Observer at Leipzig Observatory, Walter Wislicenus, astronomy student in Strassburg, and H Mayer, Mechanic of the Physico-Mathematical State Collection in Munich. Peter's (1884) report, written in Spanish, gives a detailed description of the trip, the station, and the observations. A steamer brought the members from Hamburg to Buenos Aires, and a small warship of the Argentine Navy took them to Bahia Blanca. A little farm west of the settlement owned by Domingo Pronzati was chosen, "... the occupied terrain was encircled with a fence to shield it from animals which grazed freely in the pampa ...", and the domes were erected in the vicinity of the house (Figure 16).

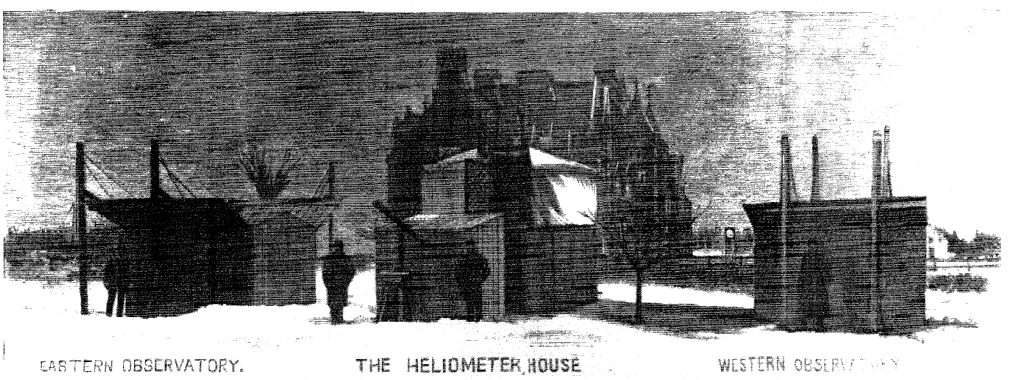

Figure 13. The station in Hartford, Connecticut, in front of Trinity College (Frank Leslie's Illustrated Newspaper, made available by the Connecticut Historical Society).

On the day of the transit, the Sun rose in a layer of cloud, but ten minutes before first contact the clouds dissipated and the contact was observed; however, the second was lost by new clouds. During a clear stretch, two sets of measurements were taken, then strong wind brought forth new clouds and it started raining. Then the Sun reappeared, measurements were continued, and egress was observed.

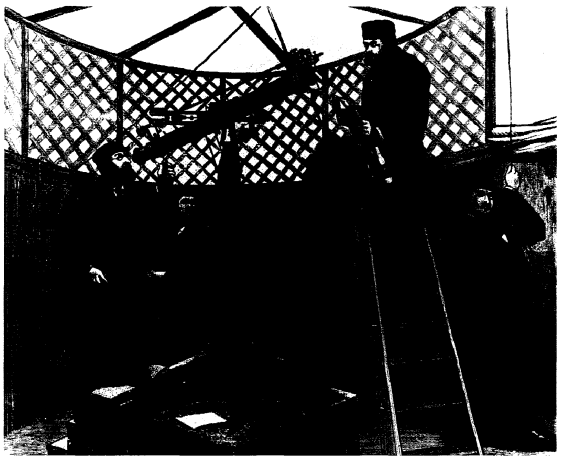

Figure 14. The heliometer observations in Hartford. At the telescope: Müller (left) and Deichmüller (right), Bauschinger taking notes in the background, Dölter is operating the dome slit (Frank Leslie's Illustrated Newspaper, made available by the Connecticut Historical Society).

Members of expedition IV (Punta Arenas) were astronomers Friedrich Küstner and Paul Kempf from Berlin, geologist Gustav Steinmann from Strassburg, and mechanic Friedrich Schwab from Marburg. Auwers decided on short notice to join the expedition, along with his servant Bohne. A steamer brought the party to Montevideo, and they took another one to Punta Arenas. Auwers (1883) gave many details in an address to the Academy:

> The town has at present only about one thousand five hundred inhabitants, and is only a group of little wooden houses scattered copiously on the sloping green lawn. Their appearance in primitive forms and partly in the natural colour of weather-beaten wood, partly, including the peculiar light-house which forms the most prominent object on the beach, with a fantastic colourful paint, fits perfectly into the landscape.

The station was erected near the light-house (Figure 17), and the team started to practice observations with an artificial Venus transit model (Figure 18). Auwers describes the critical hours:

> Indeed, in the afternoon of [December] 5, rain started to pour with such a standard strength that hope sank deeply. The rising sun illuminated a transparent blue sky, only swarms of small cumulus arose behind the Cordillera and were driven by moderately strong western wind over Punta Arenas.

First contact occurred, and twenty minutes later, the important second one: "Just when the light thread will reach the solar limb, a thick cloud moves in front of it, and when it had passed one and a half minutes later, Venus stands completely inside the solar limb." In spite of this disappointment, many heliometer observations were carried out, and the two egress contacts were observed.

Figure 15. The station in Aiken, South Carolina. The heliometer dome is to the left, a small refractor shelter is in front. A wooden hut in the background houses the pendulum clock, a cabin with two slits contains the passage and universal instruments; a geodetic pillar is in the foreground. The refractor dome is to the right. From left to right: unknown person, Carl, Franz, Marcuse, Kobold. (Archive of the Berlin-Brandenburg Academy of Sciences).

Expedition V (South Georgia) was an extraordinary project. Already before 1874, the pioneer of German polar research, Georg von Neumayer, had given advice to the Commission concerning possible southern observing stations, and since the southern expedition of the German Polar Commission of the first International Polar Year 1882/83 was installed on the island of South Georgia, it was obvious to also equip it with suitable astronomical instrumentation. The station (Figure 19) was installed at Moltke Harbor (named after the steam corvette SMS *Moltke* that carried the expedition) in the Royal Sound, which was occupied by eleven people between 1882 August 20 and 1883 September 6. Observations were carried out by Carl Schrader, an observer at Hamburg Observatory, assisted by mathematician Peter Vogel, physicist Otto Clauß, and engineer E Mosthaff.

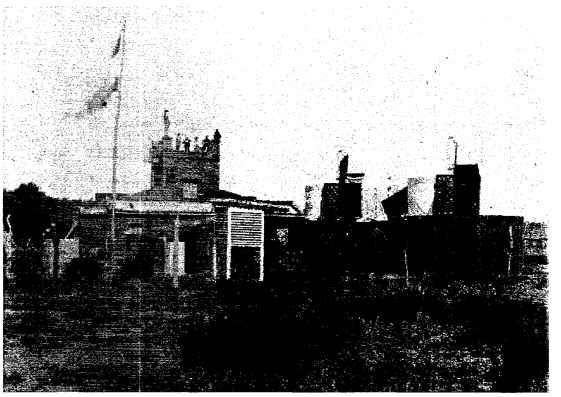

Figure 16. The station in Bahia Blanca, Argentina, showing also the house of Sr. Pronzati and some of its inhabitants. Wislicenus, Meyer and Peter (from left to right) are near the telescope; Hartwig's head is seen in the slit of the refractor dome (right) (Archive of the Berlin-Brandenburg Academy of Sciences).

The transit occurred in clear skies but presumably strong air turbulence as the observing log notes "very strong storm", and Mosthaff reports:

> The observation of the Venus transit on December 6 was especially favourable, which, in spite of strong storm, which endangered the rotating dome so that it had to be kept by three or four men with ropes, gave a quite favourable result because of the

> fact that the weather remained bright all day long, and the sun remained uncovered. (Mosthaff and Will 1884):

Auwers' comments indicate obvious errors in recording, setting and scale-reading, as well as poor calibration of the Hamburg Observatory heliometer, and he notes that the observations of the South Georgia station were of little use, that is they could not improve the result based on the 'official' heliometer stations of 1874 and 1882.

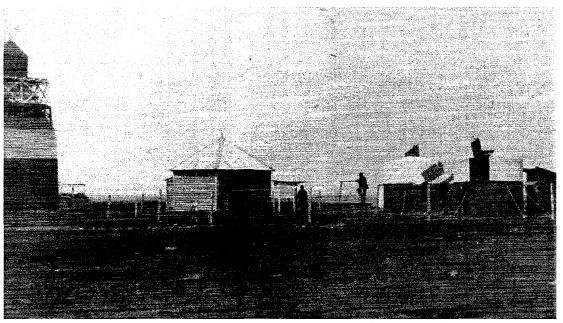

Figure 17. The station in Punta Arenas, Chile (Archive of the Berlin-Brandenburg Academy of Sciences).

Figure 18. The members of the Punta Arenas expedition in front of a Venus transit model on a pillar. From left to right: Kempf, Küstner, Auwers, Steinmann, Schwab, Bohne (Archive of the Berlin-Brandenburg Academy of Sciences).

6 ANALYSIS OF THE MATERIAL

The transit of 1882 meant the end of the proper observations, but by no means the end of calibrations, or investigation of the properties of the heliometers at different temperatures etc., that were carried out at Berlin and Strassburg Observatories. Six quarto volumes totalling 3,600 pages were edited by Auwers between 1887 and 1898, and these contained instructions, reports, measurements, reductions, and finally the overall results of the project. Auwers painstakingly presented the complete material, even including uncomplimentary remarks by expedition members (for example: "Our splendid medicine-chest and the even more splendid user's manual obviously leave us in the lurch, here like in all other cases.", along with Auwers' footnote: "Ed. could not omit anything ... The composition of the chest and the manual had been done by a medical man, with several years experience of travel in other continents and uncivilized countries"). Auwers painstakingly analysed all observations, visual contacts, photographic positions, and heliometric settings. He also filed all of his correspondence in a meticulous way, so that at present 110 files exist (only one has been lost), filled with letters and drafts, manuscripts and proofs, invoices and receipts, sea charts and steamer timetables, as well as some photos, often marked with stamp of receipt and inventory number. But this is only one side of the picture. Some expedition members wrote popular reports (we have given some examples above), and a few surviving private letters from Fritsch to Foerster (who had familial ties) show that Auwers' apparently arrogant as well as book-keeping manners were certainly not appreciated by everyone—although it should be said that only such a person could successfully carry out so vast a project, involving many scientists and assistants with differing tempers and temperaments.

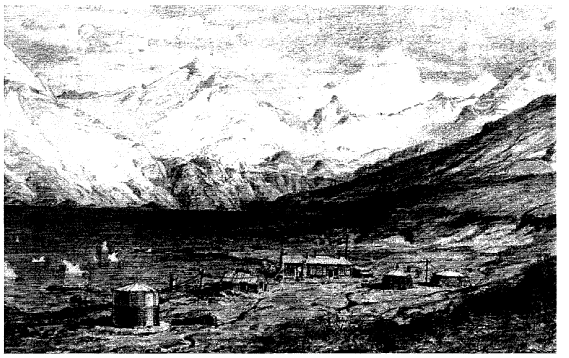

Figure 19. The station at Moltke Bay, Royal Sound, South Georgia (drawing by Mosthaff; Neumayer 1890/91).

As seen by the general public, the project was a resounding success, and this is reflected in a letter the Emperor wrote Auwers on 1884 July 4:

> When in the years 1874 and 1882 the transit of the planet Venus in front of the solar disc was approaching – a celestial phenomenon which is extraordinarily important for many research purposes, and which will only occur again after more than a hundred years – whose full utilization was depending on a collaboration of many astronomers in different remote points on earth, Germany also participated in this project by sending several scientific expeditions. Effectively supported by my navy, these expeditions occupied a series of stations which were especially important for the observation of this phenomenon, the first time in the range between the Chinese coast, Persia and Egypt on one hand and the borders of the Antarctic on the other, the second time between the north and the southern tip of America. Under your [Auwers] prudent and devoted guidance, German science managed in a high degree to win success and appreciation in a field of earth-embracing activities, in which in previous times Germany had to stand down in similar occasions as compared to the achievements of other nations. The more vivid was the interest, with which I have followed the ventures of German science for the observation of the phenomenon since their beginnings; the more joyful is the satisfaction with which I consider their resultful [ergebnißreich] conclusion. Herewith I pay my tribute to your merits for this success, as well as to the true co-operation of all which have contributed to such a success; I furthermore express my thanks for the help and hospitality encountered in a high degree by our scientific expeditions, and which was rendered to them not only by compatriots living abroad, but also by many people of other nations... (Wilhelm I, 1884):

What did that "resultful" outcome look like? One has to browse carefully though Auwers' 3600 pages. He collects, corrects and analyses all contact observations, without attempting to determine a solar parallax according to Halley's method (Auwers, 1887–1898, VI: 49). The results of photographic observations of the four stations of 1874 are given (op. cit.:186), and a parallax value of 8″.810 ± 0.120 is derived. The detailed analysis of all heliometer observations follows (op. cit.:714), from which Auwers derives a value of 8″.8796 ± 0.0320. The photographic result is closer to the modern value of 8″.794148 within its—disappointingly large—errors, while the 'more accurate' heliometric value appears to be 1% too large. Obviously the heliometer observations suffered from uncorrected systematic errors (which were overlooked even by diligent Auwers), the cause is difficult to establish today.

7 CONCLUDING REMARKS

Around the time when Auwers finished the manuscript of the last volume, somewhere else in Berlin two little-known astronomers, Gustav Witt and Felix Linke, discovered a minor planet on a plate taken at the popular Berlin Urania Observatory. This planet, later named Eros, had a path that at times brought it close to that of Earth. Thus it offered the same advantage as Venus, without having its disadvantages, that is a poorly-defined disc in front of the solar disc, that had to be observed during daytime in poor seeing. At its opposition of 1900, a new and improved value of the solar parallax was derived, and interest in transits of Venus as a research tool rapidly vanished.

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10 APPENDIX 1: OBSERVING STATIONS

In the accompanying table, the geographic longitudes and latitudes of the German observing stations (in °, ′ and ″) are given. References indicate volume and page of the Auwers report; comments indicate drawn plans of the stations. Notes on the stations are taken from Auwers (1887-1898) and additional sources:

Tschifu, China: the site belonged to the merchant Clarke of the Ferguson Company, in the immediate neighbourhood of the Beach Hotel. After the transit observations, foundations had to be removed; a pole was buried at the site of the heliometer, and next to it a bottle with the names of the expedition members (Auwers, 1887-1898, I:307).

Betsy Cove, Kerguelen Island: the foundations were left in position.

Port Ross, Auckland Island: the pillar of the passage instrument, on whose stone plate Mr Krone Jr. has incised the words "German Expedition 1874", was recommended to the special protection of the shepherd who lives on the Island (Seeliger 1898). There is one sentence and one picture in the book of Allen (1997:145): "All that remains is the brick plinth on which they placed their apparatus." A triangular base of 5-6 layers of red brick is seen on page 103 in Allen's book.

Solitude, Mauritius: the station on the site belonging to count Rochecouste is determined by the pillar which belongs to the triangulation network of Mauritius. The co-ordinates refer to the passage instrument.

Ispahan, Persia: the station was on the site of the garden palace Baugh-i-Zerescht between Ispahan and the southern suburb Djulfa. On the plate of the foundation of the heliograph, the inscription "Deutsche Venus-Expedition 1874" was incised, and an agreement was reached with the administrator of Baugh-i-Zerescht to keep this place undisturbed for the following eight years—furthermore, the Persian Government declared to take care of the preservation (Auwers, 1887-1898, I: 309, and Fritsch, in Auwers, 1887-1898, II: 403).

Luxor near Memphis, Egypt: I have designated this as expedition 1874 (VI), since designation VI is never used in official documents. This is the "German-Russian Station" by Auwers and Döllen. Auwers' passage instrument was 464.78 m W and 497.37 m S of the obelisk in front of the Luxor temple (Auwers 1878:144). The longitude of the station is calculated using the correction given in (op. cit., I:309).

Hartford, Connecticut: there is a marker stone designating the place of the heliometer. Since Auwers (op. cit., I:463) states "... nothing is mentioned about a marking of the point ...", it is obvious that the marking was done by Trinity College scientists. Its inscription reads: "Transit of Venus/December 6, 1882/German Imperial Commission./Lat. 41° 44′ 47″/Long. 4h 50m. 46.4s. W." The marker was moved a few feet from its original location almost 50 years ago to make way for the construction of an engineering building. Both the marker and building remain in place (information provided by P Knapp; photo provided by M Johnson).

Aiken, South Carolina: the owner of the site, Mr Henry Smith, has agreed to take care of the pillar of the passage instrument; it was covered with a stone plate inscribed with: "Venus-Durchgang 1882/Deutsche Expedition II/Länge 5h 26m 52s.6 W./Breite 33° 33′ 51″" (Auwers, 1887-1898, I: 463).

Bahia Blanca: to fix the observing site, a pole was buried 2.3 m south of the heliometer; its distance from the SW corner of Sr. Domingo Pronzati's house (Figure 18) is 37.4 m.

Punta Arenas: Auwers (op. cit., I:465) mentions that the wooden houses were destroyed by fire, and new houses were built on the site of the station; a wall covers the pillars. A re-measurement by J Lederer, made in 1897, could not be included in Auwers' report.

Royal Bay, Moltke Harbour, South Georgia. I have designated this as expedition 1882 (V), since the designation V is never used in the official documents: No information on 'markers' is available from German sources, because the station was actually abandoned. The area was visited several times, a detailed report of the visit in 1982 January is given by Headland (1982), where also a map can be found. The ruins of the Moltke Harbour station are described. The collapsed iron skeleton of the 'Venus cupola' is clearly visible, and shown in a photograph.

Expedition	Station	Longitude	Latitude	Elevation	Ref.	Comments
1874 I	Tschifu	121 23 36.6 E	+37 32 48.1	12 m	I:308	
1874 II	Betsy Cove	070 11 04.6 E	- 49 09 13	17 m	I:308	plan II:186
1874 III	Port Ross	166 13 27.9 E	–50 32 14.4	4 m	I:309	plan II:190
1874 IV	Mauritius	057 40 00 E	–20 25 51.0	85 m	I:309	
1874 V	Ispahan	051 40 03.3 E	+32 38 16.2	1530 m	I:309	
1874 (VI)	Luxor	032 38 09.3 E	+25 41 40.7	?		see notes
1882 I	Hartford	072 41 34.5 W	+41 44 48.3	?	I:463	
1882 II	Aiken	081 43 05.7 W	+33 33 50.9	200 m	I:463	plan III:77
1882 III	Bahia Blanca	062 18 16.2 W	–38 42 49.0	20 m	I:465	
1882 IV	Punta Arenas	070 54 08.7 W	–53 09 39.3	10 m	I:465	
1882 (V)	Royal Bay	036 01 04.6 W	–54 31 00	?	I:466	see notes