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An international campaign of the 19th century to determine the solar parallax

The US Naval expedition to the southern hemisphere 1849–1852

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Abstract. In 1847 Christian Ludwig Gerling, Marburg (Germany), suggested the solar parallax to be determined by measuring the position of Venus close to its inferior conjunction, especially at the stationary points, from observatories on nearly the same meridian but widely differing in latitude. James M. Gilliss, astronomer at the newly founded U.S. Naval Observatory, enthusiastically adopted this idea and procured a grant for the young astronomical community of the United States for an expedition to Chile. There they were to observe several conjunctions of Venus and oppositions of Mars, while the accompanying measurements were to be taken at the US Naval Observatory in Washington D.C. and the Harvard College Observatory at Cambridge, USA. This expedition was supported by A.V. Humboldt, C.F. Gauß, J.F. Encke, S.C. Walker, A.D. Bache, B. Peirce and others. From 1849 to 1852 not only were astronomical, but also meteorological and magnetic observations and measurements recorded, mainly in Santa Lucia close to Santiago, Chile. By comparing these measurements with those taken simultaneously at other observatories around the world the solar parallax could be calculated, although incomplete data from the corresponding northern observatories threatened the project's success. In retrospect this expedition can be recognized as the foundation of the Chilean astronomy. The first director of the new National Astronomical Observatory of Chile was Dr. C.W. Moesta, a Hessian student of Christian Ludwig Gerling's. The exchange of data between German, American and other astronomers during this expedition was well mediated by J.G. Flügel, consul of the United States of America and representative of the Smithsonian Institution in Europe, who altogether played a major role in nurturing the relationship between the growing scientific community in the U.S. and the well established one in Europe at that time.

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1 Introduction

In the 17th century, determining the size of the earth's orbit (the astronomical unit) and thus, by applying Kepler's law, the size of the solar system was a matter of realising the dimension of the known universe. After the surge of Newtonian mechanics in the 18th century the precise astronomical unit became crucial to understanding the structure of the solar system, e.g. the masses of sun and planets and the perturbations of the Kepler orbits of planets and small bodies. Finally, in the 19th century, the first calculation of a stellar parallax by Bessel [Bessel 1839] showed that the astronomical unit is a key value in the cosmological distance ladder. It was therefore unsurprising that Benjamin A. Gould, a 19th century pioneer of the American astronomy stated in his introduction to the analysis of the above mentioned research campaign, *"The measure of the sun's distance has been called by the Astronomer Royal of England the noblest problem in astronomy"* [Gould 1856].

One of the main challenges to solving this problem was the parallax measurements of the inner planets Mercury and Venus during their transits. After some first observations in the 17th century, scientists vested all their hope of accurately determining the dimensions of the earth's orbit into the transits of Venus, recorded in 1761 and 1769. The first of these transits failed to improve the solar parallax value, but the results stimulated the scientists in their efforts for the next transit in 1769. The values then derived for the solar parallax from different participating groups ranged from $8''.42$ to $8''.82$. It was Franz Encke, who, after a detailed analysis of all data for both transitions, finally deduced a value for the solar parallax of $8''.5776 \pm 0''.0370$ [Encke 1824]. One critical point was that the data delivered by the two most distant stations, at Wardhus in Norway and at Otaheite on the Friendly Islands, be most accurate. On page 109 Encke says: *"The probable error in the observation of a contact being seven seconds is so great as to render the determination of the sun's parallax within $0''.01$ almost hopeless for the next two centuries. . . . Such precision would require a hundred of observers at Wardhus and the same number at Otaheide. . . . All the observations of 1761 together have but a value equal to three complete observations at Wardhus and at Otaheite. If the weather would have been good at the eight northern stations in 1769 and there had been eight good observations at the Friendly Islands, these sixteen observations would have been as valuable as the 250 observations of the two transits actually made"* [Encke 1824]. After Littrow discovered that Father Hell, the astronomer at Wardhus in 1769, had computed an erroneous time for his observations, Encke revised the computation of the solar parallax value for the transit of 1769 and, combining the corrected value with that of the transit in 1761, published the value $8''.57116 \pm 0''.0370$ [Encke 1835], which has been accepted since.

Two other methods had been suggested to find a more precise number for the solar parallax. Around 1760 Tobias Mayer [Mayer 1767] developed the so called lunar theory and used the motion of the moon to deduce the solar parallax. One of the perturbation terms depends on the angle between sun and moon, the coefficient of that term on the solar parallax. Later, in 1825 Bürg, used a more refined lunar theory to find a value of $8''.62 \pm 0''.035$ [Bürg 1825] and Laplace calculated a slightly smaller value of $8''.61$ [Gould 1856].

One of the earliest ideas of how to find the size of planetary orbits was to measure the position of Mars with observatories at different latitudes. In the 17th century Cassini and Richer made the first efforts to observe the declination of Mars. In 1750 Lacaille made more such observations during his expedition to the Cape of Good Hope and compared them with corresponding measurements in the northern hemisphere [Gould 1856]. At that time the instruments lacked the necessary precision. However, Encke did point out that *"these measurements can be useful to encourage the hope*

Fig. 1. Christian Ludwig Gerling (1788–1864).

that by a greater perfection of instruments we may become more independent of the transits of Venus, which occur so seldom" [Encke 1824].

It was Christian Ludwig Gerling who in 1847 came up with a *third method* (not counting the lunar theory): *the observations of Venus during the period of its retrograde motion, especially at its stationary points* [Gerling 1847a]. The paper presented here is based on publicly available information about the U.S. Naval expedition to the southern hemisphere and the scientific estate of Chr. L. Gerling containing his correspondence concerning this expedition [Gerling Archive].

2 Christian Ludwig Gerling

Christian Ludwig Gerling (Fig. 1) was born in Hamburg, Germany, in 1788. He was educated together with his longtime friend Johann Franz Encke, who later became director of the Berlin Observatory. After finishing school, Gerling attended the small University of Helmstedt, but in 1810 he continued his academic education in the fields of mathematics, astronomy, physics and chemistry at the University of Göttingen. He started to work at the observatory of Göttingen under Carl Friedrich Gauß and Karl Ludwig Harding, and, after some visits in 1811 to the observatories of Gotha (Seeberg), Halle and Leipzig, he completed his PhD in 1812.

After he received his PhD, Gerling entered a position at a high school in Cassel, Hesse. At that time he used a small observatory in Cassel for astronomical observations and occupied himself with calculating the ephemerides of the asteroid Vesta. He continued to seek a university position and finally in 1817 was appointed full professor of mathematics, physics and astronomy and director of the "Mathematisch-Physikalisches Institut" at the Philipps-Universität of Marburg. In spite of several offers he remained at the university in Marburg until his death in 1864 [Madelung 1996].

Gerling's scientific work was affected by two major topics: in his early period in Marburg from 1817 to 1838 he was well occupied with organizing the triangulation of Kurhessen. During that time Gerling did not have an observatory, so his astronomical work was reduced mainly to corrections on a section of Encke's "Berliner Akademische Sternkarten".

In 1838 the institute moved to a new home in Marburg at the "Renthof". After the building was reconstructed in 1841, he could finally put into operation his new but small observatory, built on top of a tower of Marburg's old city wall [Schrimpf 2010]. Gerling pursued the scientific topics of astronomy of that time, making meridional observations and differential extra-meridional measurements of stars, planets and asteroids, observations of lunar occultations, etc. mainly to improve the precision of star catalogs and orbit parameters of solar system bodies.

Carl Friedrich Gauß and Christian Ludwig Gerling started their relationship as a teacher and his student but during the following years they became each others counselor and finally close friends. Their correspondence not only contains details of scientific discussions but also reflects their close relationship [Schäfer 1927; Gerardy 1964]. Gerling died in 1864 at the age of 76. His estate has been stored in the library of the Philipps-Universität Marburg [Gerling Archive]. About 1000 letters of his correspondence with Gauß, Encke, Nicolai, Gilliss, Flügel and many more give an insight into his personal and professional life and can be a valuable source for historians.

3 The idea of the project

In 1841 Christian Ludwig Gerling was able to begin operating his new observatory. The discovery of new asteroids, beginning with (5) Astrea in 1845 and the expansion of the solar system after the discovery of the planet Neptune in 1846 must have encouraged many astronomers to increase their research into the solar system.

A clue to the ideas that occupied his time can be found in the letters that Gerling and Gauß exchanged [Schäfer 1927]. They encouraged each other to observe *"Leverriers planet"* ([Schaefer 1927, pp. 740 and 742]) as they called Neptune, but there is no hint at any special focus of Gerling's on the solar parallax. However, in 1847 Gerling published his article *"About the Use of the Venus Stationary Points for Determination of the Solar Parallax"* [Gerling 1847a] (title translated by the author).

There are two main points in this paper: First, Gerling suggests performing parallax measurements of Venus instead of Mars, because during the inferior conjunction, Venus is much closer to Earth than Mars is during its opposition, which thus increases the observed planet's parallax and reduces the error of the solar parallax derived. There is, however, a disadvantage in observing Venus: during the conjunction it is visible only at day time and only few bright stars can serve as comparisons for differential measurements. Under these conditions observatories required meridional instruments of highest quality to obtain results, which could improve the solar parallax value. Second, Gerling proposes observing Venus at the stationary points of its loop (Fig. 2), for two reasons. One of these is that at these points the distance between the sun and Venus is about 29° and, using equatorial instruments, Venus can easily be observed early or late at night with many comparison stars. The other reason is that at the stationary points the planet is moving so slowly that day-time meridional observations at different latitudes can easily be reduced by interpolation to the same meridian, if the longitudes of the observatories involved are fairly similar. Higher precision can be achieved by increasing the number of observations.

On July 15th, 1847, Gauß acknowledged the interesting article ([Schaefer 1927, letter no. 364]), but he was unconvinced that comparing meridional with equatorial measurements of lower quality would lead to an improvement of the solar parallax.

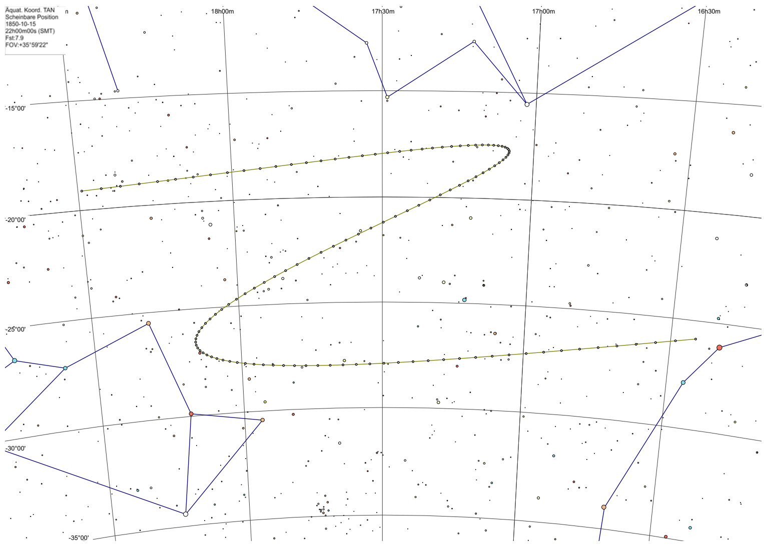


Fig. 2. The loop of the planet Venus in 1850/1851 according to JPL ephemerides DE423. Gerling suggested measuring the position of the planet through differential meridional and extra-meridional observations, especially at the stationary points of the loop, where the apparent motion of the planet is almost zero. He calculated a rough observation plan for the Venus loops of 1847 and 1849. However the final observations were made during the loop of 1850/1851.

Two days later Gerling sent his thanks to Gauß and, noting his concerns, he added that the same comparison stars used for differential measurements of Venus at its stationary points should have to be observed with meridional instruments when they are accessible earlier in the year ([Schäfer 1927, letter no. 365]). Gerling also published a statement with these additional explanations in the *Astronomische Nachrichten* [Gerling 1847b].

The success of the project required the cooperation of suitable observatories in different hemispheres of the world. In his publication [Gerling 1847a] Gerling considered observatories in Königsberg and the Cape of God Hope, in Washington and the Antilles, and of course in Greenwich. Gerling began collecting information about the situation of astronomy in different parts of the world. In his pursuit he contacted Dr. J. Flügel, the consul of the United States in Leipzig, Germany, to learn about the situation of astronomy in the United States ([Gerling Archive, Ms. 319/217], Flügel to Gerling, February 8th 1847). He also sought to directly contact someone in South America, and although this attempt was in vain ([Gerling Archive, Ms. 319/219], Flügel to Gilliss, May 15th 1847), Gerling was perhaps already thinking about a new observatory in that part of the world.

4 James Melville Gilliss

Before moving on to the realization of Gerling's idea, one must take a closer look at James Melville Gilliss, the key person in organizing and leading the expedition to the southern hemisphere. A good source of information about his life can be found in his memoir, read before the National Academy on January 26th, 1866 by Benjamin A. Gould [Gould 1866].

Gilliss was born in 1811 and entered the U.S. Navy at the age of 15. Being interested in scientific work, he applied for leave of absence in 1833 to pursue an education at the University of Virginia. In 1835 he continued his studies in Paris before returning to his professional duties as a lieutenant of the Navy in Washington. He was given responsibility for the care and distribution of charts and instruments required by national vessels and for the rating of chronometers by determining the time with transit instruments. In 1838 he joined the U.S. Exploring Expedition as the observer responsible for moon culminations, occultations and eclipses to determine differences in longitudes. Gilliss observed more than 10.000 transits, embracing the moon, the planets and about 1100 stars, and finally compiled the first report of astronomical observations conducted by a US scientist. B.A. Gould stated: *"Gilliss must be considered the first representative of practical astronomy in America. It was Gilliss who first in all the land conducted a working observatory, it was he who first published a volume of observations, first prepared a catalogue of stars"* [Gould 1866]. After his return from the expedition, the Secretary of the Navy assigned him the duty of preparing building plans and collecting the instruments for a new observatory. In September 1844 Gilliss reported the work complete and the observatory ready for use. However, it was Lieut. M. F. Maury, a young officer without scientific education or experience, who became the first director of the new U. S. Naval Observatory in Washington. Maury had become known for his contributions to charting winds and ocean currents, but never as an astronomer. Gilliss was assigned to duty upon the Coast Survey under Professor Bache.

It is very likely that Dr. J. Flügel made Gilliss and Gerling known to each other. Gilliss probably came into contact with Flügel while he was planning the instruments for the U.S. Naval Observatory [Gould 1866]. In turn, Flügel sent Gerling a volume of Gilliss' observatory report. After Gerling had a look at this report, he published a very positive note in the *Heidelberger Jahrbuch* of 1847 and in August 1847 Gilliss was elected a member of the *Naturwissenschaftliche Gesellschaft* ([Gerling Archive], Ms. 319/220, Flügel to Gerling, August 30th 1847).

In June 1847 Gilliss received a letter from Gerling introducing the idea of the Venus observations for determining the solar parallax. Gilliss was overwhelmed by this proposal, which should almost completely occupy his life henceforward. From 1849 to 1852 he operated the expedition to the southern hemisphere and, after returning, began with reducing the data. In 1855 the Congress of the U.S. enacted a law, that Navy officers without recent active duty on board of a Navy vessel, should be put on a "reserve list" and retired. Although Gilliss found his name on this list, the Secretary of the Navy offered him the same salary to continue his work and prepare the remaining volumes of his report. Gilliss was later returned to duty, in 1861 he received a commission as Commander and a year later as Captain ([Gerling Archive], Ms. 318/295, Gilliss to Gerling, November 23rd 1855, and [Gould 1866]). In 1858 and 1860 he went on expeditions to observe total eclipses. At the beginning of the American Civil War Maury left the U.S. Navel Observatory and finally in 1861 Gilliss was set in charge of this institution, *"a post which the scientific world had expected for him sixteen years before"* [Gould 1866]. He revived the idea of determining the solar parallax by simultaneous observations in Chile and in the United States – and finally succeeded! He died early in 1865 at the age of 54, just as the results of these observations were published.

During the years they were communicating, Gilliss and Gerling became friends, sharing personal matters of their professional lives and each others' family affairs. However, neither did Gilliss return to Europe nor Gerling travel to the United States; they never met personally.

5 The expedition to the southern hemisphere

A letter of Gerling's to Gilliss dated 17th April 1847 marked the beginning of the expedition to the southern hemisphere [Gilliss 1856][1]. In this letter Gerling explained the idea of the specific Venus observations including some first information about the Venus loops of 1847 and 1849, hoping to attract Gilliss' attention and through him that of the American astronomers. Gerling suggested the co-operation of many observatories in the northern part of the world with a few meridional instruments in the southern hemisphere, which *"perhaps is in your* (Gilliss) *power to facilitate"* ([Gilliss 1856, p. iv]).

It is remarkable that at that time the young and developing American scientific community was becoming involved in astronomical research but had not yet published a noticeable contribution to science [Rothenberg 1999]. Gerling's letter to Gilliss therefore came at an opportune time: new observatories had opened in the United States and the American astronomical community was waiting for a chance to participate in the progress of science. Gilliss' very first reaction was to pass Gerling's letter on to Prof. Sears Cook Walker (at that time at the U.S. Naval Observatory) and soon both were forwarding it to all American astronomers and observatories and to the *National Intelligencer*, one of the leading newspapers in Washington at that time. Noteworthy are the several articles this newspaper published during the preparations and actual course of the expedition.

Until November 1847 Gilliss studied the idea. Counting on the new U.S. Naval Observatory in Washington, the Harvard College Observatory, founded in 1839, and the observatories in Philadelphia and at West Point as possible northern stations, and on a new observatory on the island of Chiloé in the South of Chile as a southern station, Gilliss, the visionary, foresaw the relevance: *"I am the more keenly sensible of the noble opportunity now within our grasp to present the world, from our own continent as a base, the dimensions of our common system"* ([Gilliss 1856, p. v]).

5.1 Planning the expedition

In the fall of 1847 Gilliss and Gerling were busy collecting the opinions of well known astronomers. C.F. Gauß, though not really convinced that Gerling's method could result in a more precise solar parallax, did suggest testing the idea ([Schäfer 1927, letter no. 368]) whereas Prof. Boguslawski, director of the Breslau observatory welcomed and published it in his circular *Uranus*. F. Encke also sent an encouraging note.

Gilliss soon was able to convince all of the leading American astronomers! After receiving Gerling's forwarded letter Prof. A.D. Bache replied: *"I do not see, however, that the two reasons which strongly favor Dr. Gerling's method are met by any opposing arguments. The large number of observations upon which results may be found, and the independence of the new method with that formerly used, are, indeed, striking factors in this method"* [Gilliss 1856].

B. Peirce, professor of mathematics at Harvard University, responded: *"A more accurate measurement of the sun's parallax in the the method proposed by yourself*

[1] Gilliss included the organization and operation of the expedition, the observations taken in Chile and the data analysis in volume III of his report to the House of Representatives. There are however many other very important observation and measurements, which Gilliss reported in volumes I, II and VI. The volumes IV and V never have been published. The data planed to be included in these volumes where published later by the U.S. Naval Observatory in its Astronomical and Meteorological Observations (Washington observations) for 1868, app. I, 1871, and Astronomical, Magnetic and Meteorological observations (Washington observations) for 1890, app. I, 1895.

(Gilliss) *and Dr. Gerling cannot be regarded as inferior in importance to any problem in practical astronomy. ... Most cordially, therefore, as well as deliberately, I send you my humble testimony in favor of the enterprise you have so much at heart and are so certain to accomplish, if it is, as it appears to be, within the bounds of reasonable possibility"* [Gilliss 1856]. And then Peirce continued: *"I shall bring the subject before the Academy* (i.e. the Academy of Arts and Science) *early in the month of January* (1848)*, and shall be greatly disappointed if a resolution is not immediately adopted in approbation of your project"* [Gilliss 1856].

In December 1848 Gerling relayed the opinions of Gauß, Encke and Boguslawski and discussed the location of the new southern observatory. Unlike Gilliss he preferred an observatory on the mainland of Chile and not at one of the southern islands. He recommended a location near to Valparaiso, mainly because of the more stable weather conditions in that area, whereas the closer proximity to the northern station at Washington D.C. could be compensated by a much higher number of expected observations. Gilliss then also agreed to Valparaiso.

In his reply to Prof. Peirce Gilliss estimated the expected error of the solar parallax reduced from the proposed measurements to be smaller than $0''.1$. He proposed an expedition to a location near Valparaiso to observe Mars – in the same way as former observations of Mars have been done – and to make a new attempt at observing Venus during her retrograde motion.

This proposal was put forward to the two leading scientific organizations of the country, the Academy of Arts and Science and the American Philosophical Society. The Secretary of the Navy referred the matter to the action of Congress, and F.P. Stanton, the chairman of the Naval Committee cordially approved the plan, limiting the expenses for the expedition to $ 5000. With this budget it passed both Houses of Congress and was finally approved by the President of the United States on August 3rd 1848.

Soon after the news reached Gilliss, he started with detailed preparations for the expedition. He proposed observations of

- the Mars oppositions of 1849 and 1852 using simultaneous extra-meridional measurements taken at pre-arranged times in participating observatories to determine the parallax in right ascension and using meridional measurements for the parallax in declination;
- Venus at about the times of the inferior conjunctions with the sun in 1850 and 1852 and, more particularly, near its stationary terms with meridional and extra-meridional differential measurements. That is, daily micrometrical comparisons with preselected stars and simultaneous pre-arranged comparisons during daylight with bright stars should be made and compared between observatories lying near the same parallel for parallax in right ascension and observatories at nearly the same meridian but in opposite hemispheres;
- the moon, smaller planets, and lunar occultations;
- stars in zones between the south pole and 30°of south declination;
- the terrestrial refraction;
- comets;
- magnetic and meteorological occurrences;
- seismometer evidence of earthquakes.

The instrumentation required comprised of a meridian-circle, an achromatic equatorial telescope, a sidereal clock and several chronometers, as well as further instruments for meteorological and magnetic measurements.

The meridian-circle with 91 cm (36 inches) in diameter and reading at least to 1" by four microscopes was ordered from Pistor & Martins, Berlin. Because the circle was quite expensive, Gilliss sought a manufacturer in the States to build the equatorial.

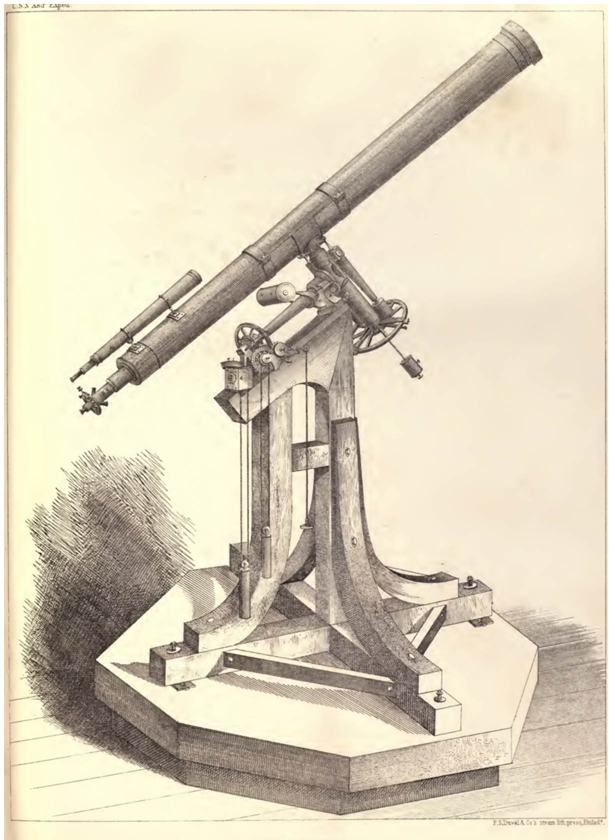


Fig. 3. The equatorial of the expedition was the first American telescope of considerable size! The lens had a diameter of 173 mm and a focal length of 2.63 m and was prepared by Henry Fitz, New York; the mechanics were constructed by William J. Young, Philadelphia [Gilliss 1856].

He finally succeeded: the mechanics were made by William J. Young, Philadelphia, and the objective was prepared by Henry Fitz, Jr., New York. The diameter of the object glass was about 173 mm (6.4 french inches) with a focal length of 2.63 m (103.7 inches). This actually is the first American telescope of considerable size (Fig. 3), and *"it marked an era of progress of mechanics and optics in the U.S. of the 19th century"* [Gould 1866]!

The U.S. Navy was to supply the remaining instruments, but everything Maury offered to Gilliss was broken, oxidized and thus totally unusable. Gilliss seemed to be running out of money when he received generous support from Prof. Henry, the Secretary of the Smithsonian Institution. Henry lent the expedition a seismometer and a complete meteorological outfit.

Gilliss also had to organize the observatory's construction. Small assembly parts suitable for transportation were set up for inspection in Washington and then packed for shipment to Chile.

Gerling and Gilliss were in close contact during that time and Gerling regularly sent a progress report of the preparations to C.F. Gauß. Gauß expressed his compliments toward Gilliss: *"The American expedition to Chile will surely bring some treasurable results. Mr. Gilliss has planned to study so many different topics, that I have nothing to add"* ([Schäfer 1927, letter no. 368], translated by the author).

5.2 The expedition to Santa Lucia, Chile

The departure was scheduled for June 1st 1849, but there was still one important matter to take care of: the star charts, including the comparison stars for the proposed Venus and Mars observations, had to be prepared. Two former midshipmen, Archibald MacRae and Henry C. Hunter, were assigned to assist Lieutenant Gilliss. They made selections of stars from available recent catalogues: *Mittlere Oerter von 12.000 Fixsternen* of Rümker, Hamburg; *Histoire Céleste* of Lalande, Paris; the as yet unpublished observations of the Washington Catalogue, as well as Bessel's zones. They also calculated the ephemerides of the two planets and reduced the catalogue entries to the 1st of January of the year the ephemeris was calculated. These locations and those of the planets were plotted to charts. A *Circular to the Friends of Science* was prepared, which explained in short the purpose of the expedition, the planned observations in Chile and the necessary accompanying observations at the other observatories. The astronomers in charge were asked to co-operate and to conduct all the requested observations.

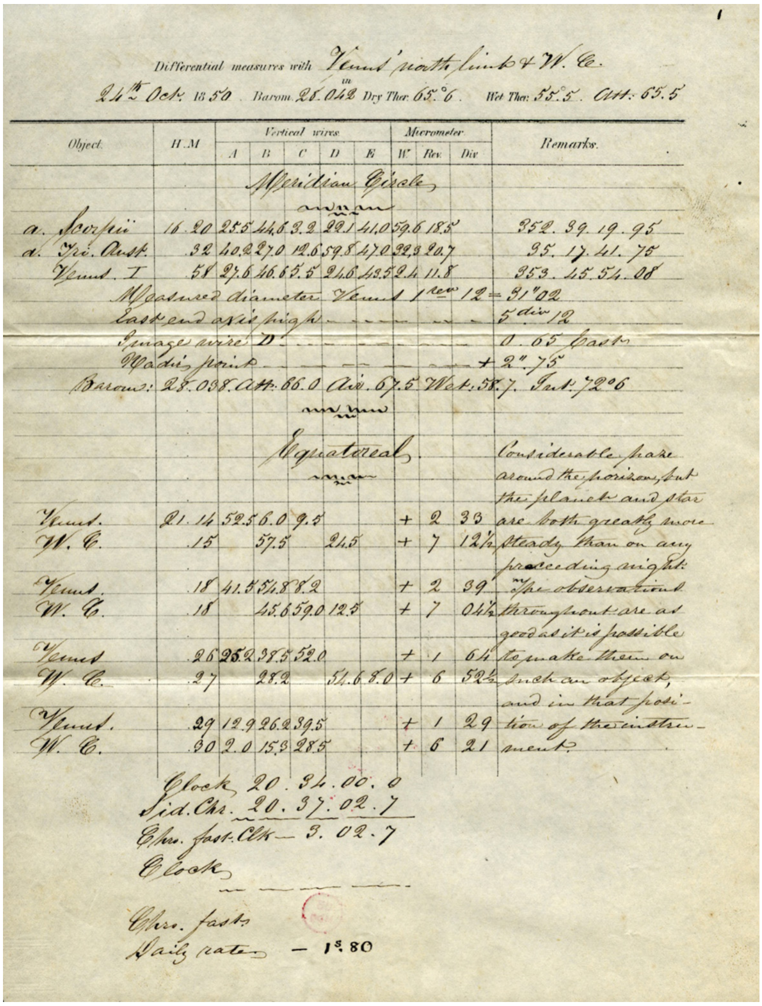
The circular, including copies of the charts, was sent to every known observatory and it was published in the *Monthly Notices of the Royal Astronomical Society* [MNRAS 1849]. As Gilliss wrote in his report: *"In order to insure the impartial trial of Dr. Gerling's method, under date of August 11, Lieut. Maury was instructed by the honorable Secretary, that – 'As the success of the Astronomical Expedition to Chile, under the direction of Lieut. Gilliss, will greatly depend on the care with which the corresponding observations are made in the northern hemisphere, you will designate an assistant whose special duty it shall be to make the observations at the times and in the manner specified in the 'Circular to the Friends of Science,' which you prepared under the direction of this department' "* ([Gilliss 1856, p. xxx]).

The equipment was shipped in June on board the *Louis Philippe* to Chile and on the 16th of August, James Melville Gilliss left New York aboard the steamer *Empire City* towards Valparaiso, Chile. Gilliss reached Valparaiso on October 25th, 1849 and travelled through the night to arrive in Santiago the next day. There, presenting his letters, he was welcomed by the government: *"Indeed, the good will and liberality of the President and his Cabinet then, and throughout our stay in the country, were uniformly manifested"* ([Gilliss 1856, p. xxxi]). Fourteen days later Gilliss decided to set up the observatory at Santa Lucia, a small porphyritic knoll in the eastern quarter of the city.

B. Gould praised the support of the Chilean government: *"The Chilean government received the expedition with a cordial hospitality, placing at his disposal any unoccupied public ground, admitting free of duty all effects of the officers as well as the equipment of the expedition, and from first to last facilitating the enterprise by every means in their power"* [Gould 1866].

On December 5th, 1849 the observatory building was ready for the instruments, the equatorial was mounted on the 6th of December and four days later the series of Mars observation commenced. By the following February the circle was ready for use and after completing the first series of Mars observations the zone observations were instituted. *"Each night's work comprised observations of level, nadir point, collimation by reflection of wires from mercury and standard stars before and after a zone extending through three to four hours in right ascension, so that we were occupied from five to six, and sometimes more hours"* ([Gilliss 1856, p. xxxiii]). The expedition was at work!

During the expedition Gilliss maintained close contact to Gerling. On October 25th, 1850 he sent him a short report about the progress in Santa Lucia ([Gerling Archive, Ms. 319/282]) mentioning that Henry Hunter had been injured right at the beginning of their stay in Chile and was unable to participate in the



Differential measures with Venus' north limb & W. C.
24th Oct. 1850. Barom. 28.042 Dry Ther. 65°6. Wet Ther. 55°5. Att. 65.5

Object	H.M	Vertical wires A	B	C	D	E	Micrometer W	Rev	Div	Remarks
Meridian Circle										
α. Scorpii	16 20	25.5	44.6	3.2	29.1	41.0	59.6	18.5		352. 39. 19. 95
α. Tri. Aust.	32	40.2	27.0	12.6	59.8	47.0	32.3	20.7		35. 17. 41. 75
Venus. I	58	27.6	46.6	5.5	24.6	43.5	24.4	11.8		353. 45. 54. 08

Measured diameter Venus 1 rev 12 = 31″02
East end axis high 5 div 12
Image wire D 0. 65 East
Nadir point + 2″. 75
Barom: 28.038. Att: 66.0 Air. 67.5 Wet. 58.7. Int. 72°6

Equatoreal

Object	H.M	A	B	C	D	E	W	Rev	Div	Remarks
Venus.	21. 14	52.5	6.0	9.5			+	2	33	Considerable haze around the horizon, but the planet and star are both greatly more
W. C.	.15		57.5		24.5		+	7	12½	steady than on any preceding night.
Venus.	.18	41.5	54.8	8.2			+	2	39	The observations
W. C.	.18		45.6	59.0	12.5		+	7	04½	throughout are as good as it is possible
Venus	.26	25.2	38.5	52.0			+	1	64	to make them on
W. C.	.27		28.2		51.6	5.0	+	6	52½	such an object, and in that posi-
Venus.	.29	12.9	26.2	39.5			+	1	29	tion of the instru-
W. C.	.30	2.0	15.3	28.5			+	6	21	ment.

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Fig. 4. Data sheet of the expedition. Gilliss sent his observations of October 24th, 1850 to Gerling ([Gerling Archive, Ms. 319/282]). In them he noted the meridional observations of α Scorpii (Antares), α Triangulum Australis (Atria) and Venus, 35 differential equatorial observations of Venus and a of star from the Washington Catalog (W.C.), which could be identified in the modern UCAC catalog as UCAC4-314-105903, a star with $m_V = 9.37$ mag. Here only the first of five pages is shown. These measurements are listed in Gould's data reduction ([Gould 1856, pp. clxxvii and clxxviii]).

observations. The same month a new assistant, Seth Ledyard Phelps, arrived at Santa Lucia. Gilliss thanked Gerling for a re-computation of some of the comparison stars for the Mars observations in January 1850, sent him the lunar occultation observation of a smaller group of stars close to χ^2 Ori and asked him to have students reduce these data. Knowing that Gerling would be very interested, he also sent him the Venus observation data of the 24th of October, for an insight into the conditions and the quality of the data (Fig. 4.)

The 24th of October was the fifth day of the first Venus series. During the daytime the astronomers observed the planet Venus and two bright stars – α Scorpii (Antares) and α Triangulum Australis (Atria) – passing in the meridian circle. At night between

9:20 pm and 11:00 pm they measured 35 differential equatorial positions of Venus and the comparison star 116 ([Gould 1856, pp. clxxvii and clxxviii]). In his letter, Gilliss explained the conditions at night which allowed him to make between 30 and 40 observations before Venus and the comparison star were set.

On the clear nights, while he was using the equatorial, the assistants spent a lot of time with the meridian circle, adding an average of more than a thousand stars to the catalogue each month. They checked their personal estimates of magnitudes by comparing their observations of small and well-known stars with the British Association catalogues. They also observed the famous variable star η Argus, now η Carina ([Gilliss 1853], and see next subsection), which, through observations by Halley, Lacaille, John Herschel and others, had been known to display huge an irregular changes in brightness. Their observations of η Carina had been recorded between February 1850 and March 1852, with η Carina reaching the brilliance of Canopus and topping that of the two stars of α Centauri.

The time in Chile was rapidly drawing to a close. Gilliss, MacRae and Phelps had made in total 217 series of observations of Mars and Venus, extending over nearly three years. They had recorded about 7000 meridional observations of 2000 stars, mainly standard stars which were used for determining instrumental errors. Their monitored zones comprised approx. 33 000 observations of about 23 000 stars within 24 1/5° of the south pole. *"Such are the astronomical results of this most honorable and useful expedition"*, Gould stated in his memoir of Gilliss [Gould 1866].

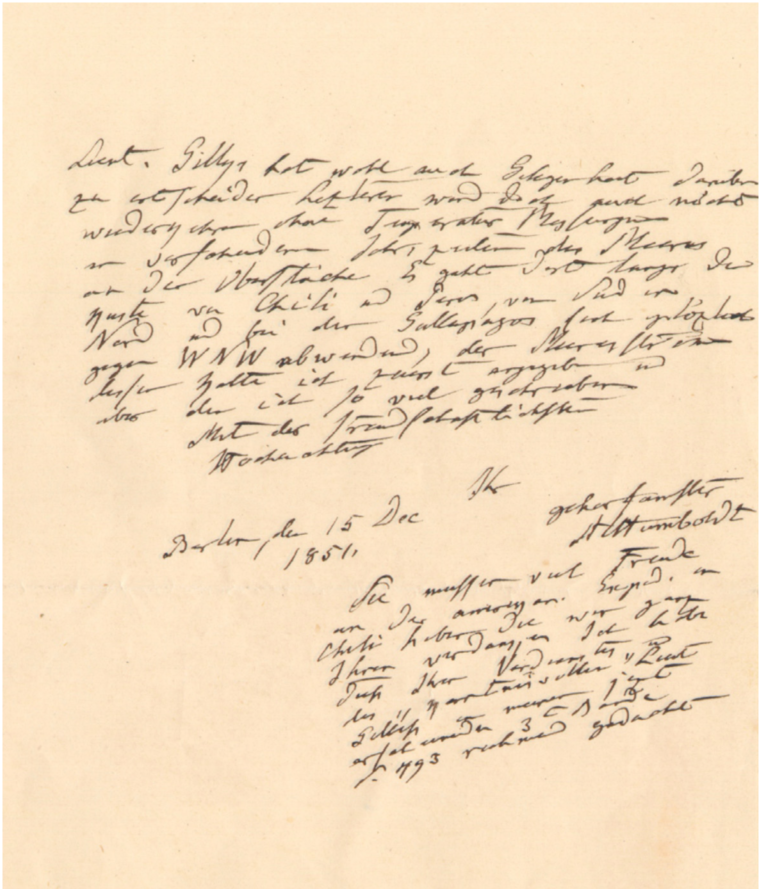
On January 5th, 1852 they were able to observe a very rare double occultation of η Geminorum at the observatories in Valparaiso and Santa Lucia [Gilliss 1852] and to synchronize their clocks via telegraphic signals. They could thus determine the difference in longitude between the two locations to be 3 m 56.51 s $\pm$ 0.021 s [Gilliss 1856] in response to Alexander von Humboldt, who had asked for new data about the longitude of Valparaiso (see next subsection).

Lieutenant MacRae was sent home via the Uspallata Pass of the Andes, where he made some more meteorological and magnetic measurements. He returned to the States in April 1853. Phelps and Gilliss left Valparaiso by steamer on the 1st of October and reached New York in November 1852.

5.3 Acknowledgements of the expedition

Dr. Flügel, the consul at Leipzig, acknowledged receipt of the circular in a letter to Gerling, dated September 18th 1849. He distributed the circular among many of his contacts and reported back the responses. One of them came from John Parish, Baron of Senftenberg, in the Pardubice Region of the Czech Republic. John Parish had built a private observatory at his castle and employed the Danish astronomer Theodor Brorsen. He offered to assist in the accompanying observations but regretted that his smaller instrument might lack the precision needed to observe the smaller stars ([Gerling Archive, Ms. 319/232], Flügel to Gerling, December 31st 1849). Unfortunately, no observations of the Senftenberg observatory were mentioned in Gilliss report. A short note also arrived from Prof. Kupffer, St. Petersburg ([Gerling Archive, Ms. 319/233], Flügel to Gerling, February 4th 1850), saying that he would contact Gerling directly, although so far no letter of Prof. Kupffer could be found in the Gerling-Archive.

Another very interesting response came from Alexander von Humboldt, dated December 22nd 1849 (Fig. 5): *"I hasten, my respected Doctor, to express to you my best thanks . . . for the notices of Gilliss referring to the ascertainment of the parallax in Chili, and the astronomical longitude of Washington. . . . For an (antediluvian?) who, like myself, is attached with his whole soul to the new world . . . it is renovating*



Berlin, den 15 Dec 1851

Ihr gehorsamster AvHumboldt

Fig. 5. Last page of a letter from A.V. Humboldt to Gerling dated December 15th 1851 ([Gerling Archive, Ms. 319/362]). He asked Gerling to send a note to Gilliss in Chile and have him perform some additional observations. In the postscript Humboldt mentioned the acknowledgement of the southern expedition in his book *Kosmos*, vol. 3 [Humboldt 1850].

and pleasing to follow the quick and proud expansion of scientific sentiments in the United States, and to have to acknowledge how much the government participates in an expedition to Chili of three years, because of a Professor in Marburg wishing for it, and nobody listens to him in Europe!" ([Gerling Archive, Ms. 319/232], Flügel sent a copy of Humboldts letter to Gerling, and [Schwarz 2004, letter no. 156]).

Gilliss kept up his correspondence and on February 25th, 1850 he sent a letter to Flügel about their observation of the variable star η Argus (now η Carinae), which had become very famous after John Herschel's observation of the dramatic change in magnitude. Flügel passed this letter on to Humboldt, which spurred his interest in this expedition ([Schwarz 2004, letter no. 160]). In December 1851 Humboldt contacted Gerling concerning the expedition and expressed interest in two observations. First, he asked that Gilliss take a good measurement of the longitude of Valparaiso, to compare it with the reduction from his observation of a Mercury transit. Second, he was interested in a red glow, that he, Humboldt, had observed on high snow-covered mountains during sunrise and sunset in the Alps and the Himalayas. He asked if Gilliss had information of such a red glow of the Andes. He ended his letter with the very cordial comment: *"you must be very pleased about the American expedition to*

Chili, which we owe solely to you. I have praised yours and the very knowledgeable Gilliss' achievement in my recently published book 'Kosmos', volume no. 3, page 493" ([Gerling Archive, Ms. 319/362], and [Schwarz 2004, letter no. 177], translated by the author).

6 The results of the expedition

After returning home Gilliss was occupied with reducing the observations and preparing the reports of his expedition for the Navy Department.

In 1855 the first volume, a narrative report about Chile, was published. However, Gilliss, fearing he would not be able to focus his full attention on determining the solar parallax, arranged for the total body of the data to be given to Benjamin A. Gould, at that time director of the Dudley Observatory, for further analysis.

Unfortunately, very disappointing news came soon from the northern observatories: the Navel Observatory at Washington reported eleven observations of Mars, three of which were partially unsatisfactory, and eight of Venus, two described as poor. The Harvard Observatory at Cambridge reported five observations of Mars, four of them of one limb only, and the Royal Observatory at Greenwich could report four observations of Mars, three of which were considered poor! Gould could not contain his disappointment: *"These are the only observations at hand for combining with the magnificent series of Lieutenant Gilliss, according to the method suggested by Professor Gerling, and contemplated by the expedition. It is impossible to refrain from the expression of deep regret that, from all the observations of the well equipped and richly endowed observatories of the northern hemisphere, so few materials could be found"* [Gould 1856]. To some extent the rivalry between Gilliss and Maury – in spite of the order Maury received – may account for the failure of the northern observations. Why the observers at Cambridge did not follow the original and euphorically accepted schedule of measurements remains open.

As the corresponding observations were totally inadequate, Gould had to seek other observations made in each hemisphere during the Mars oppositions and Venus conjunctions between 1849 and 1852. Besides the meridional observations and the micrometric comparisons from Santiago, Washington, Cambridge and Greenwich, Gould received data from the Cape of Good Hope (micrometric comparisons and meridional observations of Mars), Athens (meridional observations of Mars), Cracow (meridional observations of Venus), Kremsmünster (meridional observations of Mars), and Altona (meridional observations of Venus).

For each of the comparison measurements Gould calculated the absolute position and compared these with the meridional observations. These results were combined in a series of approximate solutions by means of least squares. He found that the results from the first Mars opposition by far surpasses the three other series in precision; he therefore used this series for further analysis. First, Gould noted the results for the angular semi-diameter in a mean distance of one astronomical unit of the two planets, determined solely from observations of Santiago and Washington

$$\begin{aligned}\text{semi}-\text{diameter of Mars} &= 6''\!.83\\ \text{semi}-\text{diamater of Venus} &= 8''\!.35\end{aligned}$$

and then gave the results for solar parallax

$$\text{mean solar parallax} = 8''\!.4950.$$

Comparing this with the slightly higher value obtained by Encke he suggested adopting $8''\!.5000$ as a more accurate value for the solar parallax. He published these results in *The Astronomical Journal* [Gould 1858], Gilliss in the *Monthly Notices of the Royal Astronomical Society* [Gilliss 1859] and Gerling in *Astronomische Nachrichten* [Gerling 1858].

7 Some impacts of the expedition

7.1 The beginning of the Chilean astronomy

The Chilean government was pleased with the astronomical activities in Santiago. Early in 1850 they asked Gilliss to instruct three young Chileans in practical astronomy, with the intention of establishing a permanent national observatory [Gerling 1851].

In October 1850 Dr. Carl W. Moesta, a former student of Gerling's, came to Chile and introduced himself to Gilliss, showing Gerling's certificate of qualification. He received an appointment as Professor in the College at Coquimbo ([Gerling Archive, Ms. 319/282], Gilliss to Gerling, October 25th 1850). A year later Gilliss helped Moesta attain a post as assistant to the chief of the Topographical Survey in Chile, a piece of news that Gerling was happy to send to Gauß ([Schäfer 1927, letter no. 376]).

As the expedition was drawing to its end, the Chilean government decided to set up a national observatory and asked Gilliss if they could purchase the expedition's equipment. Gilliss was very much interested in a continuation of the work at the observatory in Santiago and he was authorized by the Secretary of the Navy to sell the instruments, books, etc at the price paid for them without costs for transportation. As Gilliss wrote in his last letter from Santiago to Gerling on August 12th 1852 ([Gerling Archive, Ms. 319/288]), Moesta was appointed the first director of the new Chilean national observatory: *"I write but to tell you that your old pupil Dr. Moesta has been appointed Director of the National Observatory of Chile with a salary of $2000* (pesos). *He will have two assistants, and I have no doubt will so conduct the establishment as to reflect credit on himself and consequently on his Professor"*. At the same time Moesta became professor of astronomy and mathematics at the university in Santiago.

On August 17th, 1852 Dr. Moesta took charge of the Chilean observatory [Keenan 1985], equipped with the first American telescope of considerable size and a German meridian circle ([Gilliss 1856] and [Gerling 1853]). The Chilean government continued to promote astronomy; for example, in 1853 the President sent an expedition to Peru to observe a total eclipse [Gilliss 1854]; they also bought a Kessel's clock with a new self-winding telegraphic register. Moesta held the position till 1865 and then returned to Germany, where he continued to publish results from his work in Santiago and served as Consul for Chile.

One interesting incident highlights later developments in Marburg. In 1882 Friedrich Schwab, mechanic at the Physics Department of the Philipps-Universität Marburg and self-trained astronomer at the Gerling Observatory Marburg, came to Punta Arenas in southern Chile as a member of one of the German teams to observe the Venus transit on December 6th 1882 [Duerbeck 2003]. It is possible that Moesta used his connections to Marburg and to Arthur Auwers, the head of the group, and his knowledge about Chile to help Schwab acquire this position.

7.2 Solar parallax by observation of the opposition of Mars 1862

In July 1856, when Gilliss and Gould realized the extent of data lost from the northern observatories, Gilliss started thinking about a new source of corresponding measurements. In a letter dated July 7th 1856 ([Gerling Archive, letter Ms. 319/296]) he revealed to Gerling: *"I have already taken steps to have new differentials made by the Washington and Santiago* (observatories) *at the opposition of Mars April - June 1858"*! At that time he did not have the power to organize this new campaign, but by 1859 he was totally occupied with that idea again. He conveyed to Gerling the content of a letter from Prof. Peirce to the President of the U.S.: *"He* (Gilliss) *has demonstrated the possibility of a new and untried method of its (the solar parallax) determination, and if the requisite observations had been made by the astronomers of the northern hemisphere with all the appliances so readily at hand, with the same fidelity and skill which are manifest in his own observations, conducted under much difficulty at his temporary station, the solution would have been all which could be desired. ... How greatly would it ...* (be for) *the advancement of science if ... (he) were directed to undertake a new determination of the parallax, with such ample powers and means as would secure the proper cooperation in the northern hemisphere and enable an American astronomy to have the honor of permanently establishing the value of the great basis of astronomical measurements and fixing the vastest of all the recognized standards of lengths"* ([Gerling Archive, Ms. 319/301], Gilliss to Gerling, May 5th 1859).

However, Gilliss had to wait until in 1861, when he was assigned the head of the U.S. Naval Observatory. In 1862 he announced a campaign to observe the oncoming Mars opposition [Gilliss 1862], which he organized together with Moesta in Santiago. He received observations from Santiago, Uppsala, Leiden and Albany. Reducing those data together with the results from the Washington observations a new value for the solar parallax could be extracted [Gilliss 1865] *"by the joint activity of the two observatories founded through his own exertions five thousand miles apart"* [Gould 1866].

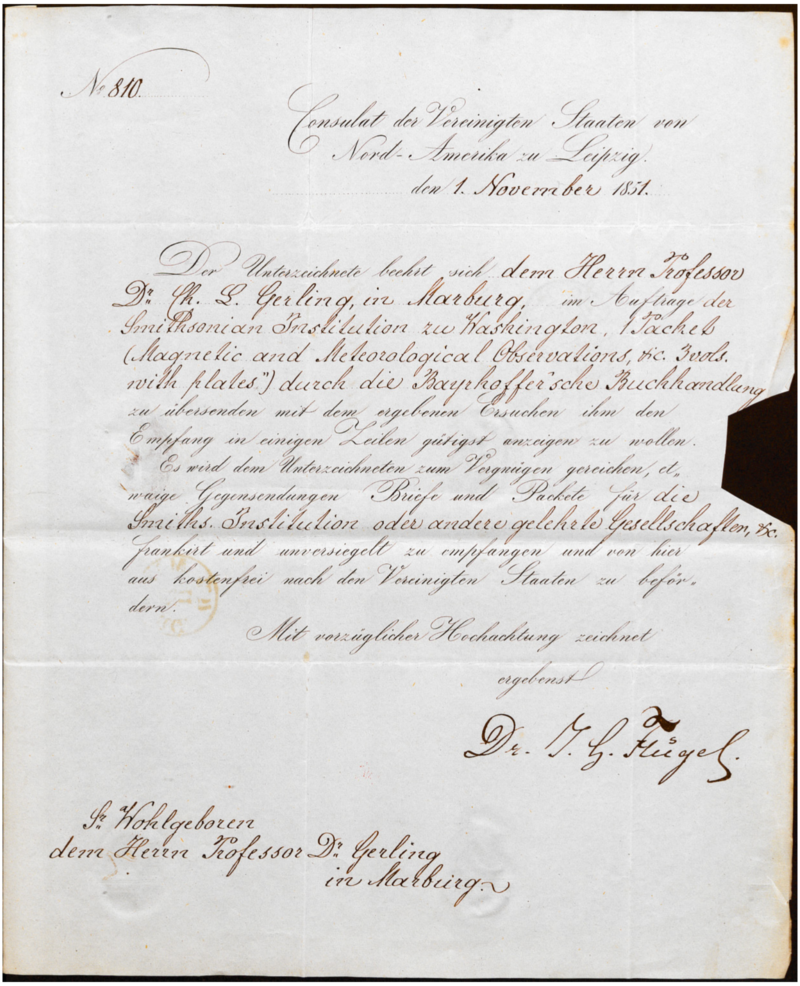
Simon Newcomb, astronomer at the U.S. Naval Observatory since 1861, additionally collected data from observations of the Mars opposition 1862 at Pulkowa, Helsingfors, Greenwich, Williamstown and Cape of the Good Hope, and finally adopted a solar parallax of $8''.848 \pm 0''.013$ [Newcomb 1867], which was a great improvement over the parallax that Encke had derived from the 18th century observations of the Venus transits.

7.3 Contacts and exchange of literature

A very interesting role in this story was played by Dr. Flügel. As U.S. Consul in Germany he acted as a mediator with a special interest in science! Using his contacts in both the Old and the New World, he was able to transfer news to the right people in the right place. Alexander von Humboldt did know that very well and took advantage of this expedient way to pass information, letters, recommendations, etc. to the U.S. [Schwarz 2004].

Dr. Flügel probably initiated the contact between Gerling and Gilliss. During the entire expedition he was circulating information about its progress. Gerling and Gilliss, wrote letters directly to each other, but whenever they wanted the information to be passed along to the scientific community, they sent it to Flügel! He was the one who distributed the circular of the expedition, asking observatories to participate in the project. He also distributed reports from Gilliss and conveyed any comments he received back to him.

Furthermore, in his position as the representative of the Smithsonian Institution, Flügel organized the transfer of reports, books and other literature to libraries and scientific institutions (Figs. 6 and 7). These were usually sent in boxes and in the cover letters he included the lists of the material. For example, among the letters Ms. 319/222 and Ms. 319/223 from spring 1848 [Gerling Archive] were listed: a perfect facsimile of the entire Declaration of Independence, documents from the Senate



№ 810.

Consulat der Vereinigten Staaten von Nord-Amerika zu Leipzig.

den 1. November 1851.

Der Unterzeichnete beehrt sich dem Herrn Professor Dr. Ch. L. Gerling, in Marburg, im Auftrage der Smithsonian Institution zu Washington, 1 Päckel (Magnetic and Meteorological Observations, &c. 3 vols. with plates") durch die Bayrhoffer'sche Buchhandlung zu übersenden mit dem ergebenen Ersuchen ihm den Empfang in einigen Zeilen gütigst anzeigen zu wollen.

Es wird dem Unterzeichneten zum Vergnügen gereichen, etwaige Gegensendungen Briefe und Packete für die Smiths. Institution oder andere gelehrte Gesellschaften, &c. frankirt und unversiegelt zu empfangen und von hier aus kostenfrei nach den Vereinigten Staaten zu befördern.

Mit vorzüglicher Hochachtung zeichnet

ergebenst

Dr. J. G. Flügel.

Sr. Wohlgeboren
dem Herrn Professor Dr. Gerling
in Marburg.

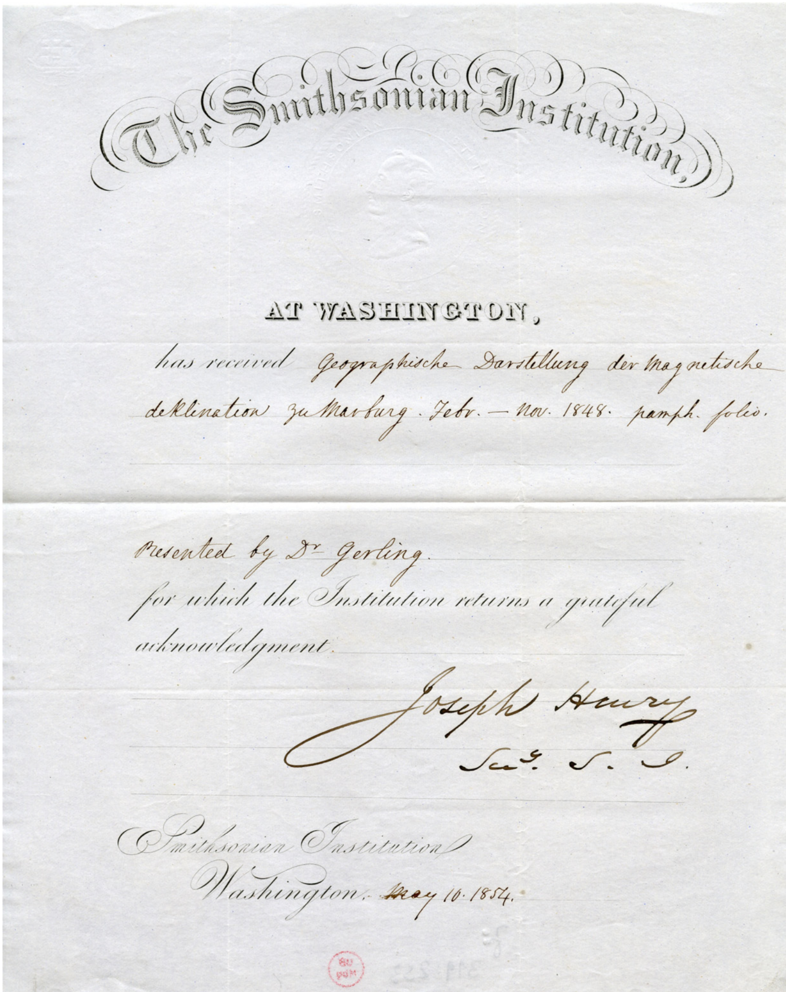
Fig. 6. The Smithsonian Institution was pleased to send Gerling a box of magnetic and meteorological observations and encouraged him, to return in exchange letters and packages of further materials like essays, books, scientific reports, etc. ([Gerling Archive, Ms. 319/246]).

Document room, a volume of the *Transactions of the American Philosophical Society*, *The Potomac Aqueduct* (Report and Maps), Hassler's comparison of weights and measures of length and capacity, the *National Intelligencer* (the most important newspaper in Washington at that time), reports on meteorological and astronomical observations.

After the results of the expedition had been published, Dr. Flügel kept in touch with Gerling, sending information and seeking advice on various scientific topics.

8 Conclusions

Christian Ludwig Gerling's idea has never really been challenged. The success of using the Mars oppositions lies in the sufficient reliance in determining a planet's position by differential measurements with respect to the stars (and not to the sun). The methods surely would have been more successful if they had been conducted with the same intensity as the Venus transit measurements in the 19th century. Later, in 1900


The Smithsonian Institution,

AT WASHINGTON,

has received Geographische Darstellung der Magnetische deklination zu Marburg. Febr. — Nov. 1848. pamph. folio.

Presented by Dr Gerling.
for which the Institution returns a grateful acknowledgment.

Joseph Henry
Secy. S. I.

Smithsonian Institution
Washington. May 10. 1854.

Fig. 7. Through Dr. Flügel Gerling was asked to send reports to the Smithsonian Institution. Here Joseph Henry, the "father" of the self-inductance and at that time the secretary of the Smithsonian Institution, acknowledged the receipt of measurements of the magnetic declination in Marburg ([Gerling Archive, included in Ms. 319/253], Flügel to Gerling, November 8th 1854).

and 1931, the improvement of the star catalogues and the emergence of photography led to a tremendous increase in accuracy of the solar parallax value by observing the asteroid Eros (see e.g. [Hinks 1904]).

James M. Gilliss founded two observatories: the U.S. Naval Observatory after his first experience with continuous astronomical observations and the National Astronomical Observatory of Chile as a result of the expedition to the southern hemisphere.

In the 19th century the time was ripe for both scientists' endeavors. First, the young U.S. community was ready to become involved in challenging scientific projects. Second, the awareness grew that high quality astronomical observatories should be equally distributed across the globe, due to that constantly rotating and moving observation place, we call our earth. The foundation of the National Astronomical Observatory of Chile was just the beginning of a series of new observatories being founded and or supported in different parts of the world by the Old World [Le Guet Tully 2013].

Finally, Gerling seems to have made a wise choice of Valparaiso/Santiago. To this day, the European Southern Observatory (ESO) is operating some of the most advanced telescopes of the world in that area.

Acknowledgements. I appreciate the cooperation with the library of the Philipps-Universität Marburg, where the scientific estate of Christian Ludwig Gerling is stored. Especially Dr. Bernd Reifenberg was very helpful in getting access to the original letters and materials of Gerling's inheritance.

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