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The two transits of Venus of 1874 and 1882 or, "the greatest astronomical events of the nineteenth century"

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Abstract: In 2004 and 2012, with the last pair of Venus transits across the Sun, there was a renewed interest in the history of this rare astronomical phenomenon. However, not enough attention was paid to the transits of 1874 and 1882, even though, in 1869, they had been described as "the greatest astronomical event of the century". Indeed, the two transits of the nineteenth century represent one of the milestones in the history of astronomy. They not only made it possible to obtain a value for the Earth-Sun distance with an uncertainty of less than 1% (as already requested by Halley in 1716), but also provided an extraordinary opportunity for testing new technologies (such as photographic plates), stimulated the development of new astronomical devices (including Houzeau's heliometer with unequal focal lengths), and facilitated collaboration among European powers and emerging nations such as Brazil, Argentina, and Mexico. With old challenges such as the black-drop effect, renewed searches for an alleged satellite, and journeys to distant lands from Cape Horn to Hawaii (through meticulously organized expeditions where nothing was left to chance), the transits of 1874 and 1882 constituted not only a fundamental scientific venture but also a popular event, managing to capture the interest of the general public, and thus contributing in heightening widespread awareness of astronomy. 150 years after the 1874 event, here is their story.

Keywords: Venus Transits, Popular Event, Nineteenth-Century Astronomy, Solar Parallax

1. Introduction

As astronomers generally know, the transits of Venus are an extremely rare astronomical phenomenon, occurring approximately every 120 years in pairs of events. First predicted by Johannes Kepler (1571-1630) in 1627 and first observed in 1639 by the amateur astronomer Jeremiah Horrocks (1618-1641), the transits of Venus allow for the determination of the Earth-Sun distance through the measurement of solar parallax, a fact that immediately made this phenomenon particularly significant for the astronomical community. Specifically, the two transits of 1874 and 1882 were even described by *Scientific American* as "the greatest astronomical events of the century" (The transit..., 1869, p. 281), underscoring the uniqueness and importance of this phenomenon, which had already captured the attention of the scientific community in the previous century.

The story of the two transits of Venus of the nineteenth century is so complex, lengthy, and multifaceted that it would be impossible to condense all its characteristics and peculiarities into just a few pages. Therefore, in this work, we will focus on three specific aspects of this extraordinary astronomical venture. First, we will outline the differences between the transits of 1874 and 1882 and those of 1761 and 1769. Then, we will highlight the astronomical and technological significance of the two nineteenth-century transits, along with their broader impact beyond the realm of science, attempting to place them within the social and cultural context of the time. Finally, we will attempt to understand what this historical and astronomical story can still teach or tell us today, 150 years after the 1874 transit.

2. Eighteenth century vs nineteenth-century transits: two ventures compared

Regarding the differences, in the last quarter of the nineteenth century, Europe was relatively peaceful, with the long reign of Queen Victoria (1819-1901) in Great Britain, the formation of the German Empire and the unification of Italy between 1860 and 1870, and the restoration of the Republic in France in 1870. This was a markedly different climate from the tumultuous period of the Seven Years' War, which had ravaged Europe from 1756 to 1763, with its aftermath lingering for decades due to ongoing struggles for colonial dominance. In addition, while, in the eighteenth century, astronomical expeditions to observe the transits had been funded by enlightened monarchs, scientific academies, and generous patrons, the two nineteenth-century transits became matters of state. National governments invested significant sums and often involved the navy to provide support to the observation teams. For example,

> By 1874, eight countries were, all together, planning about seventy-five observation stations at a total estimated cost of $1 million. *Scribner's Monthly* argued: "It may seem to some that the results to be arrived at are not worth so great an outlay, but the general voice of the non-scientific world as well as of the scientific world has contradicted this". The frontispiece to *Punch*'s bound volume for 1874 (Fig. 1) takes as its subject the multinational spectacle that the 1874 transit of Venus would be. In the illustration, transit of Venus observers are portrayed as caricatures of national personifications (Britannia and Uncle Sam are most recognizable), crowded together, peering towards the sun with various instruments, elbow-to-elbow, jostling for a view. (Ratcliff, 2008, p. 56)

Fig. 1: Frontispiece of volume 67 of *Punch*, 1874.

To give an even clearer idea, the United States Government appropriated $177,000 for the 1874 event, and more than $75,000 for 1882, to send out eight well-equipped expeditions for each transit. Similarly, for the 1874 event, the newly formed Italian government allocated a generous funding of Lit. 50,000 for the expedition to Muddapur, in eastern India, led by Pietro Tacchini (1838-1905), a generosity that, unfortunately, was not renewed for the subsequent 1882 transit.

Moreover, it was not only the major powers of the old continent (such as France, Great Britain, and Russia), or the United States, that organized expeditions to observe this rare astronomical phenomenon. The two nineteenth-century transits also saw the participation and the significant contribution of numerous nations, many of which were newly unified (such as Belgium, Italy and Germany) or emerging countries located in former European colonial territories (such as Mexico, Argentina, and Brazil). In particular, the latter were favoured by their fortunate geographical positions: the 1874 transit was fully visible from much of Asia and the southern Indian and Pacific Oceans, while the 1882 transit could be seen in its entirety from the Americas and much of the Pacific Ocean. Indeed, many expeditions were concentrated in these regions. Expeditions that were numerous (almost 80 organized in 1874, and more than 90 in 1882) and well-equipped, located not in makeshift observatories, but in perfectly organized stations where nothing was left to chance. For example, in preparation for the 1882 transit expeditions, the United States Naval Observatory published a comprehensive 70 page guide that outlined in detail,

step by step, the responsibilities of each expedition member (Commission..., 1882). This was in addition to the numerous essays, volumes, and articles written by astronomers and experts before each transit, which described all the technical and astronomical details necessary to ensure that the observation process was nearly flawless. Additionally, while in the eighteenth century it took months to circumnavigate Africa, by 1874 and 1882, thanks to the Suez Canal (inaugurated in 1869), steamships, and trains (the first transcontinental railroad in America was completed in 1869, while the linking of the Indian railways across the sub-continent in 1870), travel had become faster and more secure and, therefore, less subject to the whims of the weather. Furthermore, the establishment of a dense telegraph network (notably, the first transatlantic telegraph cable was laid in 1858) made communication instantaneous, eliminating the risk of valuable letters or documents getting lost, as often happened a century earlier.

In a world that was thus becoming increasingly smaller, traversable even in just 80 days, at least according to what was written in 1872 by Jules Verne (1828-1905) in his famous book *Around the World in Eighty Days*, there was, however, a growing human desire to push further and discover the true dimensions of the solar system. A desire that made the two nineteenth-century transits a phenomenon eagerly embraced by both the scientific community and the general public.

3. Astronomical results and advancements

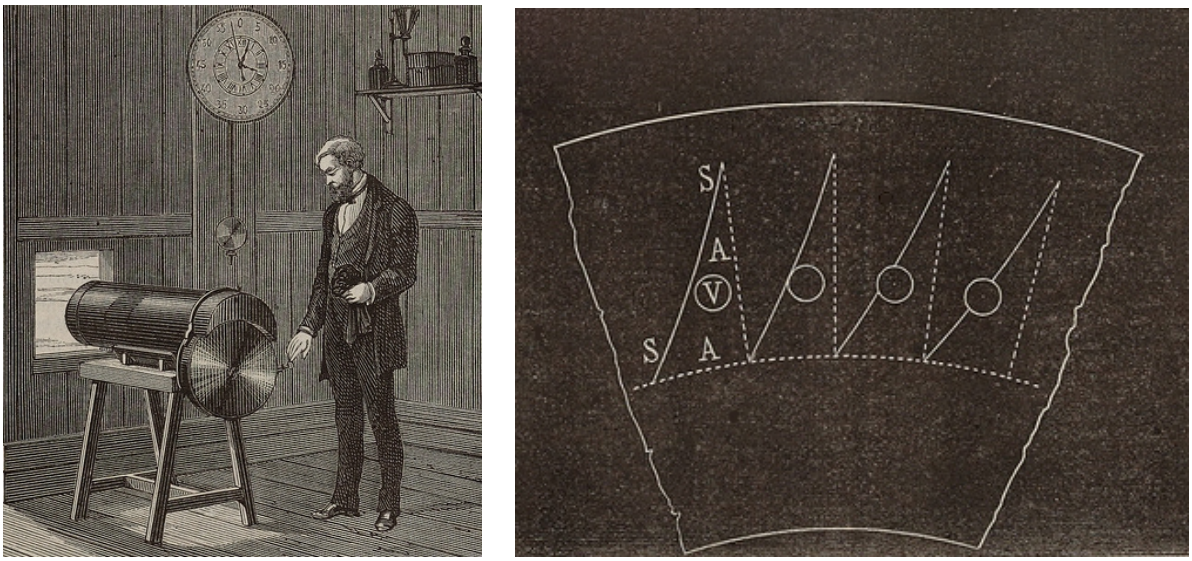
From an astronomical perspective, the two transits of the nineteenth century obviously played a fundamental role because, after nearly 250 years since the first observation of this phenomenon, they allowed for the determination of the solar parallax π (and, consequently, the Earth-Sun distance) with an uncertainty of less than 1%. This was the level of precision that Edmond Halley (1656-1742) had requested, or at least hoped for, in 1716.

Indeed, by gathering and synthesizing the data obtained from both the eighteenth-century and nineteenth-century transits, and after long and fatiguing calculations, the Naval Observatory astronomer William Harkness (1837-1903) derived a final result of π = 8.809” ± 0.0057” (Harkness, 1895, p. 34), while his more well-known colleague Simon Newcomb (1835-1909) obtained a value of π = 8.800” ± 0.0038” (Newcomb, 1895, p. 158), with the two reported errors considered as the probable errors. Both values represented a significant improvement over previous estimates. Moreover, considering the probable errors, Newcomb’s and Harkness’s results were in agreement, partly overlapping in their values for solar parallax, but Newcomb came closest (and incredibly close) to the modern (exact) value of the astronomical unit (historically conceived as the average Earth-Sun distance) of 8.794143”.

4. The best available technology and new scientific devices

The two transits of the nineteenth century also provided the perfect opportunity for systematic and planned use of photography. The French inventor and astronomer Pierre Jules César Janssen (1824-1907) conceived the idea of a “photographic revolver” (Fig. 2), inspired by the rotating cylinder of the revolver invented by Samuel Colt (1814-1862) in the 1830s. When operational, this device was capable of capturing forty-eight images in just seventy-two seconds.

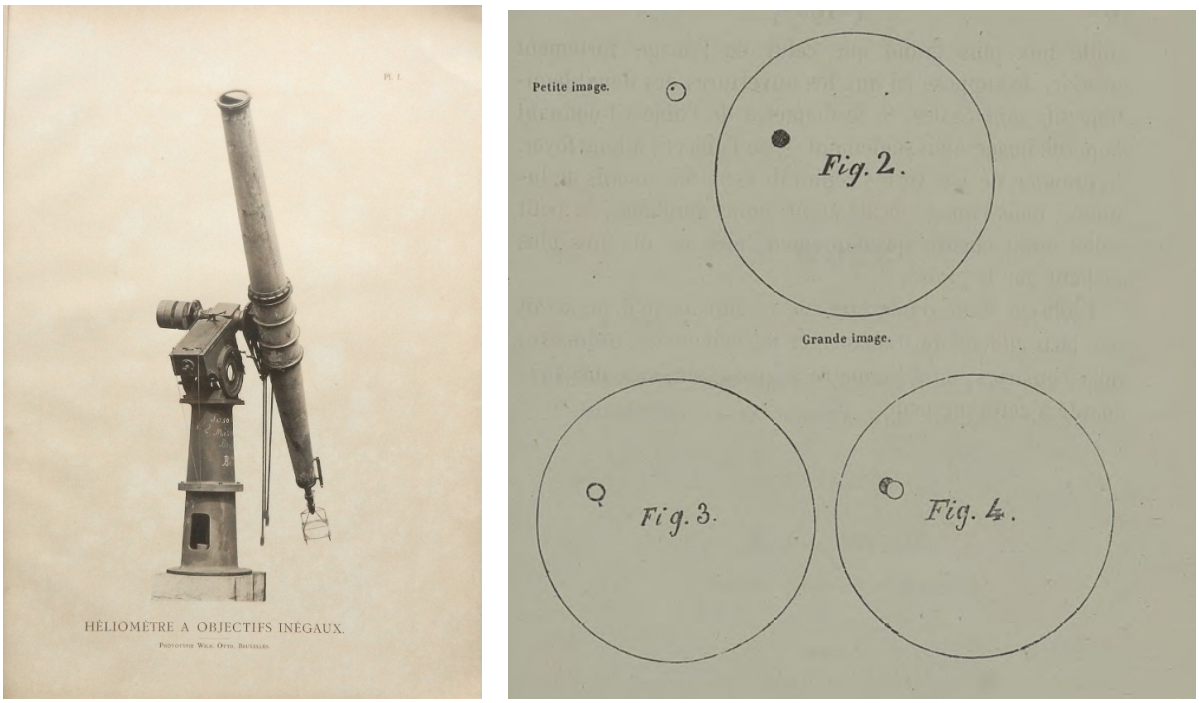
> On a common axis are mounted: 1. a copper disc C..., which is itself fixed onto a wheel that engages with the pinion of a clockwork mechanism M; 2. a large wheel R that holds a daguerreotype plate P or a silvered copper plate, intended to receive the images. The disc C has twelve openings or shutters F, evenly spaced around it. This disc completes one full rotation in eighteen seconds, while the daguerreotype plate wheel P, which also receives its circular motion from the same clockwork mechanism, rotates four times slower; that is, it completes a full rotation in seventy-two seconds. (Flammarion, 1875, p. 357)



(a) **(b)**

Fig. 2: (a) View of the apparatus during the 1874 transit of Venus. (b) Diagram of the photographic record of the transit of Venus. (Flammarion, 1875, p. 357).

Thanks to the photographic revolver, Janssen created a unique and invaluable object: the first film sequence of an astronomical event in history. To be fair, the French scientist was not the only one to use it during the 1874 transit; several British missions employed a similar device known as the "Janssen slide". However, the quality of the images captured with the photographic revolver in 1874 was deemed insufficient for improving the calculation of the Earth-Sun distance, particularly by European astronomers, who generally opted not to use the device in 1882. In contrast, American expeditions refined



(a) **(b)**

Fig. 3: (a) Photograph of the heliometer with unequal focal lengths (Houzeau 1884b, Plate I). (b) Schema of the images produced by the heliometer (Houzeau 1871, p. 164).

the instrument, substantially by changing the photographic plate material, replacing wet bromo-iodide plates with dry collodion emulsion plates, which provided greater convenience, faster exposure times, and superior light sensitivity, and they took over 1,700 photographs, more than 1,300 of which proved useful for measurements. Moreover, new instruments were specifically developed and built for this event, such as the heliometer with unequal focal lengths (Houzeau, 1871; 1884a) designed by the Belgian astronomer Jean-Charles Houzeau (1820-1888). This instrument (Fig. 3a) featured two objectives with distinctly different focal lengths and diameters. The eyepiece (with the long-focus objective) projected the image of the sun onto a screen. The image of the sun (Fig. 3b) had a diameter of 160 mm, while that of Venus was about 5 mm. The short-focus objective produced a second solar image that was slightly smaller than that of Venus. The relative positioning of both objectives can be adjusted using a graduated micrometer screw. By adjusting the relative position of the two objectives, the small image of the sun could be aligned with that of Venus. The difference in the micrometer reading between the positions of "small sun centred on the crosshairs (thus at the centre of the large sun)" and "small sun centred on large Venus", when properly calibrated, provided a measure of the distance between the centres of the objects during the transit (Flammarion, 1875, p. 357).

In addition, the two transits of the nineteenth century also provided the perfect opportunity to supplement traditional observational methods, based on the use of equatorial reflecting or refracting telescopes equipped with micrometers, and heliometers, with the spectroscopic method. This method was tentatively utilized in 1874, primarily by the Italian expedition in Muddapur, India, and the one led by George Lyon Tupman (1838-1922) in Honolulu, Hawaii, but was employed on a larger scale in 1882. With regard to Italy,

> the spectroscope... was intended by her men of science to be their chief weapon of attack, and as in no country is there such a skilled body of spectroscopists as in Italy, this determination was probably not arrived at on insufficient grounds. (The Times..., 1874, p. 103)

5. From celestial rarity to public spectacle: how astronomy captivated the masses

Furthermore, while the two transits of the eighteenth century had primarily involved the scientific community and a few educated and curious nobles, those of the nineteenth century became a cultural and global event that managed to capture the interest and curiosity of the general public. From 1874 to 1883, the American newspaper *San Francisco Chronicle* published nearly 100 articles focused on the transits of Venus. *The New York Times* featured more than 180 articles, and a similar number appeared in the *Chicago Tribune*. Readers were informed about relevant lectures and made aware of publications aimed at a general audience, and there was widespread interest in articles covering the various expeditions from different countries around the world. Such articles likely contributed to the sustained interest and support of the public for subsequent astronomical endeavours.

On 7 December 1882, the day after the transit, *The New York Times* wrote:

> The slow transit of the planet Venus across the disk of the sun was observed in this City yesterday by thousands of amateur astronomers, and, judging by the comments of the gazers, the observations were remarkably satisfactory to them, whatever may be the result of the experiments of the scientists. The day broke dark and cloudy, and the predictions that the day was to be characterized by a storm of rain or snow seemed likely to be verified. But before the time set for the opening of the celestial panorama the clouds cleared away, and by 9 o'clock the sun was shining from a comparatively clear sky. From the time Venus made her first contact with the rim of the sun until she passed completely from the disk a fine view of the transit was presented to observers in this City... A very satisfactory view was obtained through smoked glasses, but the speck which was made on the disk of the sun by the planet was 80 small that it required some time of close application to the glass before it was recognizable, The dark spot appeared no larger than a small sized dried pea. It was very dark and stood out in bold relief against the red disk of the sun.

> Enterprising proprietors of telescopes of all sized and powers stationed themselves in favorable places all over the City, and reaped a large harvest by exhibiting the planet on its tourney across the sun at the rate of 10 cents a sight. In the City Hall Park a telescope was erected, and so great was the rush of people to take a look through it that the services of a Park policeman were required to keep them in line awaiting their turn. Once at the telescope a view of a few seconds only, was allowed, and by actual count 20 men peered through the glass in 5 minutes... Broad and Wall streets were filled with bulls and bears[1], each with a piece of smoke glass in his hand, and when not engaged in scientifically examining the transit, they amused themselves by blaking each other's noses and faces... The 120 boys of the Berkeley School, at No. 252 Madison-avenue, and over 2,000 other people viewed the transit through a new telescope with a 4-inch glass. The pupils of five of the young ladies' schools were also invited... to take a look at Venus. Scores of Columbia College students wearing mortar board caps climbed to the top of the new law school building of the college yesterday to catch a glimpse of the transit of Venus. (Across..., 1882, p. 1)

And, once again, reading this time from the Italian newspaper *La Stampa*,

> The phenomenon could be conveniently observed with a pair of opera glasses, taking care that smoked glass was interposed. Many amateur astronomers were eager to satisfy their curiosity, and telescopes and spyglasses could be seen pointed from balconies and windows. (Il passaggio..., 1882, p. 3)

The spectators' comments were, in some cases, quite peculiar and even amusing. For example, a reporter from the Roman newspaper *Il Bersagliere* wrote, "I also looked at the phenomenon through the smoked glass, and it seemed to me that I saw an omelette with a fly in the middle!" (Roma, 1882, p. 2). This description is certainly not particularly refined from a scientific standpoint. . . but it perfectly conveys the impression that the reporter had of what he observed. The involvement of the general public was remarkable. In fact, on 7 December 1874, the journal *Chicago Tribune* even reported on a sermon delivered by Reverend Smith Bartlett Goodenow (1817-1897), the pastor of the Congregational Church of Benton Harbor, Michigan. In the sermon, which spanned three columns, in simple yet precise language, the phenomenon, its history, and provided numerous details about the expeditions were described (Goodenow, 1874). Moreover, on 18 January 1883, *The New York Times* published a brief article describing a dinner of the so-called "Sheriff's Jury"[2] at Delmonico's restaurant, in which

> There was a handsome display of flowers, the most notable of which was a design representing the transit of Venus, resting where the eye of the presiding officer might fall upon it. In different parts of a floral globe stood the representative heads of nations and empires, Brother Jonathan viewed the transit through a straw, the Czar of Russia took his bearings on the sun by a compass, John Bull had a spyglass levelled at the planet, Napoleon Bonaparte saw the sight through a bottle of Cliquot, and Kaiser William employed a double-barreled pretzel, in the absence of a field glass, to observe the spectacle. (The Sheriff's..., 1883, p. 5)

Additionally, around the time of the two transits, many advertisements appeared in various newspapers promoting the sale of both large and small telescopes and binoculars for amateur observers and the curious. Finally, to celebrate the transit of 1882, the American composer John Philip Sousa (1854-1952) composed a special military march. Unperformed for many years and long believed to be lost, the score was rediscovered in 2003 by an employee of the Library of Congress, just in time for the transit of 2004.

[1] In the jargon of stock-market traders, bulls are people who buy securities or commodities in the expectation of a price rise, while bears are people who sell securities or commodities in expectation of a price decline.

[2] The Sheriff's Jury was an extravagant semi-official group and social club in Manhattan composed by wealthy businessman of New York, who periodically convened to address non-criminal issues, primarily related to inheritance or libel, that the Sheriff of New York referred to them. They gained notoriety for their extravagant annual banquets, which were always well-documented in *The New York Times*.

6. Past problems back in the spotlight

However, the story of the two transits of the nineteenth century also saw the resurgence of old problems and questions that had previously emerged. For example, the issue of a possible satellite of Venus (or some celestial object in its vicinity) gained renewed attention, with Houzeau among the primary supporters. Drawing on sightings documented in the seventeenth and eighteenth centuries by astronomers such as Francesco Fontana (1585-1656), Giovanni Domenico Cassini (1625-1712), and James Short (1710-1768), Houzeau believed that the observed object was a small celestial body, initially considered a satellite and later thought to be a planet, that had a regular period and periodically came into conjunction with Venus (Houzeau, 1884a). The sighting in 1884 of a bright spot near Venus appeared to provide the long-sought confirmation of this celestial object's existence; however, the scientific community quickly dampened his enthusiasm, dismissing Houzeau's hypotheses as mere speculation.

Moreover, astronomers, such as those involved in the British expedition sent to Suez or the one located at Ohakrata in the Himalaya Mountains, had to contend once again with the troublesome phenomenon known as the "black drop". This phenomenon caused the planet to appear as if it was "stretched" or "connected" (through a thin ligament) to the edge of the Sun, creating the impression that the shape of the planet resembles that of a black drop, and thus rendering measurements during the two internal contacts between the edge of Venus and that of the Sun particularly difficult and imprecise. Long believed to be caused by Venus' dense atmosphere and initially considered, in 1761 by Mikhail Vasilyevich Lomonosov (1711-1765), the first real evidence of the existence of an atmosphere on the planet, it would later be understood that the phenomenon was actually primarily due to an issue of astigmatism, as noted by Guido Horn d'Arturo (1879-1967), in 1922 (Horn d'Arturo, 1922).

7. Multi-messengers echoes and reflections: lessons from Venus transits of 1874 and 1882

At this point, there remains only one final question to address, that is, what can the venture of the two transits of Venus of the nineteenth century teach us still today?

Firstly, it provides a clear example of how scientific knowledge is a lengthy process characterized by successive refinements (in this case, five transits, from that of 1639 to that of 1882), in a process that is anything but linear, often marked by errors, failures, and also unexpected developments. Moreover, it helps us understand that the scale and significance of a scientific endeavour should never be judged solely by the results obtained. Indeed, from a purely numerical perspective, from the observation of Mars's opposition in 1877, David Gill (1843-1914) obtained a parallax value of 8.78" ± 0.012" (Gill, 1881, p. 323), a value which is not significantly different, for example, from Tupman's result 8.813" ± 0.033", proposed in 1878 (Tupman 1878, p. 334). Yet, the two astronomical ventures in question do not hold the same relevance and extent, having a completely different impact in terms of organization and involvement of the astronomical community as well as the general public. Indeed, Each scientific event should always be analysed in light of the context (scientific, of course, but also social, economic, political, and cultural) in which it develops. And from this perspective, the story of the two transits of the nineteenth century is far more intricate, complex, and expansive than that of Mars' opposition of 1877 and also than that of any other astronomical observation conducted throughout the nineteenth century. Therefore, based on what has been said so far, I hope that readers, and especially astronomers, will not cast judgment upon me if I dare to explicitly state that I wholeheartedly agree with *Scientific American* in stating that the two transits of Venus of 1874 and 1882 were (and have thus truly and fully deserved the title of) "the greatest astronomical events of the century".

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