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Spectroscopic observations of the 1874 transit of Venus: the Italian party at Muddapur, eastern India

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Abstract
The transit of Venus over the Sun expected on 1874 December 9, gave the opportunity to the Italian astronomers of organizing the second scientific mission of the new Kingdom of Italy born in 1861. Pietro Tacchini of the Astronomical Observatory of Palermo was designated to organizing the expedition for the Transit of 1874, and at the same time Giuseppe Lorenzoni of the Astronomical Observatory of Padova took care of getting all the necessary instruments ready and of shipping them to Bengal, eastern India. In this mission the Italians obtained a very important result: they observed, for the first time, details of the spectrum of Venus which confirmed the existence of its atmosphere. At the same time they demonstrated the validity of the spectroscopic observations to determine the exact instant of the contacts.

Keywords: *Transit of Venus, spectroscopic observations, Italian astronomers*

1 INTRODUCTION

The transits of Venus over the Sun of 1874 December 9 and 1882 December 6, mobilized astronomers all around the world to measure the parallax of the Sun. This predictable pair of events, separated by eight years, occurs every 113 and a half years, plus or minus 8 years, counting from the last of the two transits, so that the next two will occur on 2004 June 8 and 2012 June 5-6. This rare phenomenon did not find the international astronomical community unprepared: *The Nautical Almanac and Astronomical Ephemerides for the year 1874* gave the elements and the Greenwich Mean Time of the four contacts, and added an appendix with the names of 46 geographical places, together with their positions (latitudes and longitudes) and the local mean time of sunrise, sunset and the contacts—first external (I), first internal (II), middle of transit (M), last internal (III) and last external (IV)—visible in the listed places; the *Connaissance des Temps pour l'An 1872* gave Puisieux's computations for 20 places. *Nature* had started in 1874 June to give news concerning transit expeditions and, from 1874 December, reports of the expeditions themselves; so too did the 1875 issues of *Astronomische Nachrichten*. From 1871 a special Commission created by the US Congress planned the American transit expeditions (see Forbes, 1874; Janiczek and Houchins, 1974; Orchiston *et al.*, 2000). The telegraph, patented by Morse in 1840, played an important role in giving information in real time about the results of observations.

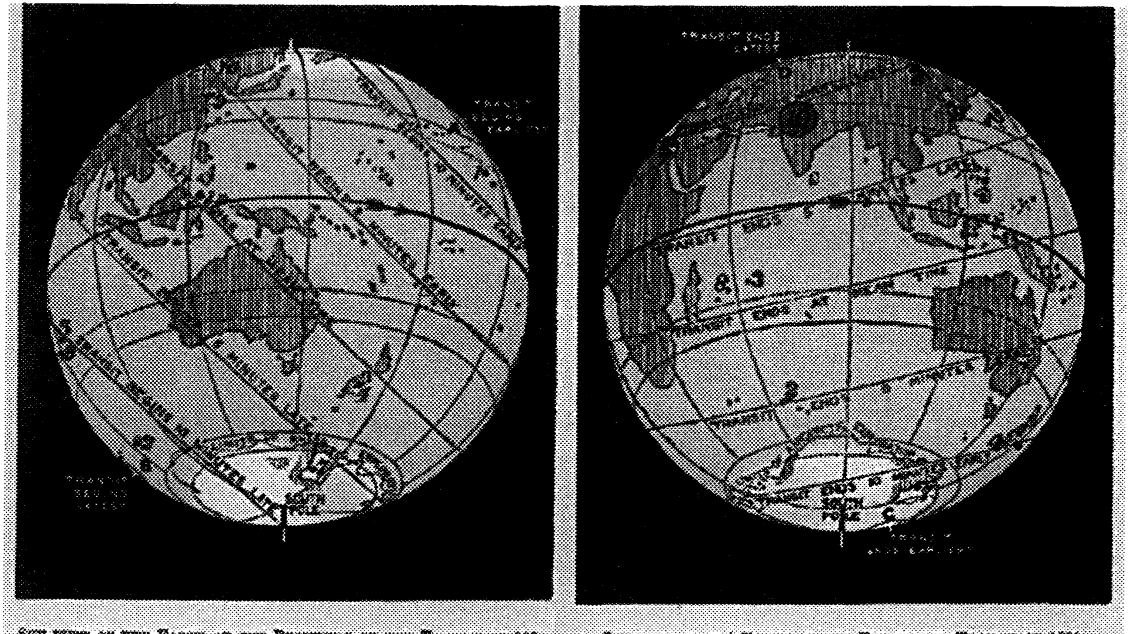
The rare phenomenon of the transit gave Italian astronomers the opportunity of organizing the second scientific mission of the new Kingdom of Italy, established in 1861; the unification of the Italian territory as a national state was completed after the annexation of the Venetian region in 1866 and of the Papal State in 1870. In December of that year, the first Italian scientific mission to Sicily, to observe the total eclipse of the Sun, was accomplished (Pigatto, 1998). This collaboration of Italian astronomers inspired Angelo Secchi[1] to found the Italian Spectroscopists Society in order to co-ordinate spectroscopic observations of the Sun, and the inaugural issue of the Society's *Memorie*, the first astrophysical journal in the world, was published in 1872.

In 1873 Pietro Tacchini[2] (Figure 1, left) from the Astronomical Observatory of Palermo began promoting the expedition to observe the transit and was subsequently charged with organizing it by the Minister of Education, who on Christmas Day granted him 50 000 lire (Tacchini, 1873c). Giuseppe Lorenzoni[3] (Figure 1, right), from the Astronomical Observatory of Padova, was responsible for preparing all the necessary instruments and shipping them to western Bengal. The site for the expedition was chosen on the basis of Proctor's (1874) maps (see Figure 2) and taking into account the cost of the journey and information received from the Italian Consul in Calcutta. The place selected was Muddapur (now Madhapur), about 300 kilometres north-west of Calcutta, at latitude $24^\circ\ 17'\ 0''.96 \pm 0''.34$ N, longitude $5^h\ 46^m\ 20^s.570$ E.

Figure 1. Pietro Tacchini (1838-1905) (left) and Giuseppe Lorenzoni (1843-1914) (right).

Because of the high cost of the mission, the Italian astronomers could not organize a second observing station necessary for determining the solar parallax; for this reason, they decided to address their efforts mainly to spectroscopic observations, in order to verify the best way of minimizing errors in measuring the exact instant of the contacts, and prepare for the transit of 1882.

The observers engaged for the expedition were: Tacchini, as chief of the mission; Angelo Secchi from the Roman College, who was prevented from leaving because of bad health; Alessandro Dorna[4] from the Observatory of Torino; Antonio Abetti[5] from the Observatory of Padova, together with Antonio Cagnato, a clever pupil from the workshop of the Observatory. Carlo Morso, an amateur astronomer from Palermo, "... well known for his aerostatic expeditions, as well as for his other travels ... " (*The Englishman*, 1874:2), joined the expedition at his own expense. Lastly the Jesuit, Eugéne Lafont, director of the St. Xavier College in Calcutta and an expert in astronomy, joined the Italians at Muddapur (Tacchini, 1875a; Chinnici, 1995/96).



SUN-VIEW OF THE EARTH AT THE BEGINNING OF THE TRANSIT OF 1874. SUN-VIEW OF THE EARTH AT THE END OF THE TRANSIT OF 1874.

Figure 2. Proctor's maps used by Tacchini to choose the place from which to observe transit.

The instruments to be shipped to India, arranged and packed at the Observatory of Padova, were five refractors (Figure 3) – a Starke equatorial refractor from the Observatory of Padova (117 mm aperture, 1.65 m focal length), a Steinheil refractor from the Observatory of Bologna, with parallactic mounting[6] modified at the Padova Observatory (162 mm aperture, 2.60 m focal length), a Fraunhofer refractor from the Observatory of Torino, with parallactic mounting modified at the Padova Observatory (117 mm aperture, 1.95 m focal length), a Starke altazimuth from the Observatory of Padova (117 mm aperture, 1.95 m focal length) and a 95-mm Dollond refractor from the Nautical College of Palermo – a Repsold transit instrument (Figure 4), three spectroscopes, chronometers, chronographs, thermometers, barometers, micrometers, other accessories and four pavilions to shelter the main instruments (Figures 5 and 6).

On 1874 November 25, *The Englishman* of Calcutta, informed its readers that "The Italian expedition of Astronomers which has come to India to observe the transit of Venus.... [had] established their quarters at Madápur, on the chord line of the E.I. Railway, where the atmosphere is very clear in this time of the year, and where they have built *pakka* platforms." (p.2). On 1874 December 7, *The Daily Telegraph* of London gave a detailed review of the transit phenomenon, both from the historical and scientific points of view, and added information on "... British expeditions which have been provided by the nation." and private expeditions like that organized by Lord Lindsay. The paper stated that

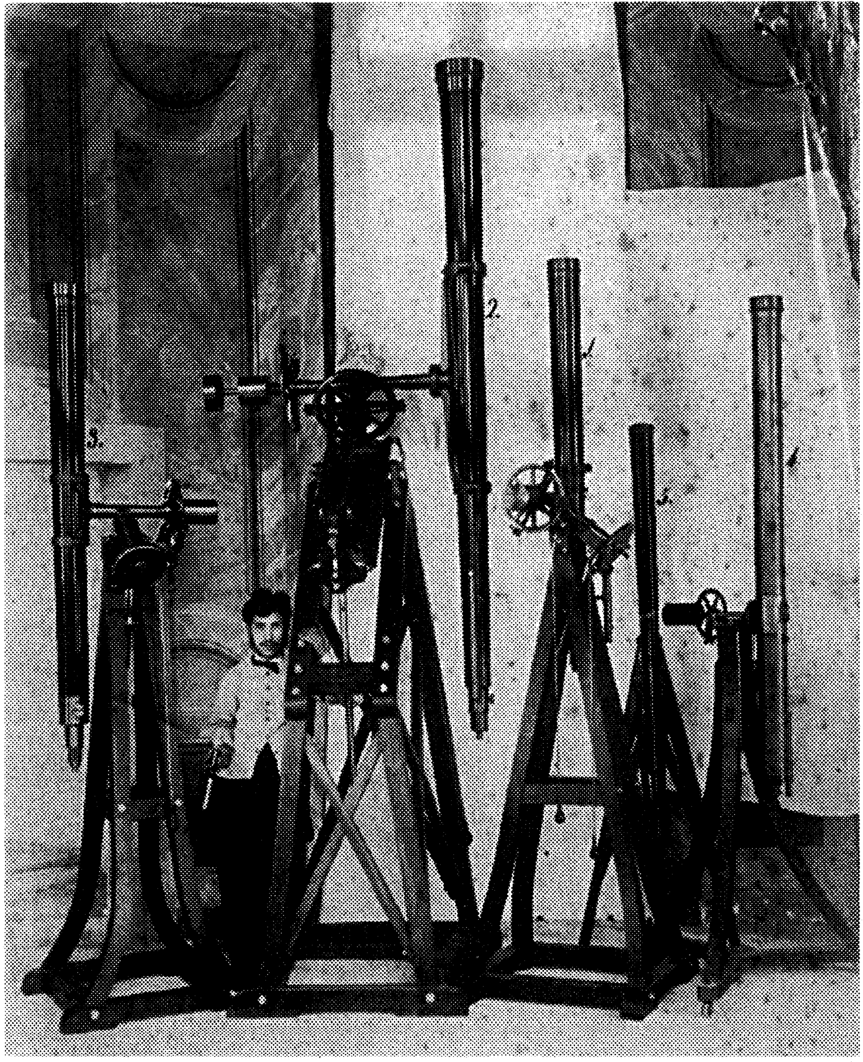


Figure 3. The five refractors photographed in the 'Sala delle figure' at the Observatory of Padova before shipping them to Muddapur (left to right): (3) the Fraunhofer refractor from Torino, (2) the Steinheil refractor from Bologna, (1) the Starke equatorial from Padova, (5) the Dollond refractor from Palermo, (4) the Starke Altazimuth from Padova. Near the Steinheil refractor is the young mechanic A. Cagnato (Photograph: Astronomical Observatory of Padova, Historical Archives).

> The Americans took up the subject upon such a scale as might been expected of them. The dollars they voted amounted to double the sum granted by the British Government ... and Italy has been so quiet over her operation that their extent is not known. (see pp.5-6).

In fact, the silent protagonists of the only Italian expedition were two passionately-keen astronomers, whose close friendship helped get the expedition ready in just a few months, as is documented in the Lorenzoni-Tacchini correspondence (which is to be published shortly).

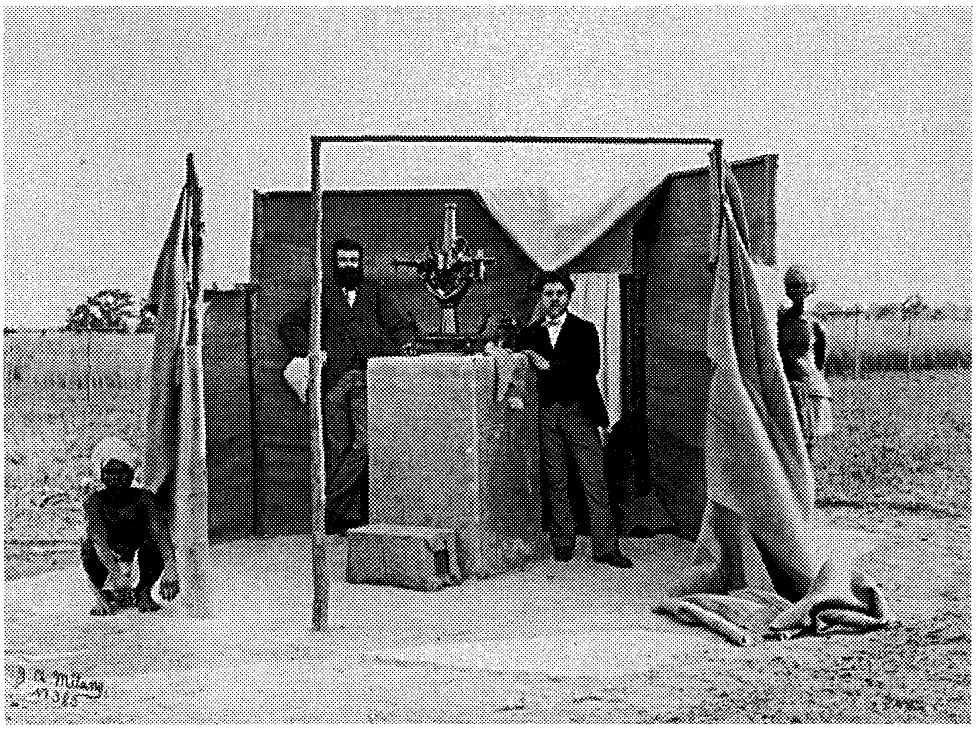


Figure 4. The Repsold transit instrument from the Observatory of Padova, used by Antonio Abetti to check the geographical latitude and longitude and the local time. Near the pillar are C. Morso (left) and A. Cagnato (right) (Photograph: Astronomical Observatory of Padova, Historical Archives).

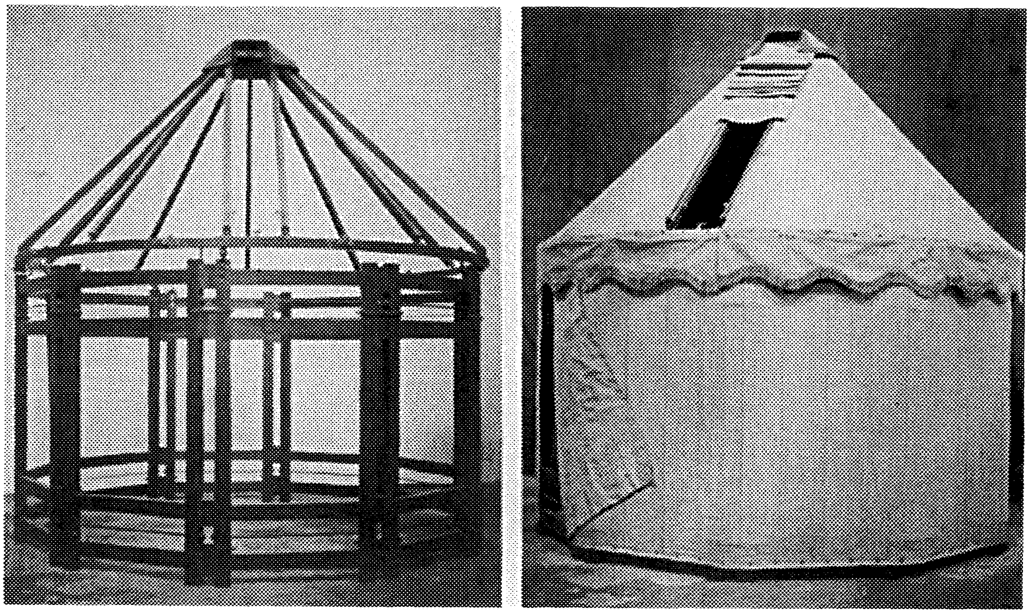


Figure 5. One of the four pavilions made to shelter the main instruments: the circular upper part of the wooden skeleton (left) could rotate like a little dome; the cover was made of sail-cloth (right) (Photograph: Astronomical Observatory of Padova, Historical Archives).

Figure 6. A panorama of the Transit station at Muddapur. From left to right: the pavilions for the Starke equatorial refractor, Starke Altazimuth, Fraunhofer refractor, the pillar for the Repsold transit instrument, and the pavilion for the Steinheil refractor. Background: the tent to shelter the astronomers (Photograph: Astronomical Observatory of Padova, Historical Archives).

2 THE SPECTROSCOPES

For the transit observations, the Italian astronomers used only two direct-vision spectroscopes, among the six carried with them. Figure 7 shows the scheme of a 19th-century spectroscope: **SS'** is the slit, **C** is the collimator, **P** the dispersing prisms, and **FO** the analyser telescope (Secchi, 1877b).

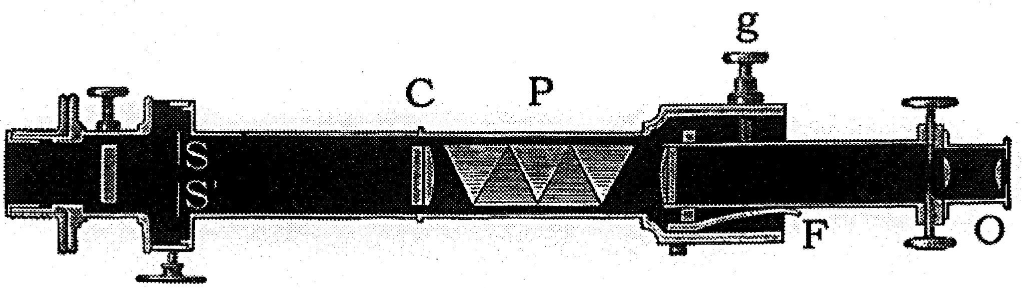


Figure 7. Cross-section of a direct-vision spectroscope.

The direct-vision spectroscope was invented in 1860 by the Italian optician Giovan Battista Amici (1786-1863) (Abetti, 1949; Abetti *et al.*, 1960; Monaco, 1994). It consisted of two crown-glass prisms alternating with a flint-glass one: by this arrangement it was possible to observe the spectrum of incident light without deviation from the line of sight. The French optician J G Hofmann improved this invention by inserting five alternating prisms to increase the dispersion. At that time, the term 'dispersion' meant the angle formed by the red and violet rays emerging from the analyser, which could be rotated to the left or right by the screw **g**, in order to look at different parts of the visible spectrum.

The Hofmann's spectroscope (Figure 8) used by Antonio Abetti during the transit was purchased in 1870 to observe the eclipse of the Sun in Sicily and was then acquired by the Astronomical Observatory of Padova (Pigatto, 1998). Originally, the instrument had a total dispersion of 10° and its telescope provided four magnifications (Lorenzoni, 1872), so that it was possible to resolve the sodium doublet. Subsequently, Lorenzoni modified the spectroscope in order to improve it and to make it more suitable for solar spectroscopy: he added a 20° graduated arc to measure the angular position of the spectral lines and inserted a slit in the focal plane of the analyser to reduce the spectral field (ibid.). Lastly, he increased the magnification of the analyser to 17 and replaced the collimator with one of 30 cm focal length; in this way, he was able to exploit the whole aperture of the prisms and of the objective of the telescope to which the spectroscope was applied (Lorenzoni, 1873f). The telescope-spectroscope system was an organic whole, so Lorenzoni coined the word *telespectroscope* (Lorenzoni, 1873c), a term which was also used by Lockyer (1873) at this time.

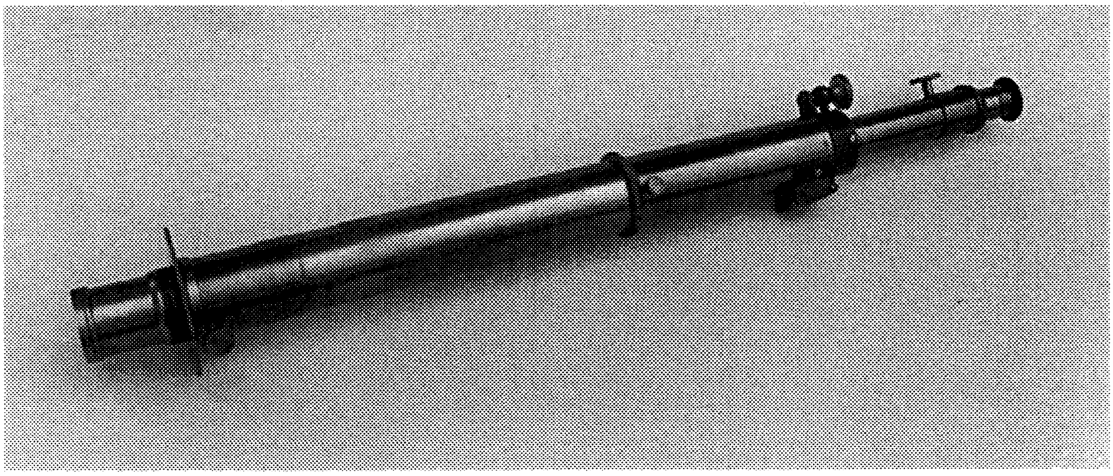


Figure 8. The Hofmann direct-vision spectroscope, modified by Lorenzoni (Museo *La Specola*, Astronomical Observatory of Padova).

The spectroscope used by Pietro Tacchini (Figure 9), purchased by the Astronomical Observatory of Palermo in 1870, was made in Tauber's workshop in Lipsia following a project of the German astronomer Johann Karl Friedrich Zöllner (1834-1882); it was composed of a double prism system (Foderà-Serio & Chinnici, 1997), with a collimator of 70 mm focal length (Tacchini, 1873a). In 1873 Tacchini asked Lorenzoni to provide his spectroscope with a new collimator: the lens was made in Venice, whereas the spectroscope tube was modified in the workshop of the Padova Observatory (Tacchini, 1873b; Lorenzoni, 1873d; Lorenzoni, 1874c).

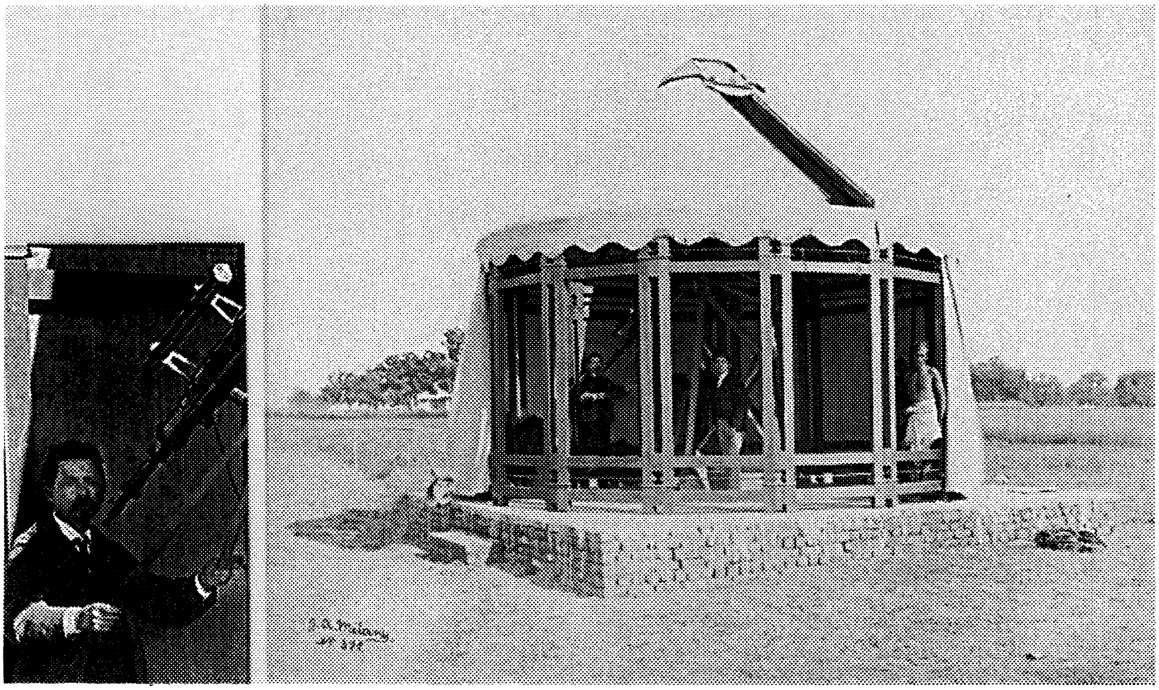


Figure 9. Tacchini at work, with his Tauber spectroscope (detail on the left) attached to the Steinheil refractor, in the pavilion with A. Cagnato (Photograph: Astronomical Observatory of Padova, Historical Archives).

3 METHODS OF OBSERVATION

Since the foundation of the Spectroscopists Society, Italian astronomers were engaged in a vivid debate about the best method to make spectroscopic observations of the Sun (Secchi, 1872a, 1874; Lorenzoni, 1872, 1873a, 1873b, 1873e, 1873f, 1874a, 1874b; Tacchini, 1874a). The spectroscopic observation of the transit was based upon the possibility of highlighting the chromosphere in emission, and observing the planet's presence on it before contact with the solar photosphere. In this way, it was possible to determine exactly contacts I and IV in addition to II and III. With traditional observations, contacts I and IV were observable, because of light diffusion, only when the planet had already entered the solar disc, or was still on it before exit.

Two methods of observation were used, one with the 'narrow slit', and one with the 'large slit'. The former consisted of putting the slit tangential to the Sun's limb, so that it was possible to observe a solar spectrum, on which the red chromospheric emission dominated, precisely in the line C (Hα) range (Figure 10, left). Once the planet entered the slit, the contact of Venus with the Sun produced a break in the spectrum and the appearance of a transversal strip, first very thin and then thicker and thicker, proportional to the fraction of the incoming planet. The exit of the planet from the slit produced a similar effect, but in opposite sequence. Therefore, the gradual appearance and disappearance of the strip gave the four contacts in succession, during the ingress and egress of Venus respectively.

The second method worked with the large slit, so that the whole part of the included chromosphere could be seen on line C (Figure 10, right). If a small portion of the solar disc were also included, it would be possible to observe the absorbed black arc of the photosphere surrounded by the bright red chromosphere. In this case, Venus appeared like a small dark disc coming over the chromosphere: the touch of the planet with the limb of the Sun gave the first contact; the second was given by the complete recomposition of the chromosphere. Also in this case, the transversal strip was present along the spectrum, but the contacts were independent of its appearance or disappearance.

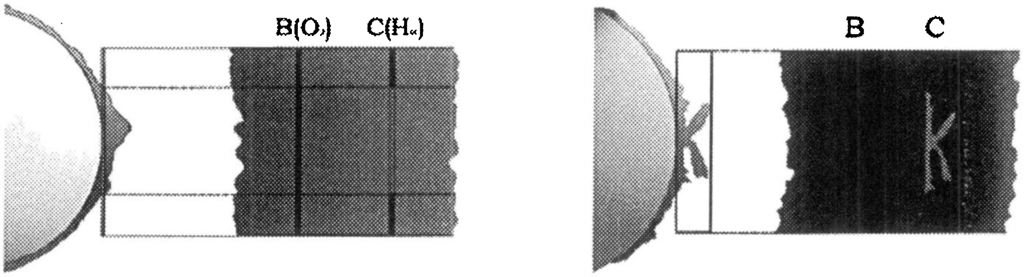


Figure 10. Drawings of the two methods of observing the solar limb in the spectral range of Hα, with narrow (left) and wide (right) slits (after Figures 152 and 158 in Secchi, 1877a).

4 THE OBSERVATIONS BY TACCHINI AND ABETTI

On 1874 December 9, clouds prevented Tacchini and Abetti from observing the first contact with the spectroscopes, but, with the narrow slit, it was presumed to be seen as in drawing 3 of Figure 11. In the original drawing, because of printing error, line C is black instead of red. After a short time, Tacchini (1875a:81) saw "... a wonderful strip of a crazy black; and it seemed almost dark tobacco colour ..." (drawing 2); a few minutes later "... this strip occupied about the third part of the slit." (drawing 1). In these conditions, Tacchini (1875a:82) decided to observe the phenomenon also with the large slit: "Actually, with the large slit, before the second contact Venus was visible over the chromosphere as in Figures 5 and 6 of table VI ..." (drawings 5 and 6 on the right of Figure 11). He concluded (ibid.) that "Also with the large slit it was possible to see the instant of the recomposition of the chromosphere, like in Figure 4." (drawing 4). Unfortunately, again because of clouds, the second contact also was invisible and was lost by both Tacchini and Abetti; the latter observed the transit with the large slit, as he had learned from his teacher Lorenzoni. The two astronomers were luckier at the third and fourth contacts: the weather cleared and Tacchini could observe the appearance, growth, and disappearance of the transversal strip over the solar spectrum, with the sequence of drawings 3, 2 and 1 (and back) shown in Figure 11; Abetti, instead, observed the phenomenon with the sequence of drawings 2 and 1 shown in Figure 12.

The other members of the expedition could see all of the four contacts, although they were disturbed by clouds: Dorna, with the Fraunhofer telescope (Figure 13), and Father Lafont, with

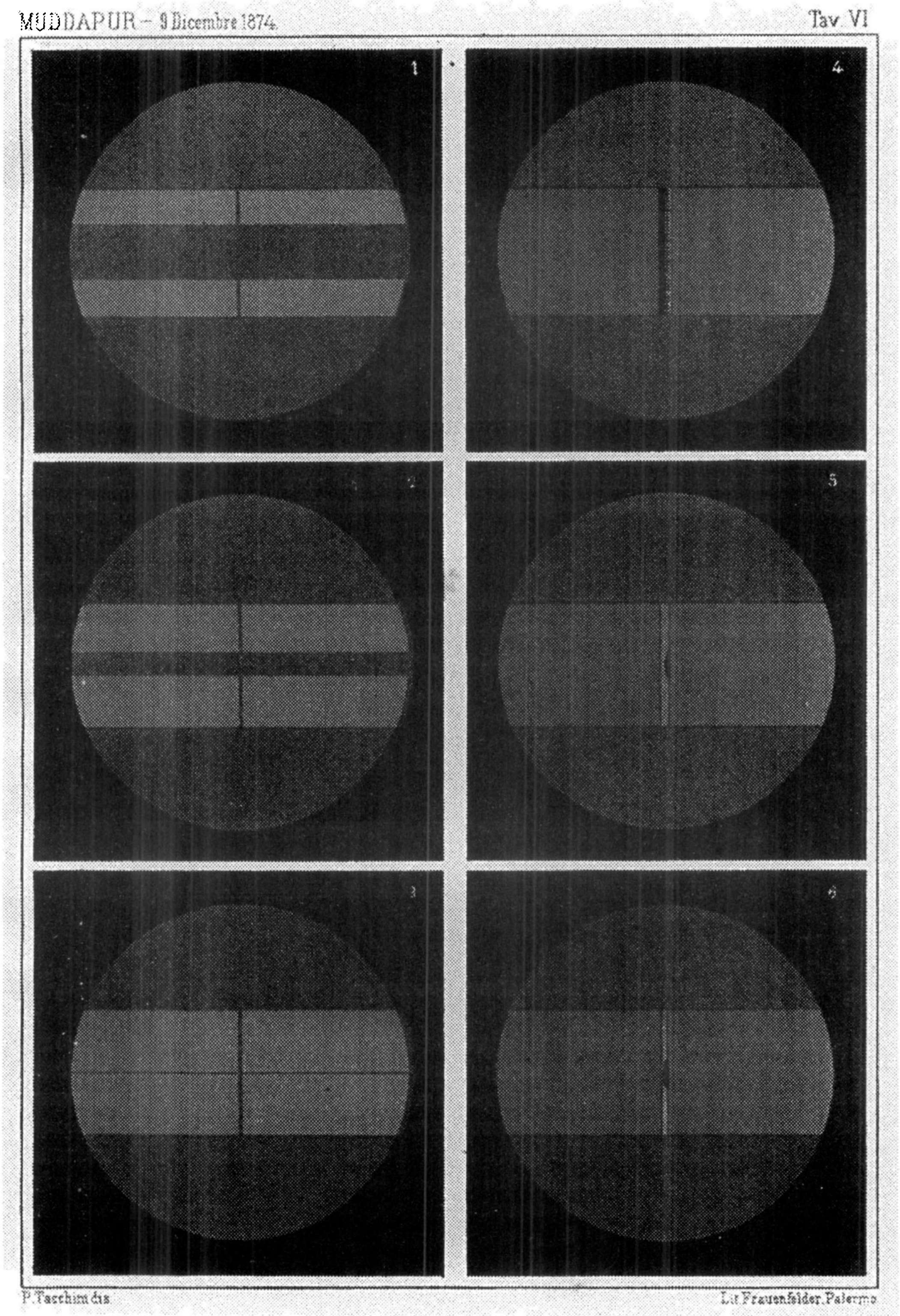


Figure 11. Reproduction of Table VI (Tacchini, 1875a) described in the text. In this Table, the drawings are numbered from 1 to 6, starting from the upper left corner; the circle represents the telescope field.

the Starke Altazimuth, viewed the phenomenon with direct visual observations, while Morso, with the Dollond refractor placed under the covering of the transit instrument, used projection, with a method perfected by Tacchini (Tacchini, 1875b). The results of the Italian observations are shown in Table 1.

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Table 1. Time of the four contacts recorded by the observers at Muddapur*

Contacts	Abetti	Dorna	Lafont	Morso	Tacchini
I	-	$19^h 38^m 36^s.55$	$19^h 37^m 40^s.78$	$19^h 41^m 35^s.06$	-
II	-	$20^h 05^m 52^s.56$	$20^h 05^m 25^s.01$	$20^h 06^m 41^s.04$	-
III	$23^h 48^m 52^s.97$	$23^h 51^m 03^s.63$	$23^h 51^m 06^s.73$	$23^h 51^m 09^s.93$	$23^h 48^m 57^s.48$
IV	$0^h 17^m 36^s.90$	$0^h 18^m 46^s.63$	$0^h 18^m 42^s.56$	$0^h 19^m 12^s.92$	$0^h 18^m 06^s.41$

* Contacts are in Muddapur Local Mean Time, 1874 December 8-9. In those days the mean time or astronomical time, started at noon[7].

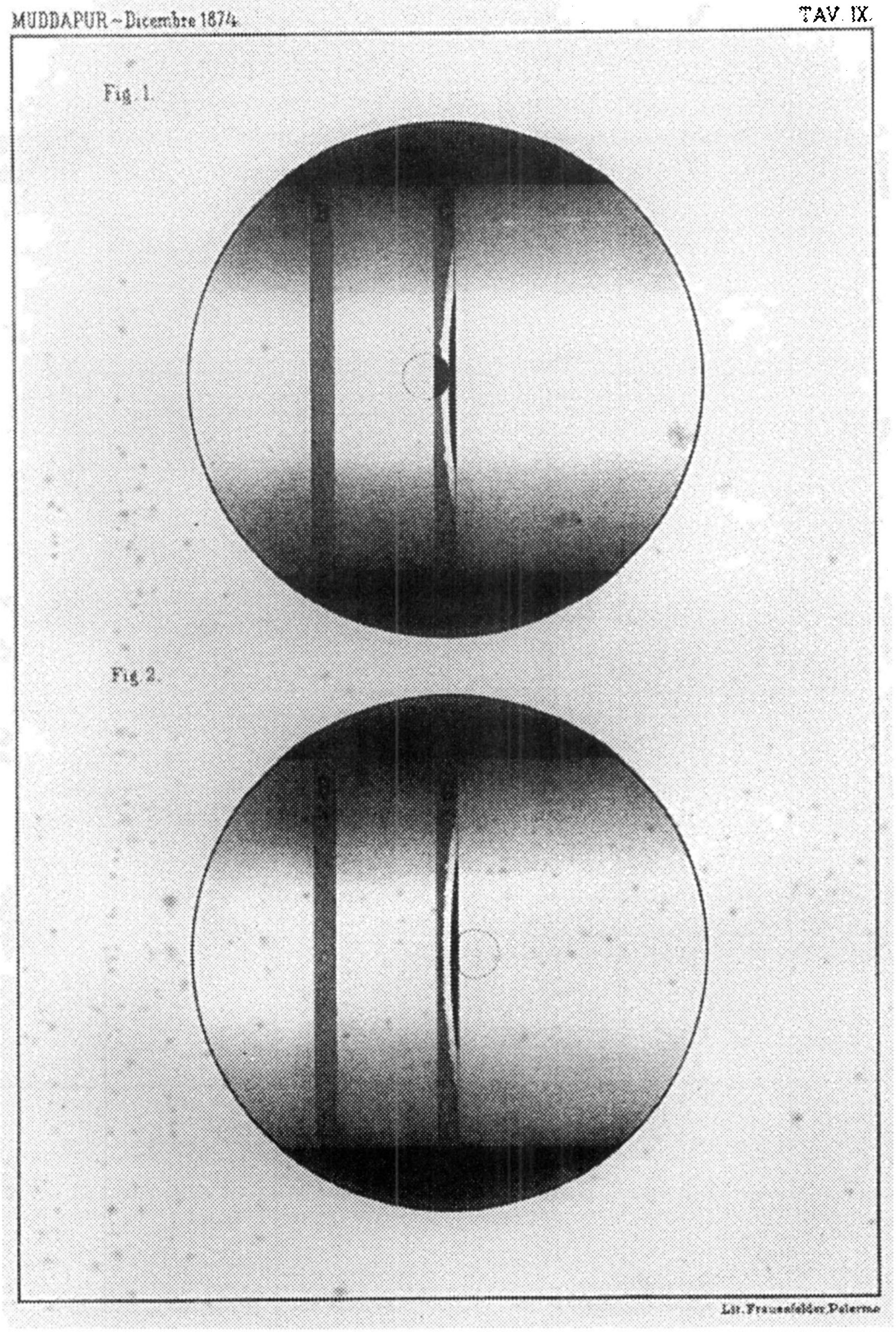

Figure 12. Reproduction of Table IX (Tacchini, 1875a), showing the solar limb observed by Abetti with the Hofmann spectroscope attached to the Starke equatorial.

As we can see from these data, contacts III and IV observed with the spectroscope took place earlier than the telescopic ones, so Tacchini (1875a:99) concluded that "... at the spectroscope the solar diameter is smaller than that observed in an ordinary telescope." In previous works on spectroscopic observations, Secchi (1872b) and Lorenzoni (1873a, 1873b) had reached the same conclusion, and Secchi (1874:13) had suggested that "... the spectroscope deprives the solar disc of that halo formed naturally by the chromosphere mixed with vapours of other metals." (translated from Italian).

The path of Venus during the transit was inclined by 57°.75 with respect to the vertical solar radius, and Tacchini calculated a difference of 4″.33 between the spectroscopic and ordinary diameters, but emphasized that this value was scarcely significant. In fact, comparing the meridian transit times of the Sun published in *The Nautical Almanac* with those of Washington, he noted differences both among observations made by the same observer in subsequent times, and among contemporaneous ones made by different observers (Tacchini, 1875a).

In the days after the transit, the Italians made new observations of the telescopic and spectroscopic solar diameter, and although the latter always furnished lower values, the differences between the two diameters varied between 2″.82 and 4″ (Tacchini, 1875a). Tacchini (ibid.) concluded that although the spectroscopic diameter was systematically smaller than the telescopic one, diameters derived from transit timings showed great differences, for reasons that were unknown.

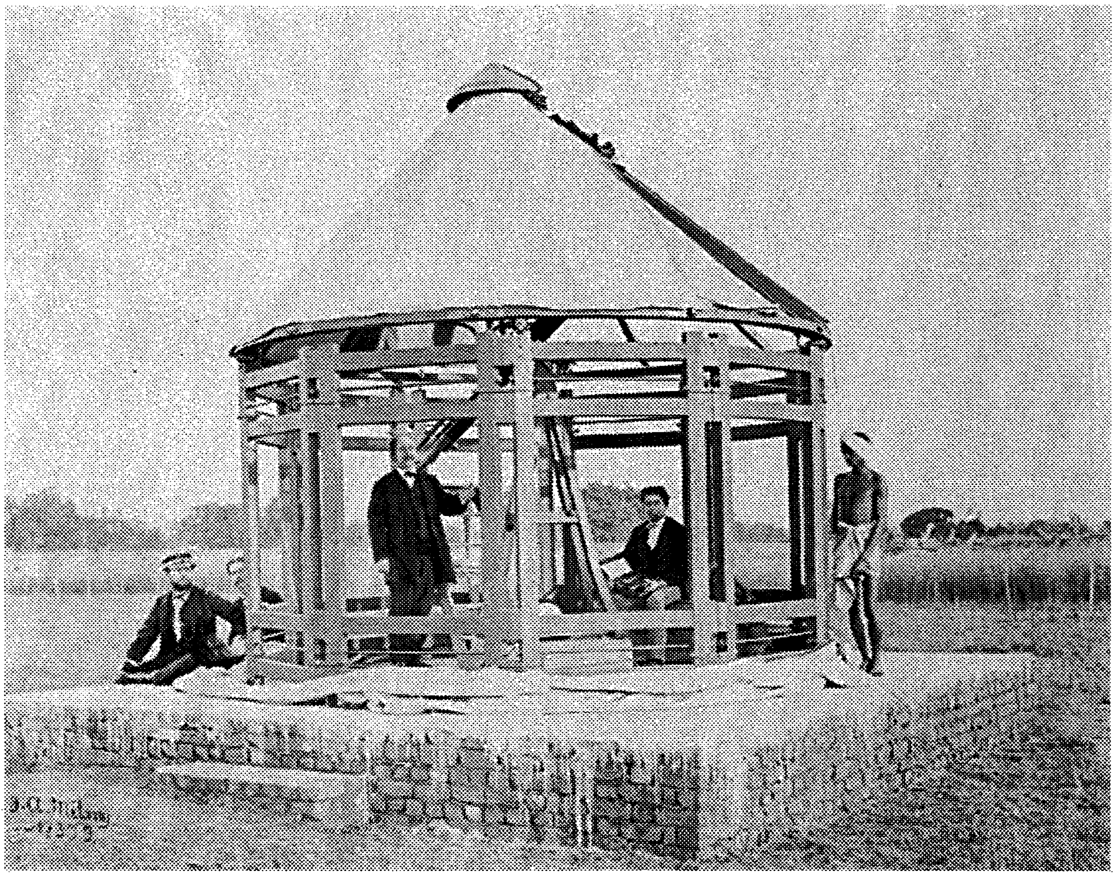

Figure 13. A. Dorna (standing) and A. Cagnato (seated) in the pavilion of the Fraunhofer refractor of the Observatory of Torino (Photograph: Astronomical Observatory of Padova, Historical Archives).

Recent works (e.g. see Delache, 1988; Stephenson, 1981; Toulmonde, 1997; Wittman, 1977, and Wittman and Débarbat, 1990) confirm that the best method of observing the solar diameter (and its supposed secular and periodic variability) is still open to debate, but these reports do indicate that the transit diameter is larger than that obtained using other methods.

Moreover, it is necessary to distinguish solar diameter with or without irradiation, but this distinction was not taken into account in 1874—it only came into use after 1890 (Stephenson, 1981). Lastly, it should be recalled that the Italian spectroscopic observations were made in Hα light, a wavelength absorbed by the photosphere, so that the measurements refer to the inner edge of the chromosphere rather than the diameter of the photosphere.

5 THE ATMOSPHERE OF VENUS

On 1874 December 9 through the Calcutta consul, Tacchini sent a telegram to the Italian Minister of Education: "First observations disturbed by small clouds – Good results spectroscopic and ordinary – Spectrum of Venus observed, details probably related to its atmosphere." [in English in the original] (Tacchini, 1875a:35). At the same time, he sent a telegram to Lorenzoni: "Osservazioni passaggio Venere riescite felicemente / Veduta atmosfera pianeta." (Tacchini, 1874b).

After the loss of the first two contacts, Tacchini had ample time to observe the planet while it was crossing the Sun's photosphere, placing the slit of the spectroscope normal to the path of Venus:

> Then I observed the solar spectrum through a narrow slit, making the planet transit across; and before the disc of Venus entered the slit or immediately after its exit, I seemed to see some modifications: I repeated the same observation many times, and I actually saw the spectrum always grow dark around the C line [Hα at 6563 Å] and near the B line [O_2 at 6867 Å], that is, in the well-known place of the telluric lines [translated from the Italian] (Tacchini, 1875a:82).

He repeated the experience in the spectral range around the D lines of sodium, but did not see any change in the spectrum. Abetti also observed and confirmed the phenomenon; lastly, Tacchini concluded that he had observed the atmosphere of Venus spectroscopically and that it was similar to the terrestrial one: "I believe that the phenomenon is due to the planet's atmosphere which has the same elements as the Earth, i.e., a large quantity of water vapour ..." (Tacchini, 1875a:83).

At that time, knowledge of the solar spectrum was greatly improved following Fraunhofer's discovery. The fundamental work of Kirchhoff, Janssen, Brewster, Van der Willingen, Draper (who introduced the first diffraction photographic spectrum) and Ängström (who introduced the wavelength unit), was well-known among astronomers (see Sechi, 1875). Within this framework, the possibility of finding a terrestrial or similar atmosphere associated with other planets and in consequence some kind of life similar to that on Earth encouraged astronomers to search for them. Tacchini, too, was involved in this fascinating problem, so that it was not at random that he observed the spectral range where telluric lines of oxygen and water vapour are in large numbers. In the field of his telescope he could observe both lines B and C. In this spectral range, water vapour lines are very near Hα; in addition, a luminous portion of the continuum is clearly visible for about 265 Å (Rowland, 1896; Moore *et al*., 1966). Perhaps Tacchini was able to perceive the instantaneous darkening, quoted above, because of the contrast with the near luminous continuum (see Figure 14). This fact may explain why he did not perceive any change around the sodium doublet, where water vapour lines are crowded, leaving little space for the continuum. This is the spectral range that was known as the 'rainband' in the nineteenth century, and because its variability was linked with meteorological events it was thought that by observing it through the spectroscope one could forecast rain and storms (Capron, 1882).[8]

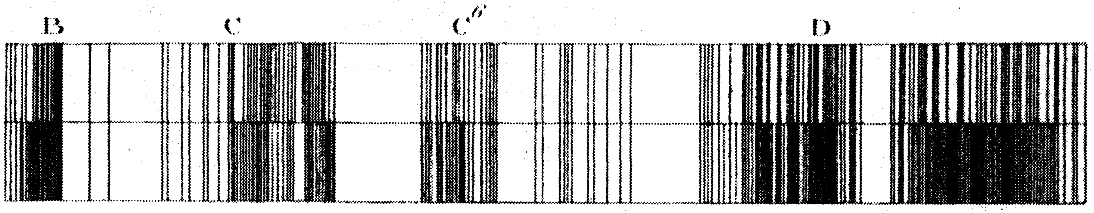

Figure 14. Solar spectra taken by Janssen, with the Sun in two different positions above the horizon. The top spectrum represents a higher solar position. The variable intensity of telluric absorption lines is evident (after Secchi, 1875a).

Today, the existence of water vapour, oxygen, and many other elements in the atmosphere of Venus (see Hunten, 1998 for a review) has been confirmed by many spacecraft experiments—and particularly those associated with the Soviet Venera 15 (Moroz *et al.*, 1990) and US Pioneer Venus Orbiter (Koukouli *et al.*, 2000)—but all observations relate to the near infrared. For this reason, it seems interesting to quote two papers which, although widely separated in time, concern observations of the visual spectrum of Venus from the Earth. Both are based upon observations of the Doppler effect on the atmospheric lines of Venus, because of the relative velocities of the two planets. In 1921, using the Snow telescope and the Littrow grating-spectrograph, St. John and Nicholson (1922) observed the water vapour lines near 5900 and oxygen bands α and B, but concluded that "No trace of any line due to the planet's atmosphere was observed." whereas in 1999 Slander *et al.* (2000) used the Keck 1 telescope and the HIRES echelle spectrometer to observe the 5577 Å oxygen green line in the atmosphere of Venus.

So what did Tacchini see with his spectroscope back in 1874? Perhaps he observed some absorption because of the peculiar condition of the transit: since Venus was at inferior conjunction at the time, the path-length of sunlight through the Venusian atmosphere was greater than at other phases. The planet was never again observed spectroscopically under these conditions, even when the 1882 transit gave astronomers the opportunity. For this reason, it will be very interesting to repeat Tacchini's observations during the 2004 and 2012 transits, using the original instruments *and* modern spectroscopes, in order to determine whether the two Italian astronomers saw a genuine effect or not.

6 CONCLUSIONS

The Italians (see Figure 15) were the only ones who made spectroscopic observations during the transit. In 1874 December, *Nature* reproduced most of an article which had appeared in the *Times* on December 9. Speaking about the scientific results of English, American and German astronomers, the article stated:

> The German observations made this morning in the South seas will be the most important obtained by all the expeditions. With regard to Italy, also, there are the same signs of scientific enterprise. The spectroscope, which forms no part of the equipment of the English expeditions, 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. (*Nature*, XI:103)

Figure 15. The Italian Transit party at Muddapur. Seated (left to right): E. Lafont, P. Tacchini, the consul F. Lamouroux, A. Dorna, C. Morso. Standing (left to right): the Muddapur station-master Witley, A. Abetti, the mechanic A. Cagnato (Photograph: Astronomical Observatory of Padova, Historical Archives).

Meanwhile, Flammarion (1877:167) was enthusiastic, and defined as "capital" the spectroscopic observation of the atmosphere of Venus by the Italian astronomer Tacchini.

The results of the Italian observations were published in 1875 (Tacchini, 1875a). Unfortunately, because of financial difficulties, but mainly due to the scientific myopia of the Ministers of Education of the new Government, the Italian astronomers could not organize the expedition for the 1882 transit, and could not even take part in the Paris meeting of 1881 organized by France to prepare the new expeditions (*Passaggio di Venere del 1882*). They were thus prevented from entering into a constructive debate with the international scientific community, and this missed opportunity had negative repercussions on the development of the modern astrophysics in Italy.

7 NOTES

1 Angelo (Pietro) Secchi (*b*. Reggio Emilia, 18 June 1818; *d*. Rome, 26 February, 1878). Instructor in mathematics and physics at the Jesuit colleges, in 1849 he took up an appointment as director of the Observatory of the Collegio Romano, and remained there until his death. His scientific activity was mainly devoted to spectroscopy and astrophysics and in particular he turned his attention to the Sun, its chromosphere and its corona. In his studies of stellar spectra, Secchi was able to identify five types, and this classification (which still bears his name) was soon adopted almost universally. Most of his work was published in the *Memorie della Società degli spettroscopisti italiani* (Abetti, 1975)

2 Pietro Tacchini (*b*. Modena, 21 March 1838; *d*. Spilamberto [Modena], 24 March 1905), received a degree in engineering from the *Archiginnasio* of Modena, and studied astronomy at the Observatory of Padova, under Giovanni Santini. In 1863 he was appointed adjunct astronomer to the Observatory of Palermo, where he began research on solar physics using the spectroscope. In 1879 he succeeded Angelo Secchi as director of the Observatory at the Collegio Romano and became director of the Central Meteorological Office. Tacchini's scientific activity was thus mainly devoted to astrophysics and meteorology. Most of his publications are in the *Memorie della Società degli spettroscopisti italiani* (Abetti, 1976).

3 Giuseppe Lorenzoni (*b*. Rolle di Cison [Treviso], 10 July 1843; *d*. Padova, 7 July 1914), received a degree in engineering from the University of Padova in 1863, and became assistant to the director of the Observatory of Padova, Giovanni Santini, in the same year. In 1872 he was appointed professor of astronomy at the University of Padova, and in 1878 became the director of the Observatory. He also held the professorship of geodesy from 1869 to 1885. Lorenzoni's scientific activity was devoted to classical astronomy, astrophysics and spectroscopy, and also to geodesy. His research is published in various issues of *Memorie della Società degli spettroscopisti italiani* and *Atti dell'Istituto Veneto di Scienze Lettere ed Arti* (Abetti, 1973).

4 Alessandro Dorna (*b*. Asti, 13 February 1825; *d*. Borgo S. Pietro – Moncalieri [Torino], 19 August 1886), received a degree in engineering from the University of Torino in 1848, and in 1850 was appointed professor of rational mechanics at the military academy, professor of astronomy at the University of Torino, and director of the Observatory of the same city. As director, he promoted and developed the Observatory and its instruments. Dorna's scientific activity was devoted essentially to positional astronomy (Monaco, 1992).

5 Antonio Abetti (*b*. S. Pietro di Gorizia, 19 June 1846; *d*. Arcetri [Florence], 20 February 1928), received a degree in civil engineering from the University of Padova in 1867 and was astronomer of the Observatory of Padova from 1868 until 1893. In 1894 he became director of the Astronomical Observatory of Arcetri and professor of astronomy at the University of Florence, and remained there until 1921. Abetti's scientific activity was devoted essentially to positional astronomy. His research was published in various issues of *Memoirs and Observations of the Observatory of Arcetri* (Abetti, 1970).

6 The terms 'parallactic mounting' and 'parallactic machine' (= equatorial telescope) were used by Italian, French and German astronomers and telescope-makers during the eighteenth and nineteenth centuries, but never by English ones. This term was invented by Cassini II (1677-1756) in 1721. In his *Astronomie*, La Lande (1797-1807: 622) writes: "The parallactic machine, also called parallactic telescope, is used to follow the parallel of a star, or its diurnal motion from east to west, describing the same parallel."

7 The unification of the civil and astronomical day started to be accepted by astronomers only in 1925. In 1928 the IAU recommended that Universal Time (UT) should be used internationally in almanacs (Howse, 1997).

8 The water vapour lines of the terrestrial atmosphere are subject to continuous variation due to observational circumstances such as height above the horizon, season and other meteorological phenomena (Salet, 1909; Secchi, 1875). The Astronomer Royal of Scotland, Charles Piazzi Smyth (1819-1900), was the first to suggest using the rainband to forecast rain and storms (Smyth, 1875). He developed this idea in 1872 during a visit to Palermo to observe the zodiacal light, on which occasion he was able to see the rainband using his pocket spectroscope both before and after a sirocco (Capron, 1882). It was in Palermo that Piazzi Smyth met Tacchini, to whom he must have mentioned the phenomenon. Tacchini (1872) speaks of this meeting in a letter to Lorenzoni that was delivered in person by the Scottish astronomer during his visit to Padova.

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The following abbreviation is used:
CL = *Correspondence Lorenzoni-Tacchini*
PAO = Padova Astronomical Observatory, Historical Archives.

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