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Observation of Venus and Mercury Transits from the Pic-du-Midi Observatory

Guy Ratier

43 rue des Longues Allées, F-45800 Saint-Jean-de-Braye, France

Sylvain Rondi

Société Astronomique de France, 3 rue Beethoven, F-75016 Paris France

Abstract. The Pic-du-Midi, on the French side of the Pyrénées, became a state observatory in the summer of 1882. The first major astronomical event to be observed was the Venus transit of 6 December 1882. Unfortunately this attempt by the well-known Henry brothers was unsuccessful due to bad weather conditions.

During the twentieth century, the Pic-du-Midi became famous for the quality of its solar and planetary observations. In the sixties, Jean Rösch decided to use this experience to monitor the transits of Mercury. The objective was not to measure the parallax, but to determine the diameter of the planet in order to confirm its high density. Observations were made using a photometric method – the Hertzsprung method – during the transits of 1960, 1970 and 1973.

The pioneer work of Ch. Boyer on the rotation of the Venus atmosphere as well as some experiments involving Lyot coronographs are also noteworthy.

A Venus transit was finally observed on 8 June 2004 with a new CCD camera, providing a significant contribution to the model of the Venus mesosphere. This opened the field for new observations in 2012.

1. Early days of the Pic-du-Midi Observatory

The site of the "Pic-du-Midi de Bigorre", on the forefront of the Pyrénées, has been known since ages as an ideal location to carry out astronomical observations.

François de Plantade (1670–1741), a lawyer from Montpellier, who met Jean-Dominique Cassini in 1693 in Paris, showed early interest in astronomical observations.[1] He died at the Sencours pass (elevation 2378 m) at the age of 71 during a mapping mission. At this very location, Dr. Costallat built in 1852 a "Hostellerie", with the intention to attract tourists and scientists. In fact, it is from this "Hostellerie Plantade" that the famous photographer, Maxwell-Lyte, successfully recorded his first photographic images of a solar eclipse, on 18 July 1860.

Thanks to the "Société Ramond" and the enthusiasm of the co-founders Général de Nansouty and C.-X. Vaussenat, there was a growing interest in the scientific community to build an observatory at the Pic-du-Midi. As a trial, it was decided to start regular meteorological observations during the 1873 summer season, from the Plantade station. In view of the success of this first experience, the Général de Nansouty decided in 1874 to perform regular observations, also during winter time.

[1]During the 1706 solar eclipse, he was the very first to give a description of the solar corona. In 1736, observing the transit of Mercury from Montpellier, he claimed to have detected a possible bright ring around the planet.

Unfortunately, severe weather conditions with huge snow falls and avalanches forced the General to evacuate the Hostellerie Plantade on December 14, 1874.

It was a painful experience. But a lesson was learned, and it was thus decided to build a permanent observatory on the very top of the mountain at 2877 meter. On 20 July 1878, the first stone was laid; but the completion of the project appeared to well exceed the financial resources of the founders.

In August 1882, the ownership of the observatory had to be transferred to the French State, and C.-X. Vaussenat became the first director.

2. The 6 December 1882 Venus transit

There was a huge interest in the scientific community for the observation of the 1882 Venus transit. France organised ten expeditions all over the world.

In France, the Sun was rather low above the horizon, but one can understand that Admiral Mouchez, director of Paris Observatory, decided to send the two Henry brothers to the recently opened Pic-du-Midi observatory. The positive experience made by Maxwell-Lyte during the 1860 eclipse has probably played a role in that decision. Indeed, Prosper and Paul Henry (Fig. 1) were excellent candidates for this task, as they were very well experienced with the set-up of the photographic laboratory in Paris observatory.[2]

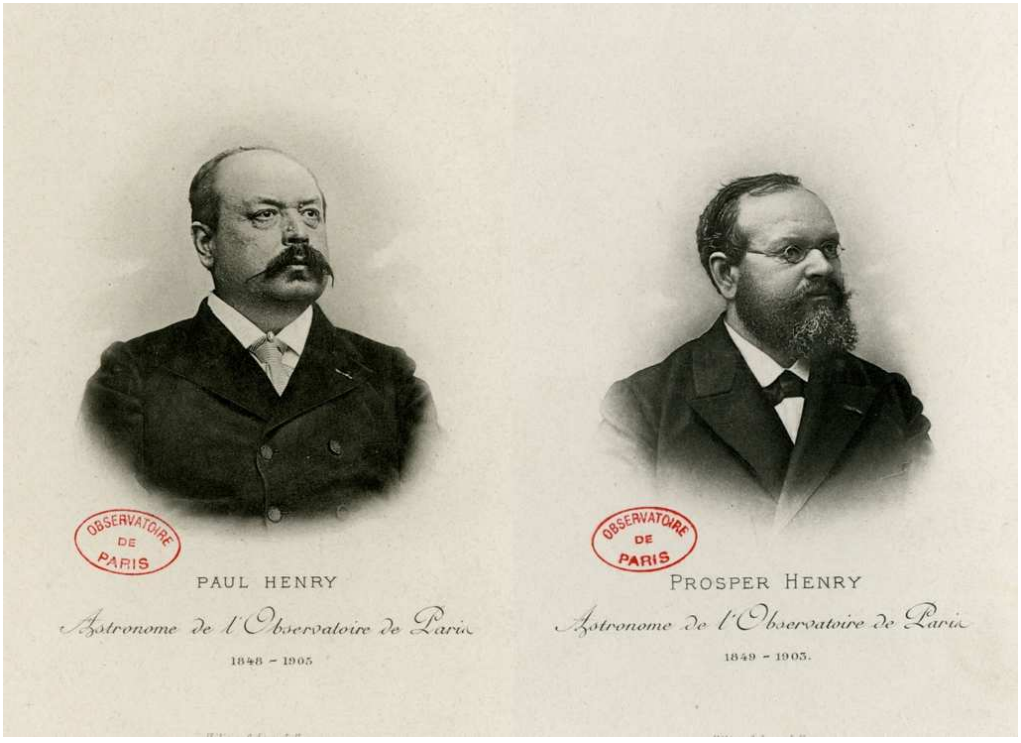

Figure 1. The Henry brothers (Paul & Prosper). Source: Bibliothèque de l'Observatoire de Paris.

[2]They later provided a key contribution to the success of the "Carte du Ciel" project.

However, snowfall was ahead of schedule that winter in the Pyrénées. The equipment needed by the Henry brothers was brought with huge difficulties to the Hostellerie in Sencours. But it was out of question to hand-carry the 60 boxes (with an average weight of 20 kg) to the summit.

Therefore C.-X. Vaussenat and the Henry brothers decided to install the astronomical equipment in Sencours. A team of porters was to bring the necessary logistic support from the valley to the Sencours pass. Unfortunately, on 2 December, four days before the transit, a snow avalanche caught the porter team shortly after leaving Sencours. Three men were killed in this dramatic mountain accident. It was a bad start for this astronomical mission.

On December 6, in the early morning, after a somewhat stormy night, the Sun was shining again. The Henry brothers took a few preliminary calibration plates. All the equipment was ready at midday to start recording. Unfortunately, half an hour later, clouds came, a strong wind started blowing, and even snow was flying horizontally! During some short periods they could see the Pic-du-Midi summit in the blue sky, but with a sudden fall in atmospheric pressure, the wind increased significantly and the Sencours pass became completely overcast. "*La partie était perdue*" C.-X. Vaussenat recorded sadly in his notebook.

Two days later, on Friday 8 December, the weather conditions became excellent, and the Henry brothers were able to observe the planet, 3 degrees away from the Sun. According to Vaussenat's notes, they saw "a special annular brightness which could originate from the atmosphere of the planet".[3]

In fact, the observation of the 1882 Venus transit from the Pic-du-Midi was a double failure, as no astronomical data were acquired and a fatal accident occurred resulting in three casualties. However, this accident highlighted the need to have permanent observing equipment at the summit. Accordingly, in 1884 two telescopes (likely a heritage from the other Venus transit missions) were erected at the Pic-du-Midi.

3. Paving the road towards the 2004 Venus transit: observation of Mercury transits

After this difficult start, the astronomical activities made a significant step forward when, following an initiative of Benjamin Baillaud, director of the Toulouse observatory, a large dome (8 m diameter) was erected at the summit in 1907. Soon after, the first observations of Mars performed by F. Baldet, an astronomer from Meudon observatory, confirmed the possibility to acquire high quality images at the Pic-du-Midi.

The exceptional quality of the atmosphere at the Pic-du-Midi was further emphasized in the 1930s by Bernard Lyot when he demonstrated the possibility to observe the solar corona outside eclipses with his "coronograph". Bernard Lyot, who was a very skilled astronomer, recorded later high-resolution images of the Moon and the planets. In the Coupole Baillaud, the 38-cm refractor was replaced in 1943 by a 60-cm refractor originally built by the Henry brothers for the "Coudé equatorial"

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[3] *"A midi, MM. Henry observent Vénus à l'œil nu et aussi avec une petite lunette; ils constatent qu'elle n'est qu'à* 3° *du soleil et qu'ils la voient avec autant de netteté qu'on la voit ailleurs avec de puissants instruments. Ils constatent même autour de Vénus un espace presque entièrement annulaire d'une clarté spéciale et qui constituerait l'atmosphère de Vénus".* C.-X. Vaussenat, quoted by J. Rösch, 1951.

at Paris observatory. A team of young astronomers, following the impulse given by Bernard Lyot, was assembled to perform observations as frequently as possible at the summit. Among them, the names of Henri Camichel and Audouin Dollfus have to be quoted.

It was in this context that Jean Rösch became the new director of the observatory from 1947 onwards. He made a lot of efforts to develop a wide spectrum of observations and to improve the necessary logistic support at the Pic-du-Midi.

One of his achievements is undoubtedly the "Coupole Tourelle"[4] dedicated to photography of the solar surface (spots and granules). This dome has a specific design where the refractive doublet is closing the aperture, preventing any heat exchange (and therefore image degradation) from the instrument. This dome, operated by A. Carlier and R. Muller, yielded photographs that were considered to be among the sharpest ones recorded by ground-based solar telescopes.

In this situation, it is no surprise that Jean Rösch took the opportunity to observe the Mercury transits. The aim was not the determination of the solar parallax, but new measurements of Mercury's diameter, a rather controversial subject due to the unusual density found for this planet. Jean Rösch's project was based on the Hertzsprung method: a photometric method in which the diameter of the planet is compared to the size of a calibrated pinhole in the focal plane of a telescope.

A first promising experiment took place during the 7 November 1960 transit at the Pic-du-Midi (as well as in Meudon with J.-L. Leroy). Following the publication, in 1967, of the radar measurements of Mercury's diameter, Jean Rösch considered that it was worth observing the next transit on 9 May 1970. In order to maximise the chance of observing the phenomenon, the experiment was duplicated. Henri Camichel and Guy Ratier would operate the "Coupole Tourelle" at the Pic-du-Midi, whereas Jean Rösch and F. Chauveau would use the refractor available at the Athens National Observatory. Unfortunately, the sky was completely overcast at the Pic-du-Midi, but Jean Rösch managed to record record the event in Athens. In spite of non-optimal atmospheric conditions in Athens, the experiment yielded an upper limit for the diameter of Mercury ($6''.79$), a value slightly higher than the one provided by the radar.

As the following transit was fully visible at the Pic-du-Midi, it was decided to repeat the experiment on 10 November 1973. This time, the atmospheric conditions were excellent and Ratier and Chauveau were ready to operate the "Coupole Tourelle". Unfortunately, soon after the start of the transit, the water tank located in the vicinity of the focal plane started to leak, creating a cloud of water vapour in the instrument. There was no way to repair the faulty equipment "on the spot", and the photometric measurements were meaningless. It was a great disappointment; obviously the "Mercury gods" again failed to cooperate.

4. Charles Boyer and the rotation of the Venus atmosphere

As previously mentioned, in the post-war years a team of young astronomers, following Bernard Lyot's impulse, was operating at the Pic-du-Midi. They recorded, weather permitting, as many photographs as possible of the planets. Venus was indeed a difficult case, as the observations could only take place shortly after sunset or before sunrise. The contrast of the images recorded, in the yellow part of

[4]This "Tourelle telescope" is now renamed "Lunette Jean Rösch" (LJR).

the spectrum, was rather poor as Audouin Dollfus experienced in 1948 and Henri Camichel in 1953–1954 (Fig. 2).

Figure 2. The "young astronomers" at the Pic-du-Midi in 1956: Henri Camichel, Marcel Hugon, Jean Focas, Audouin Dollfus in front of the 60-cm refractor polished by the Henry brothers. Photo: Henri Camichel Collection: Observatoire Midi-Pyrénées.

Henri Camichel also knew, from the work done by Frank E. Ross at Mount Wilson observatory in 1928, that one way to improve the photographic contrast was to use the near-ultraviolet part of the spectrum. Unfortunately, the equipment available at the Pic-du-Midi during the late 1950s was not optimal: the 60-cm refractor polished by the Henry brothers had a flint glass absorbing UV light, and the 60-cm reflector had a rather poor image quality. In this situation, he suggested to the amateur astronomer Charles Boyer, to try to record Venus pictures in violet light from Brazzaville (Congo). Using a 26-cm reflector, Charles Boyer immediately noted in September 1957 a periodic re-appearance of some spots every 4 days. The same period was also confirmed later by Henri Camichel, when he made a new survey of the plates he took in 1953–1954.

Following additional exposures showing some constant features (like a "tilted Y"), Charles Boyer and Henri Camichel came to the conclusion that the movement of the spots observed on Venus were due to a retrograde rotation of the atmosphere of the planet in 4 days. This was a very controversial hypothesis, as the rotation of the planet itself was found very much slower by radar measurements in 1962.

An international campaign was triggered by Audouin Dollfus (1962) to gather more photographs in sequence. Additional observations were also conducted by Charles Boyer at the Pic-du-Midi with the recently erected 1-meter telescope. He even could record pictures of Venus during daytime, thanks to the high purity of the

atmosphere at the Pic-du-Midi. He was supported in this job by new astronomers such as Pierre Guérin and Michel Aurière (Fig. 3).

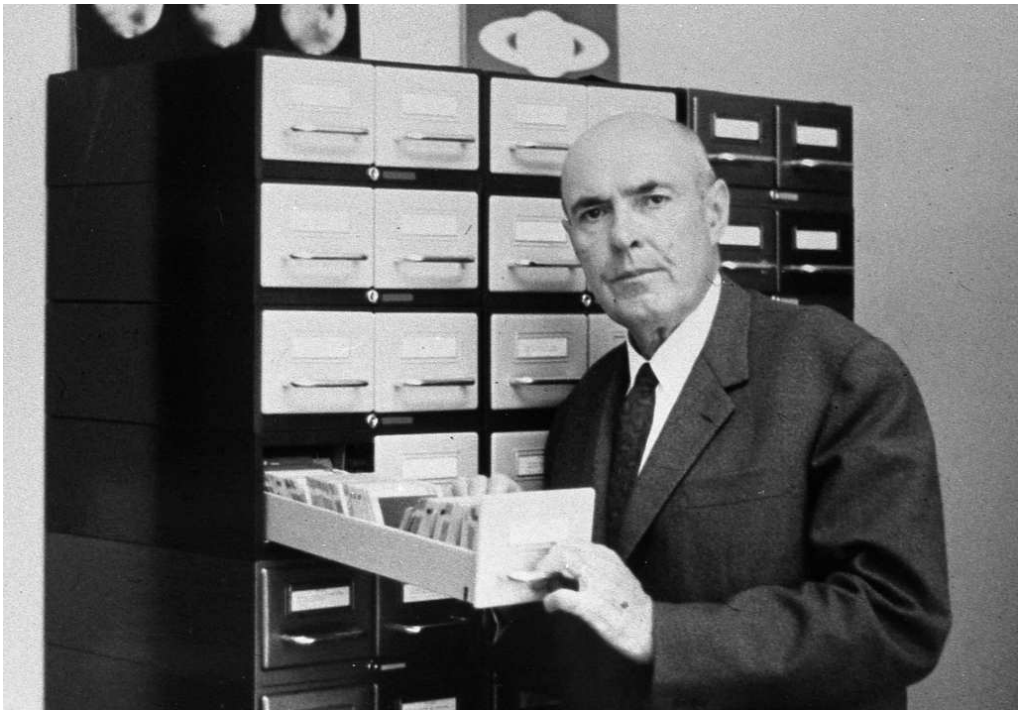

Figure 3. Charles Boyer at the "Centre de photographie planétaire" Meudon. Source: Observatoire Midi-Pyrénées.

In the years 1964–1966, Bernard Guinot and Martine Feissel, using interferometric spectroscopy detected a Doppler shift that was in line with the 4 days retrograde rotation of the atmosphere of Venus.

The controversy ended only with the results provided by various space missions devoted to Venus: Mariner 10, flying by Venus on 5 February 1974, was the first to provide a film in UV light, a brilliant confirmation of the findings of Charles Boyer.

5. Miscellaneous observations performed with coronographs

It is rather unusual to use a coronograph to observe planets, but it can be done when the planet is close to its conjunction and quasi-simultaneously in the ecliptic plane (i.e., near the line of nodes). In case of an inferior conjunction, a "transit" could take place: a fairly exceptional event (2 times every 130 years for Venus, 2 times every 13 years for Mercury). In case of a superior conjunction, the phenomenon is of similar nature, but the planet is "occulted" by the Sun, and due to the Sun's brightness, only a coronograph is then able to record the event.

On 15–16 November 1969, an "occultation" of Mercury was visible from the Pic-du-Midi and recorded successfully with the 20-cm Lyot coronograph by G. Ratier and J.L. Leroy. The aim of this experiment was to check if Mercury's albedo, close to the

null phase, had a behaviour similar to that of the Moon.[5] No specific anomaly could be detected within the limited photometric accuracy of the photographic emulsion.

On June 16, 1984 J.-C. Noëns performed, with the same instrument, a similar experiment during the superior conjunction of Venus. Images of the planet were recorded as close as 1 arcminute from the limb in order to evaluate the possibility of detecting the Einstein effect.

Finally, it is worth mentioning the special case of a "Moon transit": on February 25, 1971, a partial solar eclipse took place that was fully visible at the Pic-du-Midi. On the photographs taken by J.-P. Rozelot and G. Ratier in "white light", the Moon is clearly visible outside the solar disk. Following a fine photometric analysis, it has been possible to evaluate the light scattered (by the atmosphere around the Pic-du-Midi and by the instrument itself) and to retrieve brightness values of the "white corona" as far as 10 arcminutes from the limb.

6. Observations of the 2004 Venus transit

The Venus transit of 8 June 2004 was fully visible at the Pic-du-Midi, and a number of observatories were planning to record the event. Obviously, the main objective was not anymore to determine the solar parallax[6] but to investigate this strange "aureole" that was reported by some observers during previous transits[7].

Since the first observations made by J. Rösch during the partial solar eclipse in 1961, the "Tourelle telescope" (LJR) has been significantly improved: the old 38-cm refractor doublet has been replaced by a larger one (50 cm) polished by J. Texereau. The 35-mm cine-camera that enabled A. Carlier and R. Muller to record and select the sharpest images of sunspots and solar granulation has been abandoned, and the project was to replace it by a wide field CCD camera (CALAS). But in June 2004 only a preliminary version of the CCD camera was operational.

Sylvain Rondi operated a CMOS PixeLINK camera from June 5 onward, when the planet elongation was 4.8 degrees. The aureole was clearly visible and its aspect was progressively changing when the planet came closer and closer to the Sun (see Fig. 4). On 8 June, it was still possible to detect the aureole after the first contact and to record the variations up to the second contact. Unfortunately, clouds came later in the day, and the third and fourth contacts were lost.

In parallel, A. Rondi (S. Rondi's father) who had built his own small coronograph (diameter 90 mm) was observing from a different site in the area. He was also able to get a good record of the aureole photometric fluctuations between the first two contacts.

The records made in various observatories of the aureole have been compiled and analysed by Tanga et al. (2012). Thanks to the CCD technology, it was possible to obtain a rather precise photometric description (spatially and timely) of the aureole. Based on these data, a rather elaborate model of the mesosphere of Venus involving

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[5]This Moon anomaly was detected during the Apollo 8 and Apollo 10 missions.

[6]However, a joint initiative (by ESO-IMCCE) to promote the 2004 Venus transit among amateur astronomers was able to collect some 3700 time measurements of the contacts and to re-assess transit-based calculations of the Sun–Earth distance.

[7]Mikhail Vasil'evich Lomonosov, who observed the 1761 transit of Venus from St Petersburg, is often reckoned as the discoverer of the atmosphere of Venus. There are, however, numerous candidates to this same discovery, see for example Meadows (1966) or Aspaas (2012, p. 202).

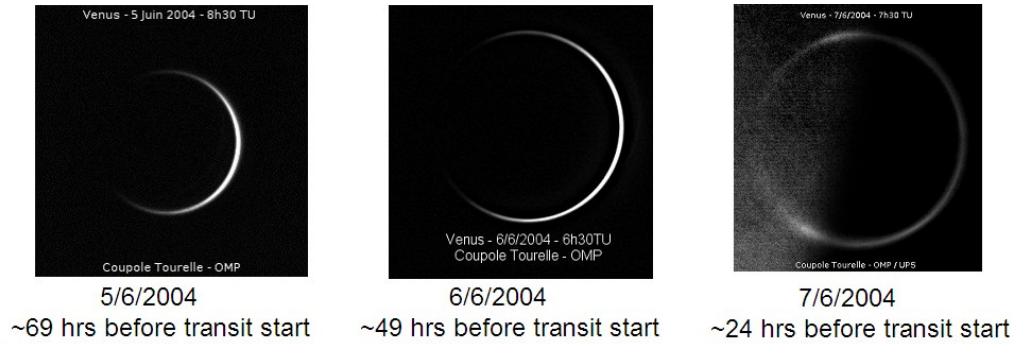

Figure 4. The Venus aureole prior to the 2004 transit as seen from the "Lunette Jean Rösch". Photo: S. Rondi.

the temperature in the South polar region, as well as the latitudinal variation of the cloud-top layer altitude, was derived. Preliminary results from this model are being compared with measurements from space probes (e.g. Venus Express).

7. Conclusions and perspectives for the 2012 Venus transit

In spite of the apparent failure of the observation during the 1882 transit of Venus in Sencours, it appears that the study of the Venus atmosphere has been an almost permanent concern at the Pic-du-Midi. These investigations have been supported by the development of an appropriate instrumentation initiated by B. Lyot and pursued by J. Rösch. Observations performed during the 2004 transit by S. Rondi have confirmed the Henry brothers' intuitive observation of an areola around Venus. Fast photometric recordings of the 2004 transit have opened a new approach for modelling the Venus atmosphere. The Pic-du-Midi staff is proud to have made a significant contribution in this field. The 2004 transit has also revealed the suitability of the coronograph concept to observe the atmosphere of Venus. As a consequence, it has been proposed to deploy some 9 small coronographs (based on A. Rondi's prototype) around the world to monitor the 2012 transit in the frame of the Venus Twilight Experiment (Venustex) project.[8]

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[8]Note added after the Tromsø conference: The Venus Twilight Experiment has been successful in 2012, see Tanga et al. (2012). The current status can be found at `https://venustex.oca.eu/`

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