Journal of Astronomical History and Heritage, 11(3), 227-234 (2008).

THE PHANTOM MOON OF VENUS, 1645-1768

Kurt Møller Pedersen and Helge Kragh
Department of Science Studies, University of Aarhus, 8000 Aarhus, Denmark
E-mails: kmp@ivs.au.dk; Helge.Kragh@ivs.au.dk

Abstract: With the invention of the telescope around 1600 astronomers saw a new world in the sky. They saw mountains on the Moon, moons around Jupiter and Saturn, and a few astronomers believed they saw a moon orbiting Venus. That moon became a problem for astronomers because they only saw it occasionally, separated by many years. The moon was reportedly seen in Italy, France, England, Germany and Denmark between 1645 and 1768. Thereafter it disappeared from the sky. The most obvious explanation was, of course, that the moon never existed. In this paper we detail the observations and how they were assessed. The last reports about this phantom moon of Venus came from the observatory in Copenhagen between 1761 and 1768. In this paper we focus especially on these observations. Observations elsewhere are treated in Kragh (2008). We shall argue that the alleged Venus moon detections were not constructions in the brain, influenced by astronomers' expectations that Venus, like the Earth, Jupiter and Saturn, ought to have a companion. Most astronomers who thought they saw the moon had no preconceived ideas about a Venusian moon. We shall show that from the late 1760s it became generally accepted that the so-called 'moon of Venus' was a ghost image in the telescope, a reflection of Venus in the lens' surfaces.

Keywords: moon of Venus, Lalande, Horrebow, Copenhagen Observatory.

"I have never before seen a spectacle in the heavens which has captivated me more; I thought that I truly saw the satellite of Venus." (Christian Horrebow, Copenhagen, 1775).

1 INTRODUCTION

On 6 June 1761 astronomers observed the transit of Venus across the Sun's disk. Such transits are rather rare phenomena, having only been seen once before, in December 1639, by Jeremiah Horrocks (1618–1641) and William Crabtree (1610–1644). These transits could only be seen through a telescope, and in 1761 not only were the lenses of a much better quality than in 1639, but also micrometers and clocks were much more accurate. Astronomers therefore hoped to measure very precisely the time of the transit of Venus, thus enabling them to calculate the solar parallax, and hence the distance from the Earth to the Sun. The history of the transits of Venus has been told many times and it is not the story of this paper. Instead we offer another story: the attempts to discover a moon around Venus. Since the beginning of the seventeenth century a handful of astronomers had claimed to have observed such a moon. Now, during the 1761 transit of Venus a new opportunity emerged for astronomers to see that moon accompanying Venus across the solar disk.

2 ALLEGED DETECTIONS OF VENUS' MOON PRIOR TO 1761

The first to report having seen a moon of Venus was the Neapolitan astronomer Francesco Fontana (ca. 1585–1656), the most renowned Italian telescope-maker of his time. On 11 November 1645 he saw two small dots or globes that followed Venus, but on Christmas Day 1645 he saw only one at the top of the convex side of Venus and on 22 January 1646 he saw it again now facing the concave edge of Venus (Fontana, 1646, and 2001). Most astronomers at the time had little faith in Fontana's observations. Evangelista Torricelli (1608–1647) called them "… stupidities observed, or rather dreamed up, by Fontana in the heavens." (Fontana, 2001: iii). Giambattista Riccioli (1598–1671), Francesco Maria Grimaldi (1618–1663), and Pierre Gassendi (1592–1655) never acknowledged Fontana's claim to have discovered a Venus moon, simply because as Gassendi (1997: 106) put it: "We have not been able to this day to seize anything about this with our telescope although it was a Galilean one." A more favourable opinion, however, was forwarded by Andreas Tacquet (1612–1660), a Flemish mathematician, who suggested that the failures of Riccioli, Grimaldi and Gassendi to confirm Fontana's observations might be due to their telescopes being of an inferior quality than the one used by Fontana (Tacquet, 1669: 310).

Much more credibility was given to the alleged detections of a Venusian moon by Jean-Dominique Cassini (1625–1712). In 1669 he was called to Paris to become Director of the new observatory. This position, his membership of the French Academy of Sciences, and the fact that his Paris Observatory telescope was one of the best in Europe led to a personal prestige that implied that his observations and discoveries should be taken very seriously. That, indeed, was the case when in October 1671 Cassini discovered a satellite around Saturn, a discovery that was accepted immediately by astronomers.

In 1672 and 1686 he claimed to have observed Venus' moon, in both cases as a faint object showing phases similar to those of Venus. Cassini, however, was not absolutely sure that he had seen a real moon and was rather vague in his written statement:

> But in spite of some research I have done from time to time after these two observations, in order to complete a discovery of such great importance, I have never succeeded in seeing it except these two times; and this is why I suspend my judgement. (Cassini, 1730: 245).

In the following almost sixty years astronomers argued for or against the existence of a Venus moon. Thus David Gregory (1659–1708) wrote in 1702 approvingly about Cassini's discoveries telling us that they gave "… more than a bare Suspicion to incline us to believe that Venus has a Satellite." (Gregory 1702: 472 and 1736: 834-35). Neither Cassini nor Gregory mentioned Fontana. Francesco Bianchini (1662–1729) argued in 1726 (Bianchini, 1996: 158-159) that the observations of Fontana and Cassini were due to a

certain thickening of "… the heavenly fluid substance …" which according to the Cartesian vortex theory occupied the space between the observer and the planet. That was also the opinion of Cassini's son Jacques Cassini (1677–1756) when in 1732 he claimed that the moon was nothing but a temporary condensation of the celestial fluid matter.

A new observation of Venus' moon was announced by James Short, an expert manufacturer of reflectors and other optical instruments and since 1737 a member of the Royal Society. In a paper titled "An observation on the planet Venus (with regard to her having a satellite)" he reported having observed on 3 November 1740 with an instrument magnifying 240 times a "Star put on the same Phasis with Venus. I tried another magnifying Power of 140 times, and even then found the Star under the same Phasis." (Short, 1744: 646). During the following mornings he continued to look for it, "… but never had the good fortune to see it again." Neither in the main text of his paper nor later in any other papers did he refer to the phenomenon as a Venusian satellite. Only in the actual title of his paper is a satellite mentioned.

Did Short at the time of his observation believe that he saw a moon? We do not know. However, when in 1763 the French astronomer Joseph-Jérôme Lefrançais de Lalande (1732–1807) paid him a visit in London, Short admitted that now he no longer believed that he had seen a satellite (Lalande, 1792, 3: 210).

Lalande's fellow academician and for a time Secretary of the French Academy of Science, Jean Jacques d'Ortous de Mairan (1678–1771), was in favour of the existence of a moon of Venus, primarily because it was given, as he believed, observational support by Cassini and Short (Mairan, 1744). He rejected other more anthropomorphic arguments for the existence of a Venusian moon, that the outer planets must have moons to enlighten their inhabitants, whereas planets closer to the Sun were in that respect not in need of moons. That argument was contradicted by the fact that Mars did not have a moon, whereas Venus being closer to the Sun than Mars did in fact, as he believed, have one.

On 20 May 1759 the German Professor of Mathematics, Physics and Astronomy, Andreas Mayer, wrote in his observation diary: "In the evening about 8^h 45′ 50″ I saw above Venus a little globe of far inferior brightness, about 1½ diameter of Venus from herself. Future observations will show whether this little globe was an optical appearance or the satellite of Venus." (Lambert, 1776: 186). Mayer's observation was not known to his fellow astronomers until it was mentioned by him in 1762 in a report on the transit of Venus (see Mayer, 1762: 16-17).

3 VENUS' MOON AND THE TRANSIT OF 1761

In 1716 Edmund Halley (1656–1743) published an *Admonition* to astronomers all over the world to follow Venus when it passed over the Sun, as he then believed, on 26 May 1761. He was wrong on the date, but right in recommending that astronomers should measure the time of the transit because that would enable them to calculate the Sun's parallax (provided that observations were taken at many different places on Earth). In good time before the event on 6 June 1761 international astronomical activities were launched to measure the time of the transit (see Woolf, 1959). More than 100 astronomers at many different places throughout the world were engaged. Jean Le Rond d'Alembert (1717–1783), who together with Diderot edited the French *Encyclopédie*, wrote in his article on Venus: "The following year, 1761 [this was written in July 1760], she [Venus] will pass across the Sun's disk, and M. Halley has shown that by means of this observation we will have the Sun's parallax." (Diderot and d'Alembert, 1765: 34, and 1781: 245).

Many astronomers who observed the transit also tried to see if there was a little moon leading or following Venus across the Sun's disk. Before we detail that story let us summarize in Table 1 what had reportedly been seen prior to 1761. Altogether we have eight observations, but many of them were questioned even by their observers as genuine testimonies of the existence of a moon of Venus. Cassini, Short and Mayer all were not too sure that they had observed a moon.

Table 1: Alleged detections of Venus' moon prior to 1761.

Year	Publish -ed	Observer	Place	No of Detections
1645	1646	Fontana	Naples	3
1646	1646	Fontana	Naples	1
1672	1730	Cassini	Paris	1
1686	1730	Cassini	Paris	1
1740	1741	Short	London	1
1759	1762	Mayer	Greifswald	1

Astronomers realized that the 1761 transit provided a unique opportunity to either confirm or refute the existence of a Venusian moon. James Ferguson, a Scottish astronomy writer and designer of astronomical instruments, wrote in his widely-read popular book on astronomy from 1756:

> But if she [Venus] has a Moon, it may certainly be seen with her upon the Sun, in the year 1761, unless its Orbit be considerably inclined to the Ecliptic; for it should be in conjunction or opposition at the time, we can hardly imagine that it moves so slow as to be hid by Venus all the six hours that she will appear on the Sun's Disc. (Ferguson, 1778: 18).

Altogether there were 19 reported observations of a Venusian moon in 1761 (more than twice as many as in the preceding years), but it is, however, quite strange that only two of these took place on 6 June during the transit. Abraham Scheuten, an amateur astronomer who was largely unknown to the astronomical community, reported in letters to Johann Lambert in 1776 that on 6 June 1761 he saw "Venus and its small moon in the middle of the solar disc." (Lambert, 1776: 186-188). However, since he was totally convinced that he had seen a moon of Venus, it is strange that he did not report his discovery until fifteen years later. An anonymous Englishman also saw the moon, as he told a London journal in a letter dated 6 June 1761. While occupied with the transit, he saw "… a phenomenon which seemed to describe on the Sun's disk a path different from the spots that is seen now and then." (Diderot and d'Alembert, 1781: 259). It is quite remarkable that the phenomenon was seen on the solar disk, but the details of the observations were so mediocre that no astronomer paid much attention to them.

Nobody else observed a moon following Venus on its transit across the Sun's disk, so why is it that astronomers saw a moon in 1761 but not on the day of the transit? One possible answer is that prior to the transit astronomers began preparing their observatories for the event and setting up their telescopes and equipment to observe Venus. Then after the transit, the equipment was there, so they continued observing Venus.

Louis Lagrange (1711–1783), a French-Italian astronomer, made three observations of a Venusian moon between 10 and 12 February 1761 at the well-equipped observatory in Marseille. However, he soon abandoned the idea that he had seen a moon because it followed a path perpendicular to the ecliptic, which to him seemed so strange that, according to Lalande, he did not find it "… difficult to abandon all the consequences which he had drawn from these observations." (Diderot and d'Alembert, 1781: 259).

Jacques Montaigne (b. 1716) was asked to look for the moon during the transit of Venus, having already seen it (or so he believed) four times between 3 and 11 May 1761, while observing from Limoges in central France. His findings were read to the French Academy of Sciences in May 1761 by Armand Henri Baudouin de Guémadeuc (1734–1817) who later that year published two memoirs on the subject, which included Montaigne's observations (Baudouin, 1761a; 1761b; 1761c). We do not know if Montaigne observed the transit, but Baudouin did so in Paris without seeing the moon.

Although he did not see the moon himself, Baudouin (1761c: 31) was very impressed by Montaigne's observations and was in no doubt: "It is certain that Venus has a moon, and we hope unceasingly to see it." From Montaigne's four observations he proceeded to calculate its period of rotation, its distance from Venus, the mass of Venus and its density relative to the Earth. The observations also showed, as did those of Lagrange, that the moon's orbit was nearly perpendicular to the ecliptic. The astronomers in Paris were quite impressed, as can be seen from an official report by two members of the Academy of Sciences, Nicolas-Louis de Lacaille (1713–1762) and Lalande:

> We have examined, by order of the Academy, the remarks of M. Baudouin on a new observation of the satellite of Venus, made at Limoges the 11th of May by M. Montaigne. This fourth observation, of great importance for the theory of the satellite, has shown that its revolution must be longer than appeared by the first three observations. M. Baudouin believes it may be fixed at 12 days; as to its distance, it appears to him to be 50 semi diameters of Venus; whence he infers that the mass of Venus is equal to that of the Earth. This mass of Venus is a very essential element in astronomy, as it enters into many computations, and produces different phenomena. But although M. Baudouin holds back in order to report many more observations about what is mentioned above, we consider this second memoir as an essential continuation of the first, and we believe it worthy of being printed. (Baudouin, 1761b: 15-16).

This indicates that the two distinguished astronomers took the observations and calculations seriously. This is not to say, however, that they took it for granted that now there was a proof of the moon's reality.

From what we have seen until now, no professional astronomer saw a companion of Venus during the transit although we know that many astronomers looked for it. A few astronomers choose to report their negative results. Thus Lacaille (1763: 78), the chief organiser of the French transit project, wrote: "We did not see the appearance of the satellite on the Sun." But most astronomers, having seen nothing did not feel it necessary to report this.

Figure 1: The Round Tower in Copenhagen.

4 ALLEGED DETECTIONS IN COPENHAGEN IN IN 1761

The Round Tower, Copenhagen's Observatory (Figure 1), was built by King Christian IV in 1637-1642 to replace Tycho Brahe's observatory *Stellæburgum* on the island of Hven.[1] In 1761 its Director was Peder Nielsen Horrebow (1679–1764), but from 1753 the *de facto* Director was his son, Christian Horrebow (1718–1776) who was assisted by his brother Peder Horrebow (1728–1812), Peder Roedkiær (d. 1767) and a dozen assistants. Christian Horrebow participated in the international endeavour to measure the contact times during the transit, and for months before the event he and his staff worked hard to ready the instruments and to hone their observational procedures.

Horrebow was very much taken by the idea of observing the Venusian moon in transit on the Sun's disk. Some years later Christian Horrebow (1764) gave a detailed history of the observations that purportedly identified a moon of Venus. He mentioned Cassini's observations (but not Fontana's), how Bianchini had looked in vain for it, Christian Wolff's (1679–1754) belief that the moon should not be included as an element of our Solar System, and that Gregory gave its existence a more lenient verdict, saying that some physical causes were responsible for

the fact that only a few observers had seen it. Horrebow also mentioned how the whole issue was reconsidered in 1740 when Short reported seeing the moon, and how Mairan thoroughly examined Short's observations and came up with the verdict that nothing was yet settled: it was not possible, using Short's data, to tell with certainty whether Venus had a moon or not (Horrebow, 1765b: 396-397).

We have already pointed out that astronomers in France and England believed that the transit would settle the question of the existence of a Venusian moon, and this was also Horrebow's opinion:

> When in 1761 Venus made a transit through the Sun, all astronomers prepared themselves to observe this important phenomenon, and they believed not without reason as they were reminded by M. Delisle in his memoir that on this occasion the question about Venus' satellite could be settled, because when Venus transits through the Sun, its satellite, which they believed was close to it, should also make a transit and thus be seen by many observers. (Horrebow, 1765b: 397).

On 4 June 1761 Horrebow published a memoir on the transit of Venus in which he detailed the history of the transit and the benefits and use of measuring the contact times of the transit. Observations made in Copenhagen when combined with those made at other places on the Earth would enable astronomers to determine the distance to the Sun. He also briefly pointed out that astronomers might be able to see the satellite accompanying Venus in its transit across the Sun's disk. Such a moon, Horrebow (1761a) wrote, had already been seen by Cassini and Short. The transit that would take place only two days later was therefore a very important event, and Horrebow and his staff were well prepared.

On 6 June only the professional astronomers of the Observatory and two trustworthy dignitaries were allowed into the Observatory. The observations had been rehearsed for a long time "… so that any single person is not being confused by the others when the real observations take place." (Horrebow, 1765a: 377). The clocks were checked and the instruments were readied, but because of clouds it was not possible to follow the entire transit, and only the times of the ingress and egress contacts were recorded. While it may have been quite disappointing to miss seeing Venus transit the Sun's disk, from a scientific perspective these transit times were all-important and they were duly passed on to Lalande in Paris (who was collecting data from all parts of the world).

The Copenhagen astronomers did not see Venus' moon during the transit, but since the instruments were operational Roedkiær continued to look at Venus during the summer of 1761, and he reported seeing its moon on several occasions and recorded his findings in the observation diaries (that are now kept in the archives of the Department of Science Studies at the University of Aarhus). Initially he did not publish his observations—for reasons to be specified later—and they only became known many years later, in 1882, when excerpts from the diaries were published by the Danish astronomer Hans Schjellerup.

The entry in the observation diary for 28 June 1761 reveals that Roedkiær saw the moon that day:

> While observing Venus with the quadrant, Roedkiær saw some whiteness which followed Venus. He found the distance between it and the upper rim of Venus to be 0.66, and he observed a transit of 11″ between it and Venus. After that he saw it again by means of a telescope of 17′, and because its appearance was sickle-shaped, not as pronounced as that of Venus but shining with almost half its face, the observer surmised that he had seen the satellite of Venus. The others of us could not see this whiteness even though we observed Venus often, with the quadrant, the meridian circle and the 17 feet telescope. (Observation diary 1761, reproduced in Schjellerup, 1882: 165).

Roedkiær saw the moon again on 29 and 30 June, and on 19 July he saw it at a distance of almost 40 semidiameters from Venus, and he could see it even if Venus herself were not in the field of view. On 5 August Roedkiær and Boserup determined very accurately the distance between Venus and its moon. Roedkiær saw it again on 8, 12 and 13 August (Schjellerup, 1882, and the observation ledger at the archives of the Department of Science Studies). In the middle of all these activities, on 28 and 29 July, Horrebow (1761b) published two dissertations detailing the time measurements made during the transit. In the main text he did not mention anything about the moon or Roedkiær's new observations, but in the Introduction he briefly stated that

> We do not dare deny that Venus has a satellite. This real satellite, very different in nature from the other satellites in our known planetary system, is probably truly seen. (ibid.).

Roedkiær's new observations were not mentioned at all, and from this we suggest that Horrebow did not consider them to constitute proof of the existence of a Venusian moon. We think it is fair to conclude that Horrebow had looked forward with great expectation to seeing a moon on 6 June, and when he saw nothing this convinced him that more solid observations were needed to turn the small and faint spot seen by Roedkiær into a real moon.

When Schjellerup published the observations in 1882 he pointed out that it was a puzzle why Horrebow chose to ignore Roedkiær's observations. We believe that they were not published because Horrebow did not want to do so. He knew all too well that the international astronomical community would come up with a very harsh verdict if what Roedkiær saw were optical illusions. He felt that he had to be very careful, now that the moon had failed to reveal itself on the disk of the Sun.

5 ALLEGED DETECTIONS IN COPENHAGEN IN 1764 AND 1768

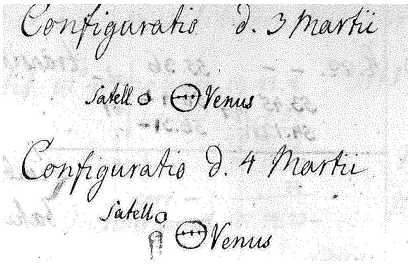
Things changed dramatically in 1764 when Roedkiær saw the moon again, as he wrote in a report to the Royal Danish Academy:

> On 3 March [1764] in the evening when investigating a new double sided convex objective glass of an extraordinary quality I saw at Venus a star which had a weak light and a recognizable diameter. Its shape was perfectly like that of Venus … Being therefore very much inclined to believe that it might be the so long searched for satellite I decided the best I could without a micrometer to determine its position relative to Venus. (Roedkiær, 1765: 394).

The focal length of his telescope was 9½ feet and he saw the moon on the left-hand side of Venus at a distance of three-quarters of its diameter.

The next day Roedkiær wrote in the observation diary:

> 1764, March 4. This evening at the same time at 6 Roedkiær again saw the satellite of Venus. Its distance to the left of Venus was ½ of Venus' diameter. Its centre made with Venus' centre an angle of about half a right angle: it appeared higher than Venus' centre in the telescope. He could also very well distinguish its phase which conformed to Venus' phase. He used partly the same glass objective as yesterday, and partly a meniscus objective of 14 feet with an ocular of 3 inches. The configurations of 3 and 4 March were:



> N.B. This is how the satellite and Venus appeared in the telescope. That it was a satellite was clear primarily because both the diameters of Venus and the satellite were enlarged noticeably (by the telescope of 14 feet as compared with the telescope of 9 ½ feet), which applied to none of the fixed stars. (Schjellerup, 1882: 166-167).

For Roedkiær, an important argument for the existence of the moon was that the spot he saw had a recognizable diameter. He first observed with the 9½ feet telescope that enlarged 38 times, and thereafter with a 24 feet telescope that enlarged 56 times—and he then saw that the object was enlarged. At 6.30 pm it could no longer be seen, although he still saw two stars close to Venus.

In the observation diary Roedkiær clearly marked the position of the moon on 3 and 4 March 1764. He concluded that he had seen a Venusian moon for the following reasons:

1. Its light was faint and weak.
2. Its shape was like that of Venus.
3. It was enlarged when viewed through the larger telescope.
4. It disappeared while other stars were still visible.
5. Both Venus and the object were seen distinctly and clearly.

Furthermore, Roedkiær saw his observations as proof of the truth of Montaigne's earlier observations, and he compiled a report on the event hoping that his Director would communicate this to the Royal Danish Academy. At the end of this report he wrote:

> I hope that my humble account shall not be unpleasant to this esteemed Academy; if I achieve this, it will be my greatest award and the most powerful encouragement to apply with more assiduity my poor strength on new and useful discoveries. (Roedkiær, 1765: 395).

Christian Horrebow in fact found Roedkiær's arguments so convincing that he decided to read his paper to the Academy, and he did so on 9 March. By a remarkable coincidence, on the very night that Horrebow was making his presentation at the Academy, Roedkiær, Peder Horrebow and an assistant, M. Boserup, again saw the moon, this time, however, not as distinctly as previously, and it was also smaller. The moon was on the right-hand side of the planet, at a distance of 1.25 or 1.5 Venus diameters. They used the 9½ and 6½ feet telescopes and also a quadrant with a 3 feet telescope. They were all so excited that they initially decided to bring a telescope to the Royal Academy so that the assembled members could witness the phenomenon, but changed their minds after remembering their former experiences when the moon disappeared as Venus approached the horizon (Horrebow, 1765c: 400).

On 10 March between 6 and 7 p.m. Roedkiær, Peder Horrebow and Boserup saw the moon again with the 9½ feet telescope which was now provided with a micrometer, but the light from the moon was so weak that they could not use it. They also used telescopes of 6½ and 18 feet but with these they saw no moon. On 11 March they continued their search with all four telescopes, but their observations from the previous night did not endow them with too much optimism. To their great surprise, however, they saw with the 9½ feet telescope a faint light on the right-hand side of Venus. This was the first time that Christian Horrebow actually saw the moon:

> I have never before seen a spectacle in the heavens which has captivated me more; I thought that I truly saw the satellite of Venus and felt happy in my heart that I now saw that the Lord had provided the inhabitants of Venus with a satellite, just as ours. I sought to establish in many ways whether this weakly shining body might be a deceptive reflection in the telescope, but … [reached the conclusion] that the light must really be the Venus satellite … To describe this observation more closely I know of no better way than to refer to precisely the expressions that Mr. Cassini uses when he describes his observations of 25 January 1672 and 28 August 1686. All of these fit closely with the ones here observed, and thus our observation might be considered a perfect repetition of the ones reported by Cassini. (Horrebow, 1765c: 401-402).

Christian Horrebow was an experienced astronomer and knew very well that he could have been deceived by reflections in the lenses or other optical illusions. In his paper he argued that this was not the case when he saw the moon:

> To be more certain, on the same evening when I saw Venus' satellite I turned the telescope towards Jupiter and Saturn, and I saw them both very distinctly and precisely. … without any indication at all of a false light in the telescope. What is more, during the observations I turned the telescope in a variety of ways, and yet the position of the satellite relative to Venus always remained fixed. In addition, a couple of times I let Venus pass through the tube, from beginning to end, and the satellite followed its primary planet all the time, just as it should; had it been a reflection, it would sometimes have disappeared. In the case where I arranged the telescope in such a way that Venus was just outside it, I could still see the weak light of the lone satellite. (Horrebow, 1765c: 403).

One last objection to having found a moon was that all they saw was a star. Against this Horrebow assembled four arguments:

1. There was a noticeable difference between the light and distinctiveness of fixed stars and the observed object.
2. The satellite had described a half circle around Venus, and that would not be possible for a fixed star.
3. He often saw the satellite and fixed stars at the same time in the telescope and could assure himself that there was a marked difference in their appear-

ances.
4. No fixed star was at the time of observation in conjunction to Venus, and therefore close enough to be mistaken for a satellite.

Horrebow ended his paper by urging astronomers to free themselves from the "… fear and modesty …" that would prevent them from presenting corroborative data.

Nearly four years later, on the evening of 4 January 1768, Horrebow saw the moon one last time (Figure 2), now in company with his assistants Ole Nicolai Bützov and Ejolvor Johnsen (Roedkiær having died the previous year). Using a Dollond telescope, the three astronomers observed below Venus

> … a small light, certainly not a star (for there were stars in the telescope, which had a fully different appearance), and it stood at a distance from Venus of about one Venus diameter. Soon afterwards Venus was observed in the Islaean telescope [a telescope named after the French astronomer Joseph Nicolas Delisle] of 12 feet.

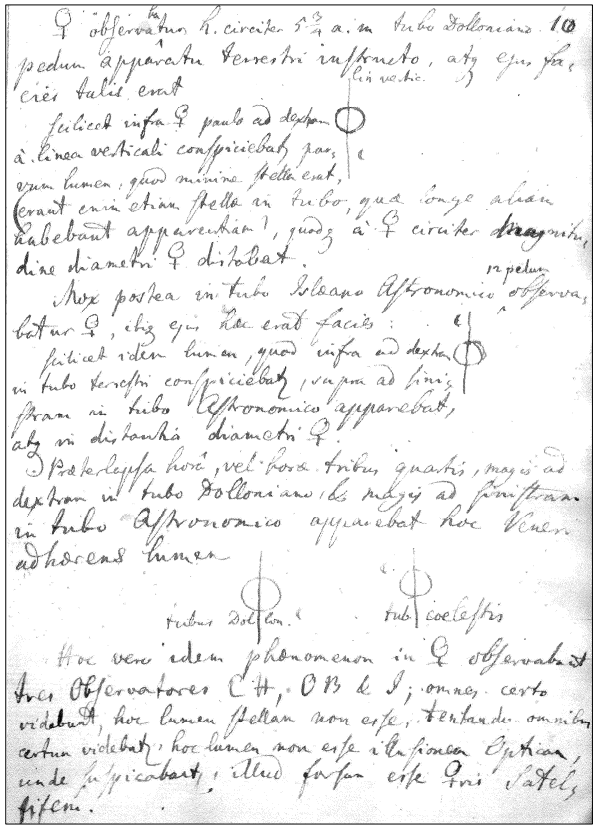


Figure 2: Drawings in the observation diary in 4 January 1768, where the moon of Venus is clearly depicted.

Christian Horrebow believed that the new observation confirmed the hypothesis of a Venusian satellite:

> After an hour or three quarters of an hour that light which adhered to Venus appeared more to the right in the Dollian and more to the left in the astronomical telescope. Three observers observed this same phenomenon at Venus, C.H., O.B., and J.; all saw with certainty that this light was not a star, and were certain that the light was not an optical illusion, and they therefore surmised that perhaps it was a satellite of Venus. (Schjellerup, 1882: 167-168).

This observation was never published. On 18 February 1768 and again on 6 April 1770 Horrebow read papers to the Royal Danish Academy on the transit of Venus, but they were oral presentations and we do not know if he mentioned the local observations of the satellite of Venus. In spite of what he enthusiastically wrote in the observation diary, had he only a few days later already abandoned his belief in the existence of the moon? Whatever the case, this 4 January 1768 observation is the last one recorded, and after this the Venusian satellite disappeared from the astronomical sky—if not from the astronomical literature.

6 EVALUATION TWENTY YEARS LATER

Lalande acted as the coordinator of all the observations of the 1761 transit of Venus, and Horrebow duly sent observations to him. Although Lalande included the Copenhagen observations in the 1761 *Mémoires* of the French Academy, apart from this he decided to ignore them, for the following reasons:

1. Bad weather prevented astronomers in Copenhagen from following the entire transit.
2. Only simple non-achromatic telescopes were used.
3. The observations were not properly reduced because Horrebow forgot to include in his letter to Lalande the corrections that should be applied to the times indicated by his clocks.

According to Pedersen (1992, 103) this left the Paris astronomers with the impression that the Copenhagen astronomers were incompetent and unable to handle even simple observational programmes requiring only a clock and a telescope.

When in 1781 Lalande summarized the observational evidence for a moon of Venus he did not include the observations that were made in Copenhagen in 1761, 1764 and 1768. The 1764 observations were the only ones published (but in Danish), so unless he had been notified by letter Lalande would have been unaware of them—and of the 1761 and 1768 results.

Lalande's report was included in the second edition of the widely-distributed *Encyclopédie*, and can be seen as a general statement of the state of affairs concerning the Venusian moon (Diderot and d'Alembert, 1781: 256-260). He reported the observations of Cassini, and he was very impressed with Short's observation:

> This observation, being one of those that best establishes the existence of the satellite of Venus by the impossibility of supposing that the observer was deceived by optical illusions, deserves particular attention … [but] still it seems that one ought to be uncertain about the existence of this satellite.

Lalande also considered the contributions of Montaigne and Baudouin and found two supportive arguments for the existence of the moon, namely that both astronomers saw the moon whether Venus was in the field of the telescope or not, and that they were able to deduce elements of the orbit of the satellite. Lalande continued his assessment, writing that "In spite of so many testimonies which establish the existence of the satellite of Venus it seems that we are still in a situation to doubt its reality."

Lalande did not totally reject the possibility of a satellite of Venus, but wrote that there were reasons to believe that what astronomers saw were optical illusions. This was also the opinion of the new Director of the Round Tower, Thomas Bugge, who succeeded

Christian Horrebow in 1776. In a 1783 report to the Royal Danish Academy on Herschel's discovery of Uranus he also mentioned the satellite of Venus:

> There has been much discussion about the satellite of Venus, Cassini, Short, Montaigne, Horrebow and Montbarron believe to have seen it; but it is strange that it was never seen at other times, when the sky was just as clear, using the same instruments and by the same persons. This inclines us to believe, that it was due to an optical illusion in the telescope, and the esteemed Vienna astronomer, Mr. Hell, has shown that in any telescope and at any planet, when the eye is in a certain position, there appears close to the planet a dioptrical ghost or a small imitation of the main planet. (Bugge, 1783: 219).

In this quote Bugge mentions Montbarron, a councillor in Auxerre, south of Paris, who observed the moon on 15 March 1764 with a 32-foot Gregorian telescope. This observation, and observations made by other amateur astronomers, were reported by Lalande in his 1781 account published in the *Encyclopédie*. The last reported observation of a Venusian moon was the one made in Copenhagen in 1768.

The search for the moon during the transit of Venus in 1769 was not on the agenda of astronomical activities. Of course astronomers looked for it, but it was not officially put forward as a scientific project. That was due to the fact that astronomers no longer believed that such a moon existed. The death blow was not that the moon failed to reveal itself on the Sun's disk in 1761, but rather that the image of the moon was due to an optical illusion. As mentioned by Bugge, this idea came from Maximilian Hell who in 1766 published a dissertation in which he concluded that the image of the strongly-luminous Venus was reflected both in the lenses of the telescope and in the eye's cornea, and that this gave the impression of a satellite with the same phase as that of Venus (see Figure 3). Careful experiments carried out from 1757 showed that this image only occurred if the eye was held in a certain position relative to the eyepiece of the telescope (Hell, 1766).

Some of Hell's conclusions were independently reached by his fellow Jesuit, Roger Boscovich, in 1767. Hell's views were known to the Round Tower astronomers, if not before then at least in 1768 when he arrived in Copenhagen to take part in the observations of the 1769 transit of Venus. He met with Horrebow and probably also with Bugge. We do not know if Hell was successful in convincing Horrebow that the moon was an illusion, but the fact that Horrebow did not publish his final observation of the moon points in this direction. Bugge was in favour of the ghost explanation, as we saw above, and he specifically mentions Hell, so was directly inspired by him.

7 CONCLUDING REMARKS

Hell's and Boscovich's views quickly became known in astronomical circles, and with them Venus' moon disappeared from the sky. Yet in his 1781 report Lalande wrote that Short was such a professional astronomer that he would never have been deceived by an optical illusion. In so doing, Lalande opened up the possibility of an alternative to Hell's and Boscovich's ghost explanation, so would a new search for the moon begin? In fact this did not happen: there are no letters, programmes, reports or memoirs from astronomers telling about a specific search for this moon. The search for Venus' enigmatic satellite effectively ended in 1768.

8 NOTES

1. The first Director of the Round Tower was Longomontanus, one of Tycho Brahe's assistants. The Round Tower has survived and is still located in the centre of Copenhagen. It functioned as an observatory until 1862 and is now a museum.

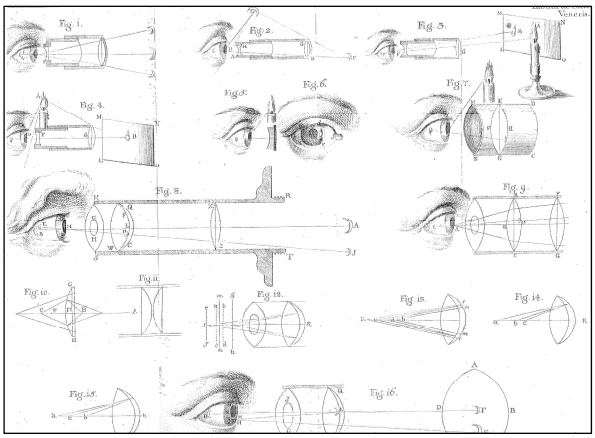


Figure 3: Hell's (1766) illustrations of how a bright planet produces an illusion of a satellite in the eye of the observer.

9 ACKNOWLEDGMENTS

We would like to thank Librarian Susanne Nørskov for her help in providing sources and Emeritus Professor Henk Bos for his valuable assistance. We also want to thank two anonymous referees for their comments and suggestions.

10 REFERENCES

Archives: Observation ledgers from the Observatory in Copenhagen, The Round Tower, are now deposited at The Department of Science Studies, University of Aarhus, Denmark.

Baudouin de Guémadeuc, Armand Henri, 1761a. *Mémoire sur la Découverte du Satellite de Venus, et sur les Nouvelles Observations qui Viennent d'être Faites à cette Sujet*. Paris, Desaint & Saillant.

Baudouin de Guémadeuc, Armand Henri, 1761b. *Remarques sur une Quatrième Observation du Satellite de Venus Faite à Limoges le 11 Mai 1761*. Paris, Desaint & Saillant.

Baudouin de Guémadeuc, Armand Henri, 1761c. *Abhandlung von der Entdeckung eines Trabanten der Venus*. Berlin, Verlag des Buchladens der Realschule.

Bianchini, Francesco, 1996. *Observations Concerning the Planet Venus*. Translated by Sally Beaumont, assisted by Peter Fay. London, Springer.

Boscovich, Roger J., 1767. *Dissertationes quinque ad dioptricam pertinentes.* Vienna, Joannis Thomæ de Trattnern.

Bugge, Thomas, 1783. Om den nye planet. *Skrifter som udi det Kiøbenhavnske Selskab af Lærdoms og Videnskabs Elskere ere fremlagte og oplæste,* Part II (for 1781), 215-225.

Cassini, Jean-Dominique, 1730. Découverte de la lumière céleste qui paroist dans le Zodiaque. *Mémoires de l'Académie Royale des Sciences depuis 1666 jusqu'à 1699,* 8.

Diderot, Denis, and d'Alembert, Jean le Rond (eds.), 1765. *Encyclopédie, ou Dictionaire Raisonné des Sciences, des Arts et des Metiers*. Volume 17. Neufchastel, Samuel Faulche and Compagnie.

Diderot, Denis, and d'Alembert, Jean le Rond (eds.), 1781.

Encyclopédie, ou Dictionaire Raisonné des Sciences, des Arts et des Metiers. Volume 35. Berne & Lausanne, Les Sociétés Typographiques.

Ferguson, James, 1778. *Astronomy Explained upon Sir Isaac Newton's Principles*. London, Strathan.

Fontana, Francesco, 1646. *Novae coelestium terrestriumque rerum observations.* Naples, Gaffaro.

Fontana, Francesco, 2001. *New Observations of Heavenly and Earthly Objects, with the Aid of Optical Instruments devised by Him and Brought to the Highest State of Perfection.* Translated by Peter Fay and Sally Beaumont. Levens, Sally Beaumont.

Gassendi, Pierre, 1997. *Institution Astronomique.* Translated by Jean Peyroux. Paris, A. Blanchard (originally published as: *Institutio Astronomica juxta Hypotheseis tam Veterum, queam Copernici, et Tychonis* ..., Paris, Ludovicus de Heuqueville, 1647).

Gregory, David, 1702. *Astronomiæ Physicæ & Geometricæ Elementa*. Oxford, Sheldonian Theatre.

Gregory, David, 1736. *Elements of Physical and Geometrical Astronomy*. Two volumes. London, D. Midwinter.

Hell, Maximilian, 1765. *De Satellite Veneris.* Vienna, Joannis Thomæ de Trattnern.

Horrebow, Christian, 1761a. *Dissertatio de semita, quam in Sole descripsit Venus per eundem transeunde die 6 Junii Ao. 1761*. Copenhagen, N.C.Höpffner.

Horrebow, Christian, 1761b. *Dissertatio de transitu Veneris per discum Solis*. Copenhagen, N.C.Höpffner.

Horrebow, Christian, 1765a. Tidens Bestemmelse i henseende til de Observationer, som skeede i Solen og Venere, da Venus Anno 1761, den 6te Junii passerede igiennem Solen. *Skrifter som udi det Kiøbenhavnske Selskab af Lærdoms og Videnskabs Elskere ere fremlagte og oplæste* (For the years 1761-1764), 373-388.

Horrebow, Christian, 1765b. Reflexioner, anlangende Veneris Drabant. *Skrifter som udi det Kiøbenhavnske Selskab af Lærdoms og Videnskabs Elskere ere fremlagte og oplæste* (For the years 1761-1764), 396-399.

Horrebow, Christian, 1765c. Videre Fortsættelse af Observationerne giorte paa Veneris Drabant. *Skrifter som udi det Kiøbenhavnske Selskab af Lærdoms og Videnskabs Elskere ere fremlagte og oplæste* (For the years 1761-1764), 400-403.

Lacaille, Nicolas-Louis de, 1763. Observation du passage de Vénus sur le disque du soleil. *Histoire de l'Académie Royale des Sciences* (for 1761), 78-81.

Lalande, Joseph-Jérôme, 1792. *Astronomie*. Three volumes. Paris, Didot l'Ainé.

Lambert, Johann, 1776. Vom Trabanten der Venus. *Astronomisches Jahrbuch oder Ephemeriden* (Berlin) for 1778, 178-188.

Kragh, Helge, 2008. *The Moon that Wasn't. The Saga of Venus' Spurious Satellite.* Basel, Birkhäuser.

Mairan, Jean Jacques d'Ortous de, 1744. Sur un satellite aperçu auprès de la planète de Vénus. *Histoire de l'Académie Royale des Sciences* for 1741, 63, 124-128.

Mayer, Andreas, 1762. *Observationes Veneris Gryphiswaldenses quibus adiecta est M. Lamb. Henr. Röhli Reg. observ. Astron. Observationis suae de transitu Veneris per Solem exposition*. Greifswald, A.F. Röse.

Pedersen, Olaf, 1992. *Lovers of Learning*. Copenhagen, Munksgaard.

Roedkiær, Peder, 1765. Beretning om een den 3 og 4 Martii 1764. giort Iagttagelse angaaende Veneris Drabant. *Skrifter som udi det Kiøbenhavnske Selskab af Lærdoms og Videnskabs Elskere ere fremlagte og oplæste* (For the years 1761-1764), 394-395.

Schellerup, Hans C.F.C., 1882. On some hitherto unknown observations of a supposed satellite of Venus. *Copernicus. An International Journal of Astronomy,* 2, 164-168.

Short, James, 1744. An observation on the planet Venus (with regard to her having a satellite). *Philosophical Transactions*, 41, 646-647.

Tacquet, Andreas, 1669. *Opera mathematica.* Antwerp, Jacobus Meur.

Woolf, H., 1959. *The Transits of Venus: A Study in the Organization and Practice of Eighteenth-Century Science*. Princeton, Princeton University Press.

Kurt Møller Pedersen is a Lecturer in the Department of Science Studies at Aarhus University, Denmark. His research interest is the history of science in the seventeenth and eighteenth centuries. He is currently working on Leonhard Euler's optical theories and Ole Roemer's discovery of the finite velocity of light. Together with Peter de Clercq he is arranging for a diary of Professor Thomas Bugge to be published in which Bugge describes what he saw when he visited German, Dutch and English observatories in 1777.

Helge Kragh is Professor of History of Science at the University of Aarhus, Denmark. His main work is in the history of modern physical sciences, including astronomy and chemistry, where he has done research on the development of quantum physics, astrophysics, geochemistry and cosmology. Among his books are *Conceptions of Cosmos* (2007), a history of cosmology from myths to the twenty-first century. Kragh is a member of the Royal Danish Academy of Science and serves as President of the European Society for History of Science.