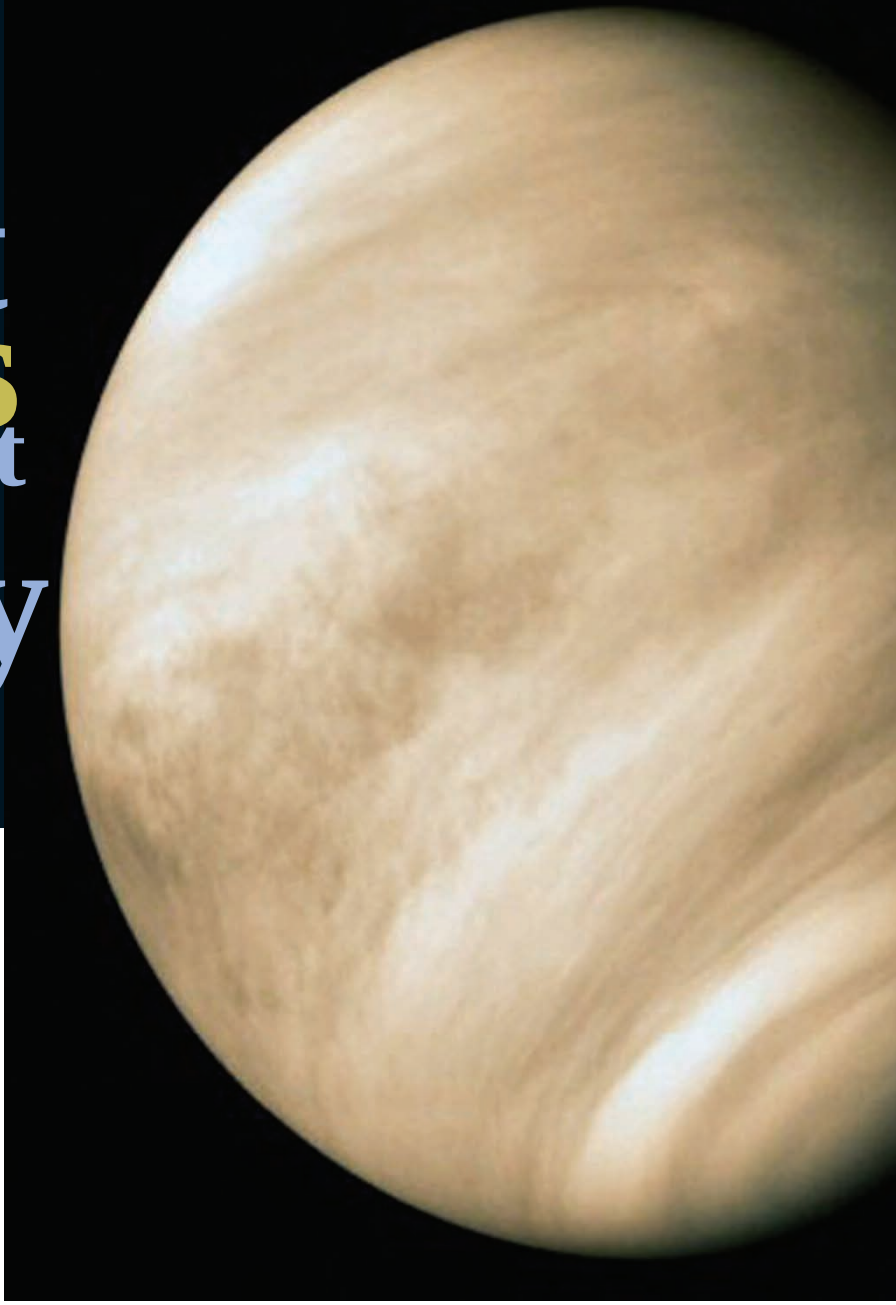
Last Transit of Venus in the 21st Century



K. SMILES MASCARENHAS

Planet Venus is fast approaching the Sun for a rendezvous on the 6th of June 2012. If you miss it, you will have to wait till the year 2117!

"We are now on the eve of the second transit of a pair, after which there will be no other till the twenty-first century of our era has dawned upon the Earth, and the June flowers are blooming in 2004. When the last transit season occurred the intellectual world was awakening from the slumber of ages, and that wondrous scientific activity which has led to our present advanced knowledge was just beginning. What will be the state of science when the next transit season arrives God only knows. Not even our children's children will live to take part in the astronomy of that day. As for ourselves, we have to do with the present . . ."

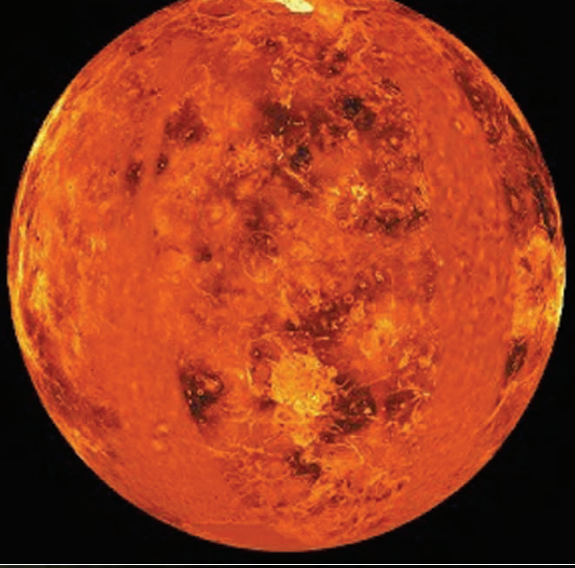
THESE prophetic words were written by William Harkness, an astronomer who led the American efforts for the 1882 transit of Venus, and the one who almost single-handedly achieved the final American result. It is remarkable that Harkness was trained in medicine, and served as a surgeon in the Union Armies during part of the American civil wars, before he became a full-fledged astronomer!

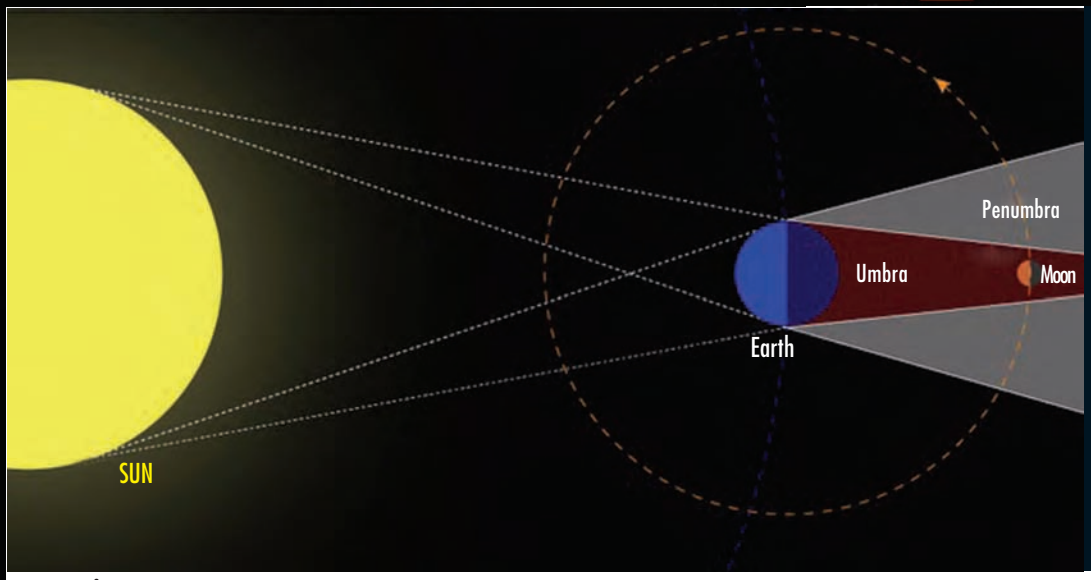
Yet another Venus transit is fast approaching – on 6 June 2012 to be precise. If you miss this event, you may perhaps not be alive to witness it when it occurs next on the 11th of December 2117. But before we proceed further, let us try to get an idea about what a transit actually is.

When two heavenly bodies apparently cross each other's path as seen from the Earth, we have the following three possibilities:

1. Eclipse: When two heavenly objects having apparently the same size (that is, they appear to be roughly the same size as observed from the Earth) cross each other's path, we say an eclipse takes place. For example, during the eclipse of the Sun, even though the Moon is much smaller, it appears to be of the same size as the Sun, because it is nearer to us. Therefore, it can completely hide the Sun behind it.

2. Occultation: When an apparently larger heavenly object covers an apparently smaller one, we say an occultation occurs. For example, when the Moon blocks the





Anatomy of an eclipse

light coming from a star, we say that the Moon has occulted the star.

3. Transit: When an apparently smaller object traverses in front of an apparently larger one, we say a transit occurs. For example, it is known that the inferior planets Mercury and Venus (inferior, because their orbits lie within the orbit of the Earth; all the other planets are called superior planets because the radii of their orbits are greater than that of the Earth) can occasionally cross the Sun's disc when viewed from the Earth.

There can be many transits of Mercury during the century. But the transits of Venus across the disc of the Sun are among the rarest of planetary alignments. Indeed, only six such events have occurred since the invention of the telescope (1631, 1639, 1761, 1769, 1874 and 1882). The transits of Venus occur in pairs separated by eight years. But these pairs are very rare! They occur once every 113.5 years or 129.5 years (on the average roughly every 121.5 years). It is remarkable that the pairs occur alternately in the month of June and December!

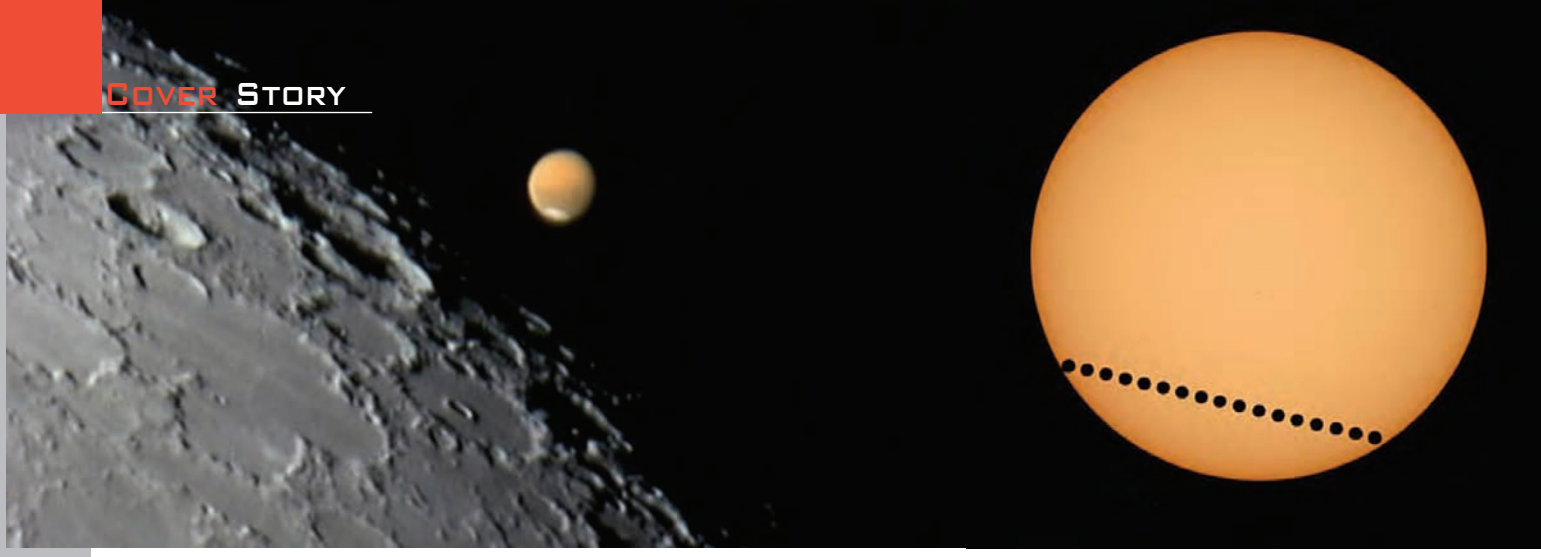
We are now on the eve of the second transit of the pair in the twenty first century. The last transit of Venus occurred on 8th of June 2004 and the next is predicted to happen on the 6th of June 2012.

If the orbit of Venus were not inclined to ours, a transit would occur every time Venus moves in between the Sun and the Earth, that is, at inferior conjunction. The orbit of Venus, however, is inclined at an angle of 3.4 degrees to the ecliptic (the plane of Earth's orbit), which causes Venus to usually pass above or below the Sun at inferior conjunction as seen from the Earth. Only when both Venus and Earth are approximately at the line of the nodes, along which the orbital planes of Venus and the Earth cross, there is a possibility for a transit to take place.

Transits of Venus occur in pairs because the length of eight Earth years is almost the same as 13 years on Venus, so every eight years the planets are in roughly the same relative positions. This approximate conjunction usually results in a pair of transits, but it is not precise enough to produce a triplet, since Venus arrives 22 hours earlier each time. The last transit not to be part of a pair was in 1396 A.D., the next will be in 3089.

Transits of Venus had great importance during the early history of modern astronomy. In fact, it was the only time when astronomers had a chance to determine the value of the Astronomical Unit (or AU as it is called, the average distance between the Sun and the Earth). During modern times, the AU can be estimated to a greater accuracy using space probes and radar techniques. So the transit of Venus arouses interest not because of its importance to astronomy, but because it is so rare!

The next Venus transit pair after the 2012 event will occur on 11th of December



2117 and on 8th of December 2125 (before 1526 A.D, Venus transits occurred on May and before 1396 A.D, they occurred in November; till the 44th century, transits of Venus will occur only in June or December!).

The time of occurrence of the 21st century Venus transits shows that the 2004 transit was placed comfortably for viewing from India, from the start to the finish. Many amateur astronomers in India observed it by simply projecting the Sun's image on the walls of their room. Only the closing stages of the 2012 transit will be visible from India. Still, there will be live coverage of this rare event by many TV channels.

History of Observations

The transit of Venus was claimed to have been observed by medieval Islamic astronomers. The Persian astronomer Avicenna claimed to have observed the 24 May 1032 Venus transit of the Sun. Soon after, he wrote the *Compendium of the Almagest*, a commentary on Ptolemy's *Almagest*, in which he concluded that Venus is closer to the Earth than the Sun.

Jeremiah Horrocks (1619-1641), a British amateur astronomer, could be one of the two persons to observe the first recorded transit of Venus in 1639. He was one of the first Englishmen to appreciate the astronomical revolution going on in Europe following the works of Tycho, Galileo and Kepler. It was Horrocks who first proved that the orbit of the moon is an ellipse. Horrocks died at the young age of 22 and it is anybody's guess how much more he could have discovered had he lived longer. Yet, he is considered to be the father of British astrophysics for the remarkable depth of his accomplishments.

According to Horrocks's Law, all the then-known planets would appear the same size if viewed from the Sun. Not true for Mars or Saturn; but otherwise very accurate. Like another astronomer, Omar Khayyam, Horrocks was also a poet, and he wrote his poetic verses in praise of his telescopes and the heavenly objects!

In 1627, Johann Kepler (1571-1630), using his laws of planetary motion prepared the Rudolphine tables, consisting of a star catalogue and a table of planetary positions. Based on it, he predicted the December 1631 transit of Venus, but wrongly predicted that in 1639 Venus would narrowly miss transiting the Sun. Kepler never lived to see his 1631 prediction come true, having missed it by just one year!

Horrocks corrected Kepler's calculation for the orbit of Venus and realized that a transit would indeed occur in 1639, and concluded that transits of Venus would occur in pairs eight years apart. Horrocks made his observations from his house in England on the 24th of November 1639. (Did I not say that transits of Venus took place only on December after the year 1396 A.D? The confusion arises because before 1752, Britain followed the old Julian system of calendar! If the present Gregorian system of calendar were to be followed, the date would be 4th of December 1639).

As it always happens, it turned out to be a cloudy day. Although he was uncertain of the exact time, Horrocks calculated that the transit was to begin at approximately 3:00 pm. Horrocks focused the image of the Sun through a simple telescope onto a piece of card, where the image could be safely observed. After observing for most of the day, he was lucky to see the transit as clouds obscuring the Sun cleared at about 3:15 pm, just half an hour before sunset.

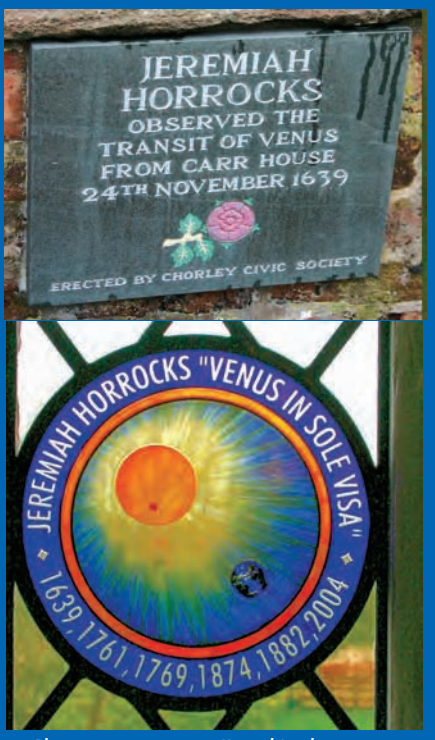
Horrocks is remembered on a plaque in Westminster Abbey and the lunar crater Horrocks is named after him. In 1859 a marble tablet and stained glass window

William Crabtree watching the transit of Venus in AD 1639

In 1627, Johannes Kepler (1571-1630), using his laws of planetary motion prepared the Rudolphine tables

Johannes Kepler

Jeremiah Horrocks with his telescope



Plaques commemorating Horrock's achievements

commemorating him were installed in The Parish Church of St Michael, Much Hoole. Horrocks Avenue, in Garston, Liverpool, is named after him. In 1927, the Jeremiah Horrocks Observatory was built on Moor Park, Preston. It is remarkable that Horrocks also predicted that a transit of Venus would occur in the year 2004!

The other person to observe the 1639 transit of Venus was William Crabtree (1610–1644). Crabtree was born in the hamlet of "Broughton Spout", near the area now known as "The Priory" in Broughton and was educated at The Manchester Grammar School. He married into a wealthy family and worked as a merchant in Manchester. However, he had a passion for astronomy, and spent much of his spare time in observing the sky. He carefully measured the movements of the planets and undertook precise astronomical calculations.

Crabtree corresponded with Jeremiah Horrocks right from 1636. The two enthusiastic astronomers recorded the event in their own homes and it is doubtful whether they ever met in person, but Crabtree's calculations were crucial in allowing Horrocks to estimate the size of Venus. Unfortunately, Horrocks died early in 1641 the day before he was due to meet Crabtree. On 9 June 2004, a day after the last transit, a commemorative street nameplate in memory of William Crabtree was unveiled at the junction of Lower Broughton Road and Priory Grove.

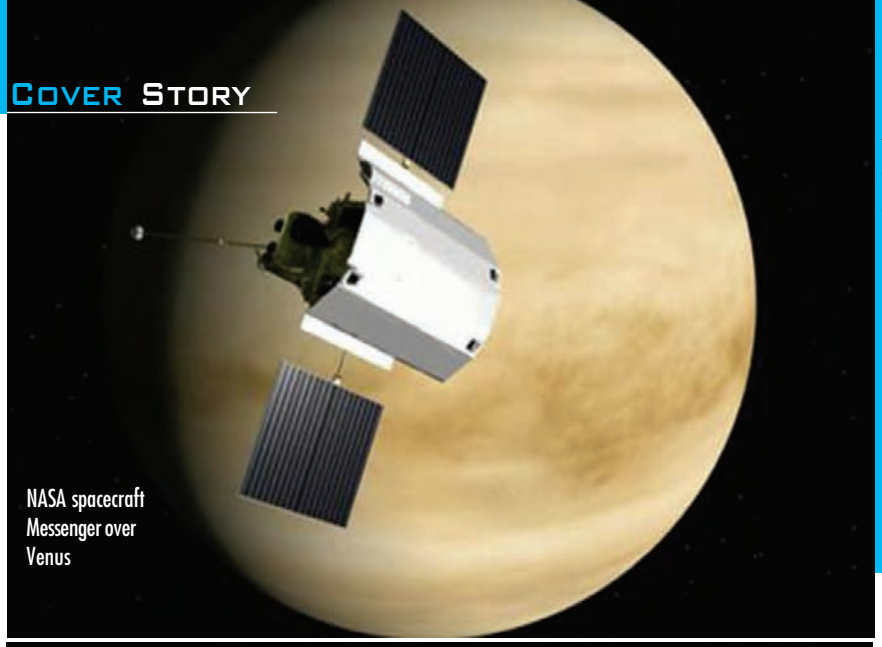
Perhaps the transit of Venus during 1761 and 1769 could be one of the first astronomical events to be predicted well in advance and publicized for observation (the other being the return of Halley's comet in 1758). The transits during these years had great astronomical significance since they were used to estimate the value of the Astronomical Unit. Edmond Halley (who correctly computed the path of the famed Halley's comet, using Newton's laws) in England and Joseph-Nicolas Delisle in France worked out the details for its determination well in advance.

Their technique was to determine the time it takes for Venus to transit the Sun, observed from two different points on the Earth, widely separated in latitude. Due to parallax, these times will differ considerably and with a knowledge of it and the distance between the observation points, the Earth-Sun distance could be estimated. But there was an optical illusion that nobody had anticipated. Venus left a "black elongated vestige" when it entered the Sun's disc. This effect called the "Black drop effect" inhibited precise timing of the transit time.

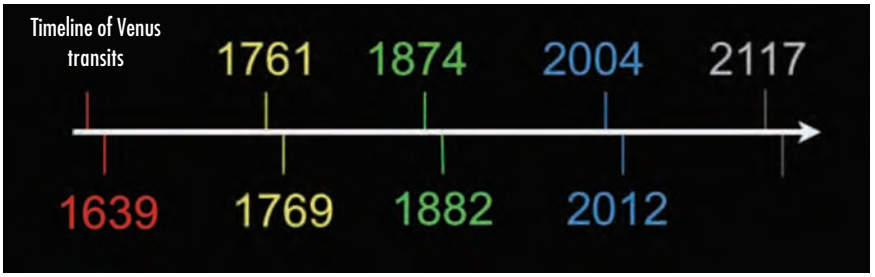
Many scientists attributed the Black drop effect to an optical illusion observed when we press the forefinger and the thumb with a bright source of light behind. Even before the finger makes contact with the thumb, a black shadow appears between them. The Black drop effect was also thought to be due to Venus' thick atmosphere, and indeed it was held to be the first real evidence that Venus had an atmosphere. In the 2004 transit of Venus, many observers reported that it was much less pronounced than had been reported in earlier centuries' transits. Is it because of the improved optics of the telescopes? Nobody is sure because even during the 1882 transit, the Black drop effect did not figure prominently in the scientists' minds.

Many sailors and astronomers undertook voyages to distant lands to get a good view of the transit. Among the most famous of these expeditions was Captain Cook's voyage to Tahiti in 1769 to see the transit of Venus from there. However, the result of the observations was not as conclusive or accurate as had been hoped. A place in Tahiti is named Point Venus because the observation of the transit was made at this point. Captain Cook had secret orders to go on and explore what was further south after the transit. He did proceed further and became the first European to map New Zealand and the coast of Australia.

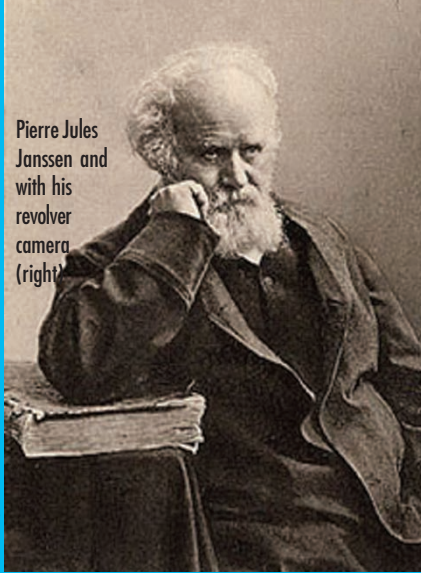
There is a sad story of a French Astronomer named Le Gentil, who tried to go to Pondicherry, India, but was denied landing in 1761 because the British had conquered Pondicherry. Le Gentil was forced to watch the transit from sea. He saw the transit, but his boat rocked because of the waves. His pendulum clock failed to function properly because of the rocking, and he could not time the transit of Venus.



NASA spacecraft Messenger over Venus



Pierre Jules Janssen, though crippled in an accident when he was young, refused to lead an unadventurous life.



Pierre Jules Janssen and with his revolver camera (right)

Now, since he was all the way there in India in 1761, he decided to wait for eight more years to watch the transit in 1769. Perhaps, he stayed in India because he liked the country, since the entire transit was not visible from India. Initially, the day of transit was very clear and highly promising. When the time of transit arrived, clouds came and he missed it again! By the time he got back to France, he had been declared dead and he had lost his seat in the French Academy, which had been given to someone else.

A wonderful play called *The Transit of Venus* shows LeGentil's plight due to his long absence, including his fiancée marrying someone else and in any case, the true story is that Le Gentil did have these setbacks but he did recover. He did marry, had a family, got his seat in the academy back, and lived happily ever after. But nonetheless, he did have 11 years of travails owing to this obsession to observe the transit of Venus!

Johann Franz Encke, Director of the Seeberg Observatory, Germany and his colleagues meticulously analyzed the results accrued during the 18th century observation of the transit of Venus. (Encke is still remembered for a periodic comet that has the shortest duration of three years, and a crater on the Moon that was named after him). In 1824 he announced a value of 153,340,000 km (with an uncertainty of ±660,000 km) for the AU. This result is off from the mean modern value of 149,597,870 km by 2.5%, but it remained the standard accepted value for several decades.

During the 19th century transit of Venus, the newly discovered technique of photography was put to use to determine the transit times with greater accuracy. A French astronomer named Pierre Jules Janssen devised a "revolver camera" for recording the 1874 transit. It is to be greatly appreciated that Janssen, though crippled in an accident when he was young, refused to lead an unadventurous life. He would often travel to distant countries just to witness total solar eclipses. Travel appears to be so simple these days, but in the 19th century it must have been definitely challenging, especially for a crippled person.

Once during his visit to Guntur, in Andhra Pradesh, he independently discovered a way to study solar prominences (outside an eclipse) by observing the Sun's limb through the slit of a spectroscope. The Prussian siege of Paris on December 1870 did not deter him from observing a total solar eclipse in Algeria. He escaped the siege by flying in a hot air balloon! His revolver camera is actually a forerunner of the cinematographic process invented by the brothers Louis-Jean and Auguste-Marie Lumière. It is really nice to know that in the 1890's, Janssen himself was one of the first to be cinematographed in their studio! But his revolver camera did not produce the expected crisp image of Venus transiting across the Sun, during the 1874 transit.

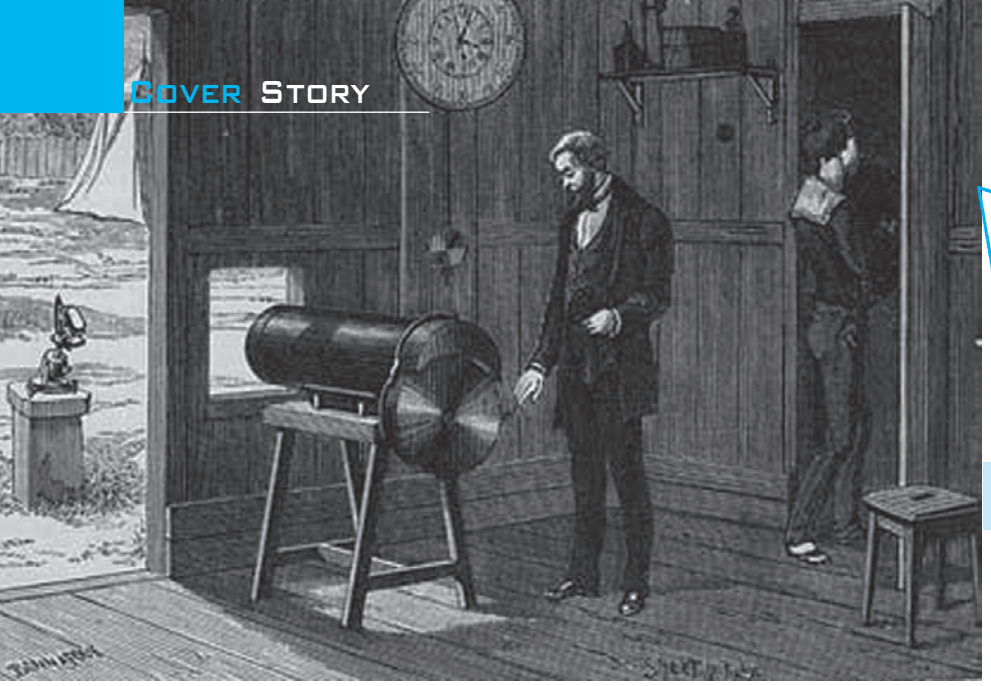
Transits of Mercury are not so rare as that of Venus (see table). It is remarkable

SOME FUTURE TRANSITS OF VENUS

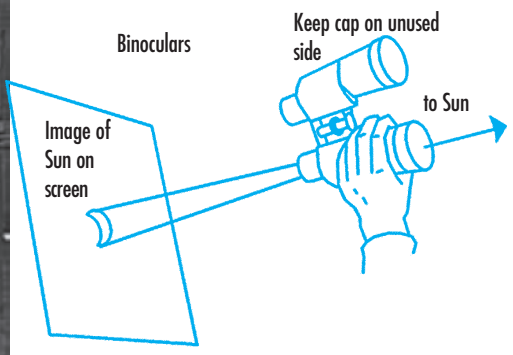
Date	U.T	Date	U.T
2117 Dec 11	02:48	2125 Dec 08	16:01
2247 Jun 11	11:30	2255 Jun 09	04:36
2360 Dec 13	01:40	2368 Dec 10	14:43

SOME FUTURE TRANSITS OF MERCURY

Date	U.T	Date	U.T
2016 May 09	14:57	2019 Nov 11	15:20
2032 Nov 13	08:54	2039 Nov 07	08:46
2049 May 07	14:24	2052 Nov 09	02:29



French astronomer Pierre Jules Janssen devised a "revolver camera" for recording the 1874 transit.



Projecting the Sun by using binoculars

that transits of Mercury also happen during fixed months (May and November), with the November transits more frequent than the May transits.

Observing the Transit

The entire transit will not be visible from India. Venus will be half way across the Sun when it rises on the 6th of June. The transit will end approximately by 10:20 am IST (depends on the local latitude). You can use the viewer glass that you used during the last solar eclipse to view the early morning Sun. You can also look at the Sun through the welder's glass, if a workshop happens to be in the neighbourhood.

Or, if black and white films are available with the local photographer, get it exposed and developed. It is quite safe if you have misplaced your viewers. Never use smoked glasses, since uneven gaps in soot deposition can prove dangerous. But you can miss the transit, because by directly observing like this, Venus will appear as a tiny black dot on the surface of the Sun.

The best way, of course, is to project the image of Venus onto a screen, through an optical telescope. Some amateur astronomer's club in your vicinity will surely do it and they will be glad to show you the transit free of cost. Or, you can make your own projection system by making a tiny hole in a huge box, to act like a pinhole camera. A pinhole projection system can also be simulated by pasting a cardboard with a hole of about one centimeter on a small mirror. If sunlight is reflected using this contraption into a darkened room, a beautiful image of the Sun can be seen on the wall.

The Next Transit

Let us come back to the prophetic words of William Harkness, made in 1882: "What will be the state of science in 2004?" A casual glance at the timeline from 1882 to 2004, shows that before 1882, there was no electrification, no automobile, no airplane, no electronic gadget, no radio communication, no computer, no internet, no imaging, no laser and fiber optics, no video recording, no nuclear power, no mobile phone, no spacecraft, no Moon landing and mission to other planets, no space telescopes, no cure for certain diseases, no genetic engineering, no Haber process (which is perhaps the greatest discovery in the twentieth century).... The list can go on and on. Did Harkness have a strange premonition that after the twentieth century, the world would never be the same again?

Now, echoing William Harkness, what will be the state of science when the next transit season arrives on the 11th of December 2117, when people gear up for the cold Christmas season? We can only speculate.

Perhaps there will be space stations up above the Earth, in the form of giant wheels visible from the Earth, rotating slowly to simulate an Earth-like gravitational field. Space ships will dock and take-off from it to the Moon and to planet Mars where we may find a huge colony of human beings. Right on Earth we may find huge skyscrapers, the higher floors being occupied by the higher echelon of society and modern buses in the form of hovercrafts cruising on the surface of the Earth for the sake of the common man. There may not be cars and scooters since busy people would find it faster to strap a contrivance to their back and jump straight out of the window.

Of course, the world might turn out to be a more dangerous place to live, and everyone will carry a Laser gun in his or her pocket for self-defense! Travelling may not be an absolute necessity, since all business, including education will be done through 3-D holographic teleconferencing. Graphene chips will be embedded in the skull to enhance memory. The very busy businessmen would prefer to have concentrated food in the form of tablets for breakfast.

A woman may choose to change her facial features by using advanced cosmetic surgery and look the way she wants. Compact devices will be strapped to everyone's hand to monitor their health parameters and warn them of potential hazards. Lie detectors may virtually eliminate crime and politicians.

If *Science Reporter* magazine manages to survive (which I am sure, it would), somebody will quote this article while reporting yet another transit of Venus!

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