Venus Transit: A rare astronomical event

Venus transit occurs when the planet Venus travels across the disc of the Sun. From Earth, the transit appears as a small black dot moving on the surface of Sun. Transits of planets whose orbits are inside the orbit of Earth (e.g. Mercury and Venus) are only visible to the observers from Earth. Planetary transits are far rare compared to the eclipses of the Sun by the Moon which is essentially transit of the Moon across the disc of the Sun.

On an average, there are 13 transits of Mercury in each century. Venus transits, however, are among the rarest of predictable astronomical phenomena. It occurs in a pattern that repeats every 243 years, with pairs of transits eight years apart separated by gaps of 121.5 years and 105.5 years. The reason behind this gap of more than a century is the inclination of ~3.4 degree between the orbital planes of Venus and Earth. During the transit Venus is seen as big as a large sunspot on the disc of the Sun.

We know that the size and mass of Venus are comparable to that of the Earth. Earth rotates on its own axis in about 24 hours where as Venus rotates in the reverse direction (retrograde rotation) in 243 days. Orbital period of Venus around Sun is 224.701 days so that a Venus year is less than one Venus day. Combination of these two periods results in the Sun appearing from West and disappearing over East within a day-night cycle of 117 days. Orbital periods of Venus and Earth around Sun are 224.7 and 365.25 days. Assuming circular orbits and

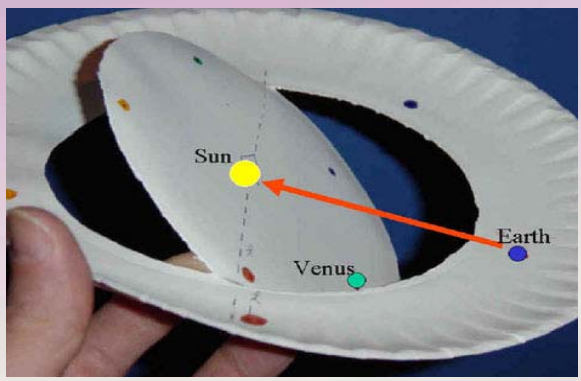

Figure 1. *Paper plate representation of orbital planes of Venus and Earth*

same orbital plane, Venus passes Earth after 2.6 laps corresponding to 1.6 years. As the orbit of Venus is inclined to that of the Earth by ~3.4 degree, we do not see Venus transits every 1.6 years. Only when the Sun, Venus, and Earth are in a straight line, we see Venus transit. The rest of the time when Venus passes in front of the Sun, it is either above or below the Sun as seen from the Earth and as shown in Figure 1. Transits of Venus are only possible during early December and early June when Venus's orbital nodes (the two intersecting points with the Earth's orbital plane) pass across the Sun.

Synodic period for Venus (period between successive appearances of Venus at the same point relative to the Sun as seen from the Earth) is 583.924 days. This implies 5 synodic periods of Venus (2919.62 d) corresponds to ~8 Earth orbital periods (~8 years - 2922.05 d) or 13 orbital periods of Venus (2921.11 d). This explains the 8 year interval between one pair of the transits of Venus. During the transit, Venus is seen as a small black dot moving slowly in an East-to-West direction across the disc of Sun. The latest transit of the planet began on 6 June 2012 at 03:39 IST and got over on 6 June 2012 at 10:23

Table 1. Dates of Venus Transit.

1631	Dec 07	A. Node	2012	June 06	D. Node
1639	Dec 04	A. Node	2117	Dec 11	A. Node
1761	June 06	D. Node	2125	Dec 08	A. Node
1769	June 03	D. Node	2247	June 11	D. Node
1874	Dec 09	A. Node	2255	June 09	D. Node
1882	Dec 06	A. Node	2360	Dec 13	A. Node
2004	June 08	D. Node	2368	Dec 10	A. Node

IST, with mid-transit taking place on 6 June at 07:01 IST (Table 1). The total transit duration was about 6 hours 40 minutes. The next Venus transit will be visible on 10-11 December 2117. Because Venus is seen against the solar disk, the transit can be viewed from anywhere on the Earth where the Sun is above the horizon at the time of the event.

A Brief History of Venus Transit

Jeremiah Horrocks was the first human to witness Venus transit across the disc of the Sun on 4 December 1639 from his home at Carr House in Much Hoole, near Preston in England. Earlier to this first observation of Venus transit , Johannes Kepler discovered the three important laws of planetary motion and published the Rudolphine Tables listing the positions of the planets in September 1627. During his laborious manual

calculations, he predicted that Venus would pass across the disc of the Sun in December 1631. Subsequently, he alerted observers on the Venus transit of 1631 as well as a second transit to take place in 1700's. However, the December 1631 transit was missed by observers from Europe. In analyzing his own observations, Jeremiah Horrocks was convinced that the available tables for planetary positions were not entirely correct. Instead of attempting to correct Kepler's tables, he tried to gather new observational data. From his new data and own calculations, he was able to predict an additional transit of Venus to occur on 4th December 1639, 8 years after the one in December 1631 and much earlier than the second transit to take place in 1761 predicted by Kepler. In fact, the transit did occur on 4th December 1639 and Jeremiah Horrocks could observe the transit of Venus across Sun. In his own words, *"Anxiously intent therefore on the undertaking through the greater part of the 23rd, and the whole of the 24th, I omitted no available opportunity of observing her ingress. I watched carefully on the 24th from sunrise to nine o'clock, and from a little before ten until noon, and at one in the afternoon, being called away in the intervals by business of the highest importance, which, for these ornamental pursuits I could not with propriety neglect. But during all this time I saw nothing in the sun except a small and common spot, consisting as it were of three points at a distance from the center towards the left, which I noticed on the preceding and following days. This evidently had nothing to do with Venus. About fifteen minutes past three in the afternoon, when I was again at liberty to continue my labors, the clouds, as if by divine interposition, were entirely dispersed, and I was once more invited to the grateful task of repeating my observations. I then beheld a most agreeable spectacle, the object of my sanguine wishes, a spot of unusual magnitude and of a perfectly circular shape, which had already fully entered upon the sun's disc on the left, so that the limbs of the Sun and Venus precisely coincided, forming an angle of contact. Not doubting that this was really the shadow of the planet, I immediately applied myself sedulously to observe it".*

In his calculations, Kepler had actually missed a second Venus transit which occurred 8 years after the predicted one. Unfortunately, Kepler was not alive to witness the transit of Venus in 1639. He passed away in 1630. Jeremiah Horrocks was the first person ever to record the phenomenon of Venus transit that occurred in 1639.

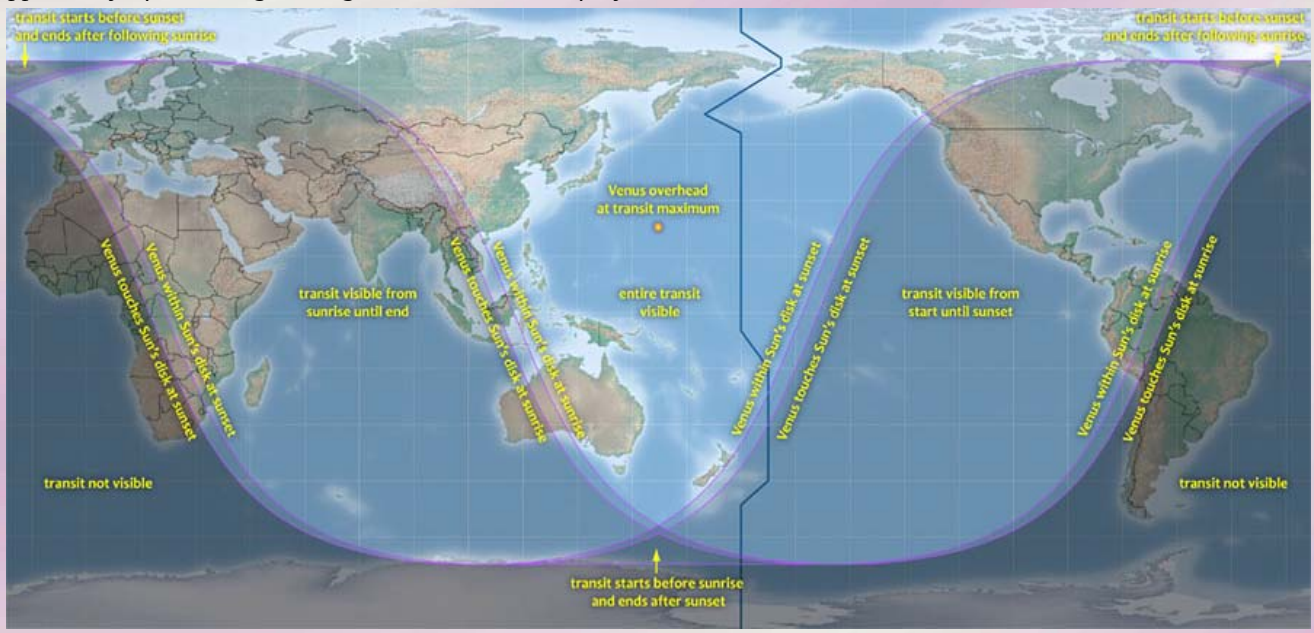

Figure 2. *World-wide visibility of Venus transit on 5-6 June 2012. Image credit: Michael Zeiler, eclmaps.commaps.com*

However, he could not work further on his discovery as he died of unknown causes two years later aged only 22. After his death, another British astronomer Sir Edmond Halley came forward to work on the phenomenon of Venus transit. In 1716, Sir Edmund Halley (1656-1742) proposed observations of Venus transit to estimate the value of the astronomical unit (the distance from Sun to Earth). By observing the apparent shift in position of

Venus against the disc of the Sun as seen from two different places on Earth, one can derive the distance to Venus which in turn gives the Sun-Earth distance (by using Kepler's law). In his article titled "A new Method of determining the Parallax of the Sun, or Distance from the Earth", he wrote "*We therefore recommend again and again, to the curious investigators of the stars to whom, when our lives are over, these observations are entrusted, that they, mindful of our advice, apply themselves to the undertaking of these observations vigorously. And for them we desire and pray for all good luck, especially that they be not deprived of this coveted spectacle by the unfortunate obscuration of cloudy heavens, and that the immensities of the celestial spheres, compelled to more precise boundaries, may at last yield to their glory and eternal fame."*

Venus transit on 5 June 1761 was observed from over 100 stations all over the world. During this observation, the curious "Black Drop Effect" was discovered by the Russian astronomer Mikhail V. Lomososov (1711-1765). Instead of the black disk of Venus sliding into the Sun's bright edge, it actually grew a beautiful halo of light all around its dark edge. The halo lasted only a few minutes and then vanished. He figured out that this is exactly what one would expect to see if Venus had an atmosphere.

Observation of Venus transit on 3 June 1769 seems to be much more fascinating. To have a better estimation of parallax and hence distance of the Sun from Earth, various observing stations were set up at different places on Earth. The French scientist Guillaume Le Gentil set sail abroad a Spanish ship bound for Manila in May of 1766. Unfortunately, he was accused of being a French spy. However, he managed to escape and make passage to Pondicherry. On the day of transit, 3 June 1769, the Sun rose behind clouds and stayed there all day during the transit of Venus. After 9 years abroad, and traveling nearly 70,000 miles, he wrote in his journal - "*I was more than two weeks in a singular dejection and almost did not have the courage to take up my pen to continue my journal; and several times it fell from my hands, when the moment came to report to France the fate of my operations."* Following a series of harrowing travel experiences on his way home to France, he crossed the Pyrenees on October 8, 1771, after being gone, by his journal, for 11 years, 6 months, and 13 days.

Another story on Guillaume Le Gentil says that on Halley's call for Venus transit observations at various places on Earth to estimate the distance between the Earth and the Sun, then he came to India to record the timing of the transit. However, he missed it because of a stormy voyage. He did not return back but waited in India for eight years to observe the next Venus transit in 1769. But he missed that too because of clouds. After that, he returned back home to find that he had been declared dead and his wife and her new husband had spent his fortune.

Using Venus transit observations, astronomers duly calculated the distance between Earth and the Sun to be between 93 to 97 million miles. Today, the accepted Earth-Sun distance is 92.96 million miles. The

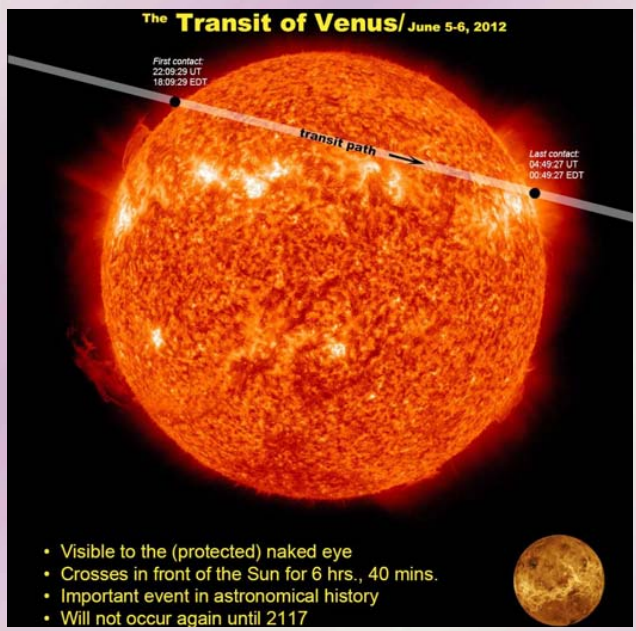

Figure 3. *5-6 June 2012 Venus transit showing the path and timing of the transit. Image courtesy - NASA*

enthusiasm for the observation of Venus transit, however, never diminished.

(Quotes are taken from an article by Dr. Sten Odenwald (NASA / ADNET)).

June 6 2012 Venus Transit observations from Physical Research Laboratory, Ahmedabad

The historic transit of the planet Venus across the disc of the Sun unfolded at about 3:40 hrs 6th June 2012. The spectacular event was visible from sunrise up to 10:23 hrs across India. A schematic representation of the 5-6 June 2012 Venus transit is shown in Figure-3.

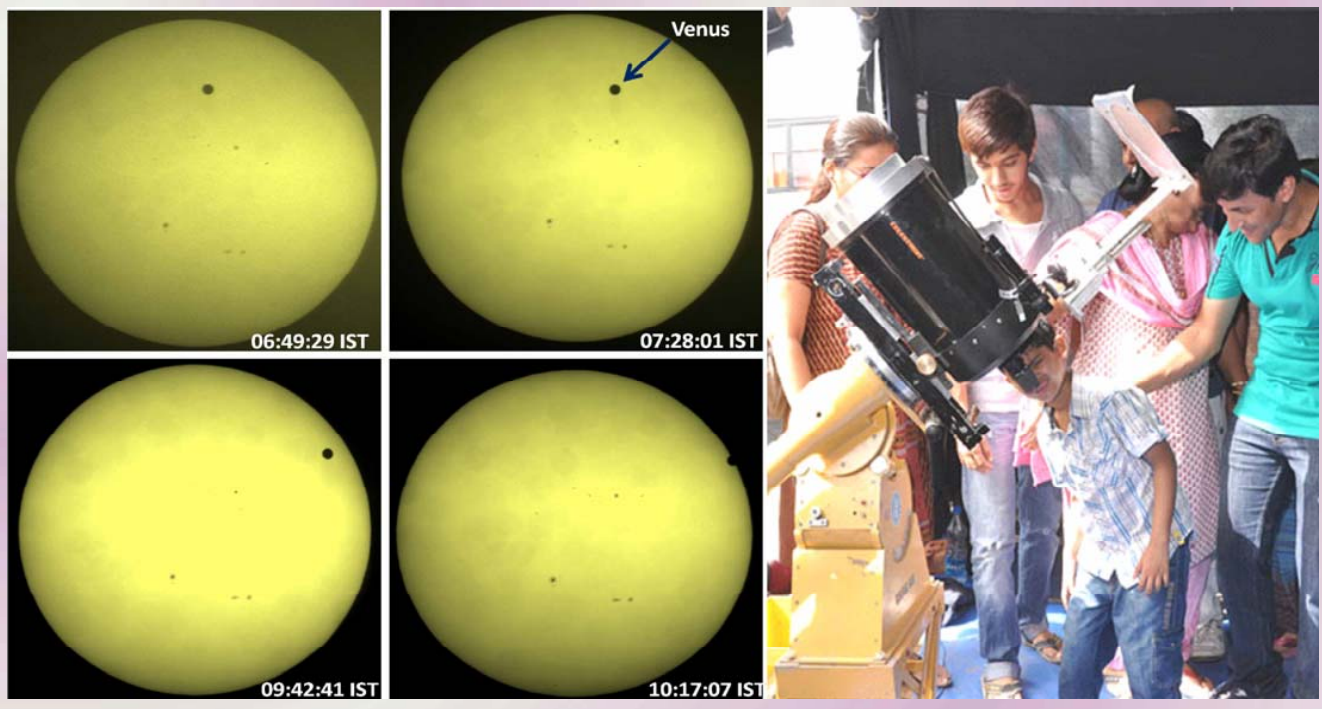

Figure 4: *The sequence of photographs of Venus Transit captured by Solar Flare Telescope at Thaltej campus of Physical Research Laboratory, Ahmedabad. The photograph shows an enthusiast exploring Vemus transit at PRL*

Arrangements were made for public viewing of this event at Thaltej Campus of Physical Research Laboratory, Ahmedabad. A couple of telescopes and the required support systems were installed in the campus. Several posters explaining the facts behind the scientific event and related explanations were displayed for the public. A large number of enthusiastic visitors of all ages, from kids who barely understand our solar system to senior people who did not want to miss the opportunity to see the event kept on coming till the event got over. Astronomers and volunteers explained the various queries on Venus transit and the long periodicity associated with it. A few of the photographs showing the transit of Venus across the disc of the Sun at different epochs are given below in Figure 4. The prominent and moving big black spot in the figures represents the planet Venus transiting across the disc of the Sun whereas the other relatively static fainter black spots are the Sunspots.

A total of about 8000 images of Venus transit have been obtained using the 100 mm refracting solar flare telescope. These high quality images will be used to study the structure of the atmosphere of Venus and its dynamics.

The photographs were captured by the graduate student Mr. Arun Kumar Awasthi under the guidance of Prof. Rajmal Jain. The Venus Transit program was co-ordinated by Prof. N. M. Ashok and Dr. Sachindra Naik of Astronomy and Astrophysics Division of Physical Research Laboratory, Ahmedabad. Efforts of volunteers from the Astronomy and Astrophysics Division of PRL are greatly acknowledged by the organizers of this event.

Further Reading:

Websites devoted to the Transit of Venus:

- http://www.prl.res.in/~snaik
- http://www.transitofvenus.org/
- http://eclipse.gsfc.nasa.gov/transit/venus0412.html
- http://www.transitofvenus.org/history/black-drop
- http://eclipse-maps.com/Eclipse-Maps/Transits.html

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