Transit of Venus: Quantitative Observing with Simple Equipment

N Rathnasree and Pritpal Kaur
Nehru Planetarium, Nehru Memorial Museum and Library
Teen Murti House
New Delhi 110 011, India.
Email:
rathnasree.nandivada@gmail.com

The possibilities of quantitative student observations during the transit of Venus, using simple equipment, are discussed. The equipment could also be used for safe observations of the Sun during eclipses, transits of Mercury as also for daily observations of sunspots. The annual variation in the angular diameter of the Sun as it passes from aphelion to perihelion and so on, could be measured with this simple equipment. School and college astronomy clubs would find it very useful to use this equipment for daytime astronomy activities and learning-oriented projects.

Introduction

From earliest times man must have studied the Sun and its movements in the heavens with a sense of awe and wonder. While positional observations would have been ubiquitous in all ancient astronomies, some observations of the disk of the Sun also appear here and there. Astronomers in ancient China recorded systematic observations of sunspots. There are references to sunspots in the writings of Greek philosophers from the fourth century BC. In ancient Indian Astronomy also, there are references perhaps to sunspots (maybe transit of Venus?). *The Chandogya Upanishad*, for instance, refers to the dark spots on the Sun as follows [1]:

"It flowed forth; it settled by the side of the Sun. Verily it is that appears as the black form (spot) in the Sun."

These observations could have been by naked eye and the above reference seems to indicate their observation over a period of time, until the spot disappeared from one edge of the disk of the Sun following the rotation of the Sun. Alternatively, of course, it could also refer to a single day's observations of a transit of Venus.

Keywords
Transit of Venus, projection of sunspots.

Some possible 17th century observations of the Sun either during an eclipse or during the 1631 transit of Venus, in India, where careful observations of the disk of the Sun are indicated, are discussed in [2, 3]. There is a definite mention of the possibilities of transits of Mercury and Venus, and perhaps some reference to statements by people who may have observed the 1631 transit of Venus, in the *Siddhanta Tattva Viveka* of Kamalakara, thought to have been published around 1658 [3, 4]. There is also the later instance of the 1874 transit of Venus observations by Samanta Chandrasekhar of Orissa, wherein he made observations of the relative angular diameters of the Sun and Venus, during the transit [5]. When we come across such possibilities of measurements involving the disk of the Sun, particularly when they are quantitative, one wonders whether telescopic projection of some kind was used or whether simple pinhole or even pinhole images under a tree were utilized.

The Transit

There is worldwide excitement about this event – the transit of Venus of the 5th/6th of June 2012, and this interest will only increase as the event approaches closer. Observers from India will miss the beginning parts of the event – the first and the second contacts, but, will see the maximum transit and the end of the event – the third and the fourth contacts, following sunrise on the 6th of June (*Figure* 1) . All over India, Sun will rise with Venus nestling on its disk, giving a wonderful opportunity to capture India's varied monumental heritage against the backdrop of this rare celestial event.

Observers from India will miss the beginning parts of the event – the first and the second contacts, but, will see the maximum transit and the end of the event – the third and the fourth contacts, following sunrise on the 6th of June.

You may wish to look up good observing locations to view the transit, as also to image it against a nearby heritage monument.

We need information about the sunrise azimuth – the angle from North, eastwards, to the point of location of the Sun. We would also need to look at the azimuth and altitude angles of the Sun as the transit progresses. We need this information while selecting our observing site, to ensure that these directions specified by the azimuth and altitude of the Sun, during the transit, are visible, and

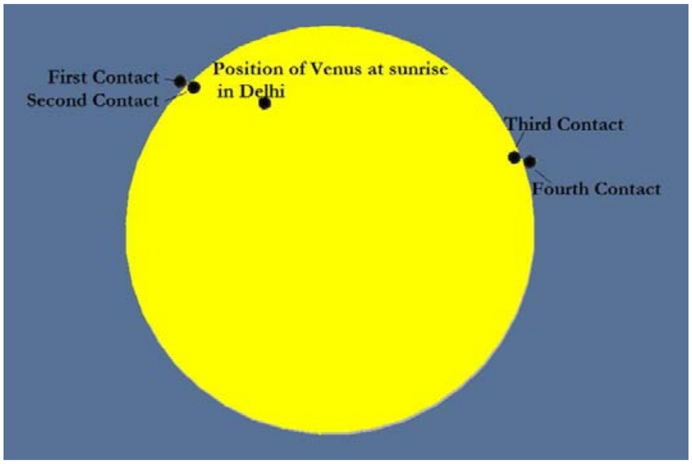

Figure 1. The four contacts. First contact: Venus just touching the disk of the Sun externally.
Second contact: Venus having just slipped inside the disk of the Sun – *both of which will be missed from India*.
Third contact: Venus, on its way out, just touching the circumference of the disk of the Sun internally.
Fourth contact: Venus just touching the disk of the Sun externally.
The third and fourth contacts will be visible from all of India.

will not be hidden behind a distant tree or a building. For any given location, these values could be obtained from the many available ephemeris software online, for example, calsky.com. The website wikimapia.com would be a useful resource for obtaining Google Earth views for heritage monuments, overlaying them with a digital protractor and checking out visibility in the relevant directions.

We have vast monumental heritage in our country and this is a unique opportunity to try and image this heritage as a backdrop for this unique celestial event. These images will remain of interest for hundreds of years to come!

One needs to identify such locations for heritage imaging and obtain images of the rising Sun with a simple digital camera. Using some optical zoom would ensure a slightly larger image of the Sun in the field of view. One will need to use a tripod to ensure a steady image. The website of the planetarium http://nehruplanetarium.org/ has a collection of 'observing sites' shortlisted for possible heritage imaging from different locations in India.

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Safety First!

Viewing the Sun directly, either with the naked eye or with a telescope, is extremely dangerous. Certified safe solar eclipse goggles would allow one to look at the Sun, and such filters could also be placed in front of a telescope objective to ensure safe viewing through the telescope eyepiece.

However, the safest method of observing the Sun is through projection. By using a telescope to project a steady, well-focused and large image of the Sun, one will be able to study the Sun at one's leisure, with no risk to the eyes.

It would not be safe to look directly at the Sun even at sunrise. While attempting the heritage imaging at sunrise as described above, one should not look through the viewfinder of the imaging camera, but rather, use the LCD viewfinder if the camera has one, to ensure that the Sun is within view of the camera. In the absence of an LCD viewfinder one could judge that this is so, by looking at the shadow of the camera on its tripod – when pointed at the Sun, the shadow will be shortest.

[1] In a Dobsonian mount for a telescope, the telescope tube sits in a cradle held inside a curved support, free to rotate in the vertical direction, which, in itself is supported on bearings on the main stand. This is free to rotate horizontally on a bearing surface. A Dobsonian is an alt-azimuth type of mount – one has to move it in both axes frequently to keep on a target.

Simple Equipment for Solar Projection

Projection of the Sun with a simple setup – a longish rectangular box, mounted on a stand analogous to a Dobsonian mount[1], with a peephole cut into it for comfortable viewing of the projected image, allows very satisfactory viewing of the Sun – absolutely safe, as also handy for some quantitative observations. A Dobsonian mount is not a must to obtain a projected image – it just allows easy maneuvering of the projection box to obtain a projected image of the Sun, for the entire duration of the transit.

Projection of the Sun with a simple setup – a longish rectangular box, mounted on a stand analogous to a Dobsonian mount, with a peephole cut into it for comfortable viewing of the projected image, allows very satisfactory viewing of the Sun

Quite a number of these projection boxes have been made and distributed by the Nehru Planetarium, New Delhi, to groups around the country during the total solar eclipse of July 2009, the annular solar eclipse of January 2010, and for the Transit of Venus 2012.

The setup is relatively simple to make – one just needs to make a long rectangular box (about 4 ft in length, with any available material – metal/wood/cardboard) for the projection. One end of the box will receive the projected image of the Sun and a peephole needs to be cut near this end. A simple refractor is to be inserted in the other end, ensuring that the refractor remains fixed parallel to the length of the box. If one is making a Dobsonian mount or any stand for the box, the projection end of the box should be resting on the stand. The purpose of the stand would be to allow the box to be rotated on one or two axes for alignment towards the Sun. The website of the planetarium http://nehruplanetarium.org/ contains video instructions for the construction and usage of these projection boxes.

Figure 2. The projection box and its creator.

We can easily adjust the position of the box for the duration of the transit – to keep the projected image of the Sun in view, inside the box. We need to adjust the orientation of the box in such a way that its shadow becomes shortest – the telescope should be parallel to the box and, as such, at this time, the shadow of the telescope will also be shortest.

We can get a good sized steady projected image of the Sun – suitable for undertaking quantitative observations.

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Using such a projection box equipment, and measuring the time in which the Sun drifts across one diameter of the projected disk, the angular diameter of the Sun can be estimated, with good accuracies.

A simple geometrical method can be used to draw a circle with diameter equal to that of the projected image of the Sun in the box – marking three points on the circumference of the projected

Figure 3. A projected image of partially eclipsed Sun inside the box (picture taken on 18 February 2007).

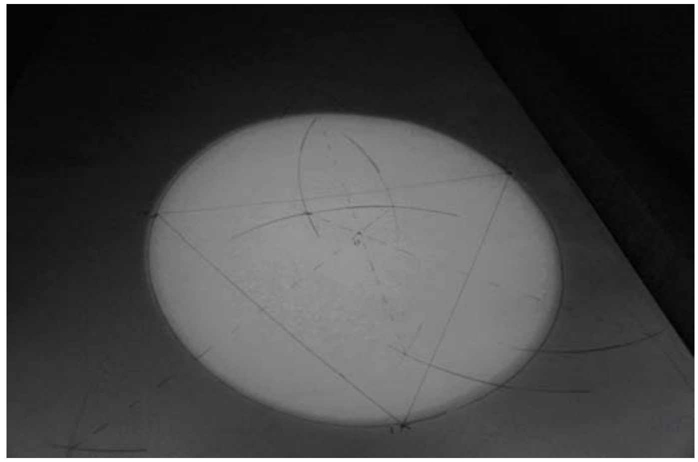

Figure 4. The drawn circle compared with the projected image of the Sun.

image of the Sun (rapidly, in order to avoid errors creeping in from the diurnal movement), drawing a triangle through these points, and then drawing the circumcircle of this triangle. The drawn circle should be placed in the projection box pointed towards the Sun, and errors in the determination of the diameter of the projected image of the Sun corrected iteratively.

This method of observations can also be used to study sunspots, as a part of a learning project on the Sun and sunspots. Using projected images of the Sun, the fractional area of the sunspot on the disk of the Sun can be determined by printing the images onto a graph sheet and counting the millimeter squares. Better analysis becomes possible, of course, through the usage of software like MATLAB or any other software that would allow processing the images of the Sun to determine the fractional area of the sunspot (or Venus or Mercury during transit) occupied on the projected image of the Sun.

The transit of Venus taking place on the 6th of June 2012, will be seen as a sunrise event from all locations in India. The Sun will rise with Venus nestling on its disk.

Possible Observations During the Transit of Venus with the Projection Equipment

The transit of Venus taking place on the 6th of June 2012, will be seen as a sunrise event from all locations in India. The Sun will rise with Venus nestling on its disk. Observers from India will miss the 1st and 2nd contacts of the event and will be able to see the end of the event through the 3rd and 4th contacts.

The projection boxes make excellent equipment for school and college groups to conduct a skywatch in their premises. Large number of visitors can comfortably view the transit while a smaller group of students could also use the projection setup for some quantitative observations during the transit.

First and foremost, of course, would be the preparations before the event. Preparing the projection equipment, purchase of a refractor and practicing with Sun projection and angular diameter measurements of the Sun which could be done at any time. For a given setup, one could obtain the reference circle, equal in diameter to the diameter of the projected image of the Sun and have many sheets ready with this circle printed. Sheets with graduated lines on them would facilitate a more accurate marking (and later sketching) of the extent of Venus and sunspots if any, on the projected image of the Sun.

Marking NEWS (the cardinal directions) on the projected image of the Sun allows one to align photographs of the Sun with Venus moving along its disk at different intervals during the transit. This can be done by the following procedure: i) First allow the disk of the Sun to drift and fit exactly inside the drawn circle. Hold the apparatus in that position and allow the Sun to drift out of the circle, marking the direction in which Venus or a sunspot moves with this drift. This will give direction East. ii) Draw East–West line and a line perpendicular to that. The 'Nudge North' procedure will then give the directions North and South – that is, gently nudge the apparatus towards rough North – any feature on the projected image (the projected image of the Sun itself) will move in the direction North on the projection. This will allow one to decide which direction on the line perpendicular to East–West line is the direction North.

Marking NEWS (the cardinal directions) on the projected image of the Sun allows one to align photographs of the Sun with Venus moving along its disk at different intervals during the transit.

Once NEWS is drawn in all sketches one obtains of the Sun – with the positions of Venus and sunspots if any, marked (and later sketched) – one can align all the sketches and obtain the track of Venus across the disk of the Sun.

Take a few moments to just witness the event – look at the Sun with appropriate Sun filters and share what you see with others. This will be an unforgettable experience.

For observers from India, who cannot time the whole duration of transit, measuring the time of the 3rd contact would allow one to obtain the Earth–Sun distance using the method elucidated in [6], when compared with similar observations from other locations on Earth. For the 2012 event, there are tools being prepared worldwide for pooling and analysis of all such data, including iphone and android applets (see transitofvenus.nl).

Following in the footsteps of Samanta Chandrasekhar of Orissa, one could attempt measurement of the angular diameters of the Sun and Venus, with the projection equipment. Using photographs of the projected image of the Sun at various intervals during the transit, printed on graph sheets, a measure of the relative angular diameter of Venus w.r.t. the Sun could be obtained which, combined with the angular diameter of the Sun, can be converted to the angular diameter of Venus.

And finally, take a few moments to just witness the event – look at the Sun with appropriate Sun filters and share what you see with others. This will be an unforgettable experience.

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Suggested Reading

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