# Practical Observations of the Transit of Venus

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The June 8th event of the transit of Venus gives us an opportunity to carry out several exercises. These include:

a) Estimation of the speed of Venus using data available from the almanac.
b) Measurement of the diameter of Venus as done by Horrocks.

How can one observe the transit? The safety measures are very important. One should never look at the Sun directly. In short, one has to take all the precautions as one would for a solar eclipse.

## 1. Projecting the Sun

As is well known the safest method is to project the Sun's image on to a screen using a telescope. The eyepiece should be adjusted so that the size of the image on the screen is about 15cm. The screen may be made with butter paper stuck on to a cardboard box, which will cover the eyepiece completely. This eliminates the possibility of anyone placing the eye anywhere near the eyepiece.

For orienting the telescope towards the Sun, the usual techniques of gunsight, etc., are going to be dangerous because it requires one to look up at the Sun. Instead it is advisable to look at the shadow. The principle is very simple. Hold any tube in the Sun and watch the shadow as you tilt it. The elliptical shadow becomes a circle only when it is exactly aligned with the Sun. Similarly the shadow of the telescope will be a circle when it is exactly aligned with the Sun. As you are looking at the shadow and adjusting it to be a circle, the Sun's image will appear on the screen.

So you have projected the Sun through the telescope. You may miss the beginning of the event (the first contact) but by second contact you have identified the dot. If you are planning to time these, it is done. You have another five hours to time the third contact.

## 2. What Next?

If you are motivated for calculations, a precise time-measuring device, graph paper and pencil should suffice for a simple calculation to estimate the speed of Venus.

### (a) *Estimating the speed of the planet*

Mark the outline of the Sun's disc on your graph paper. If there are sunspots mark their positions as well. *Figure* 1 shows the tracing obtained on 7th May 2003 during the transit of Mercury, with a 6" Newtonian telescope. It also shows two markings corresponding to the position of Mercury as A and B. Now mark the position of Venus; the position A at time $T_A$ and position B at time $T_B$. Note down the timings as precisely as possible.

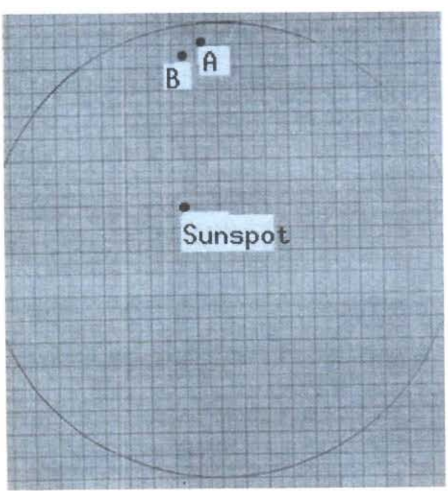
The time taken to move from position A to B is $T_A - T_B$

Our task is to find AB; the distance cannot be found directly. However, the angle can be found this way.

The angular size of the Sun is 31.514'. (This number is for June 8th as taken from the almanac). The diameter of the Sun is x cm on the graph paper, the distance AB is y cm. Then the angle AB may be found as

$$z = 31.514\, y / x.$$

*Figure 1. The tracing of the Sun's disc on 7th May 2003 with a Newtonian reflector.*




This implies that the angle covered by Venus is z in $(T_A - T_B)$ seconds. The angular velocity is $z/(T_A - T_B)$.

We can get the distance to Venus for 8th June accurately from the almanac. Multiplying this by z we get the linear velocity in km/s.

This procedure can be repeated for several points and the average value of the velocity can be derived.

Last year, Mercury provided a similar opportunity to carry out a rehearsal of these activities. The size of the dot was quite small. The telescope at the planetarium, Carl Zeiss 150/2250 Coude refractor, was used to project the Sun to a size of diameter 52cm. The following estimates were obtained.

Velocity of Mercury: 21.63 km/s.
Velocity corrected for retrograde motion: 49.47 km/s.
The value estimated from Kepler's law: 40.73 km/s.

We have to remember one important point here. During the interval ($T_A - T_B$), we on the Earth would have moved. Owing to this, our reference image, the Sun, itself would have moved by about half a degree towards the east. Recall that Venus moved in the opposite direction, namely east to west. The Sun's motion we are referring to is not the diurnal motion of rising in the east and setting in the west, but the annual motion of about 1 degree per day to the east. Thus a correction to this effect must be applied to the derived velocity of Venus. This velocity of the Earth also is available in the almanac.

Data for 8th June:
Distance of Venus from Earth = 43,218,076.65 km.
Distance of Earth from Sun = 1.0150415 AU = 1, 518,48046.4 km.
Angular size of the Sun = 31' 30.84".

Undergraduate students can calculate the speeds of Earth and Venus based on Kepler's laws. The velocity at different instants on the orbit may be calculated and verified. Even the errors involved in the measurement can be estimated.

**(b)** ***Timing the Second and Third Contacts***

As revealed by the historical documents, the most important task of determining the beginning and ending timings was marred by the black drop effect. Therefore this time attention can be paid to documenting this with sophisticated equipment like a video camera or a zoom lens.

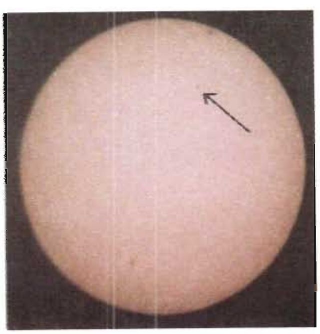
The projected disc of the Sun, on any day, would immediately bring out two aspects. The first aspect concerns the sunspots and their structure. The central region will be relatively dark and hence the name umbra. The surrounding regions have spokelike structures and less dark (called penumbra, although this has nothing to do with shadows). A careful examination of the edges of the Sun will reveal that they are dancing, giving an impression of watching the reflection of moon in water. The Earth's atmosphere, which causes the twinkling of stars, is responsible for this also.

The other factor is the limb darkening. The edges are not as bright as the central region. This is partly responsible for missing the exact time of beginning and ending contacts. On 7th May 2003 while observing the transit of Mercury, we experienced this difficulty in identifying a pale dot emerging on to the pale edge of the Sun. By the time we were sure of the beginning, the black disc was almost half way in. Identification of the black disc is not so difficult when it is away from the limb especially because it is a perfect circle. Things did not improve at the ending either. The black disc faded out gradually into the dim edges of the Sun. The situation may be better on June 8th because the disc of Venus will be larger than that of Mercury. But the difficulty due to the limb darkening cannot be totally eliminated.

The event provides a great opportunity for videography, because, unlike the other celestial events observed in the night, this will have to do with a bright Sun.

(c) ***Radius of the Planet***

*Figure 2. Photograph of the transit of Mercury on 7th May 2003 (shown by an arrow).*



For people who have to share telescopes with others and therefore may have to be content with just one view or visit, a simple exercise may be just to measure the diameter of the dot and estimate the radius of Venus (with the distance known). Horrocks had done the same exercise and arrived at a very correct value.

The photograph in *Figure* 2 gives the transit of Mercury of 7th May 2003. The following data for that day may be used for

Finding the angular size of Mercury.
Finding the diameter of Mercury.
Earth Sun distance = 1.0089361 AU.

| Place | I Contact | II Contact | III Contact | IV Contact |
|---|---|---|---|---|
| | h m s | h m s | h m s | h m s |
| Ahmedabad | 10 46 30.4 | 11 05 21.9 | 16 32 12.7 | 16 51 10.9 |
| Bangalore | 10 45 36.2 | 11 04 19.3 | 16 32 42.1 | 16 51 35.5 |
| Chennai | 10 45 19.4 | 11 04 01.8 | 16 32 31.2 | 16 51 25.8 |
| Delhi | 10 46 14.1 | 11 05 08.4 | 16 31 31.2 | 16 50 34.6 |
| Guwahati | 10 44 41.5 | 11 03 31.2 | 16 30 52.7 | 16 50 00.4 |
| Hyderabad | 10 45 42.1 | 11 04 27.8 | 16 32 16.2 | 16 51 12.7 |
| Mumbai | 10 46 20.6 | 11 05 09.1 | 16 32 31.1 | 16 51 26.6 |

***Table 1. The Contact Timings for some important cities (from Indian Astronomical Ephemeris).***

Earth  Mercury distance = 0.560040 AU.
Semi-diameter of the Sun = 15' 51.10".

This will serve as a precursor to the measurements that may be done on 8th June.

Since Venus is nearer to Earth than Mercury the errors in the measurements are likely to be smaller.

*Table* 1 gives the timings for several stations. The contacts are defined as

1. First contact – the western edge of Venus touches the eastern limb of the Sun.

2. Second contact – the eastern edge of Venus touches the eastern edge of Sun.

3. Third contact – the western edge of Venus touches the western edge of the Sun.

4. Fourth contact – the eastern edge of Venus touches the western edge of the Sun.

Many students participated in the observations on 7th May 2003; K G Geetha estimated the speed of Mercury and applied the correction for retrograde as well. I am thankful to her for giving me this additional data.

## Suggested Reading

[1] E Maor, *June 8, 2004– Venus in Transit*, Princeton University Press, 2000.
[2] Halley's method from http: //sunearth.gsfc.nasa.gov/eclipses/ Halleyparallax.html
[3] Indian Astronomical Ephemeris