The scale of the solar system: Re-enacting the Transit of Venus observations 5 – 6 June 2012

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The sighting of Australia by Captain Cook in 1770 was preceded by one of the most important scientific expeditions of the time;

to measure the distance between the Earth and the Sun (an astronomical unit - AU) and so compute the scale of the solar system.

This was achieved by measuring the time taken for Venus to transit across the face of the Sun for different locations on Earth and uses the parallax effect to compute 1 AU.

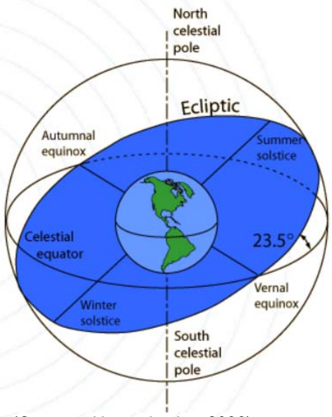
Title: Transit of Venus

Author: Craig Roberts & Matthew Cooper

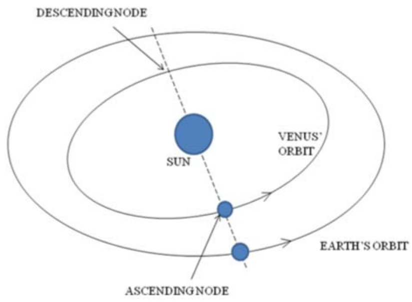

June 8, 2004


... and later that day!

The Transit of Venus



(Courtesy Hyperphysics, 2006)



Venus' orbit is inclined (by 3.39 degrees) relative to the ecliptic

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List of Transits and intervals

Date of transit	Ascending (A) or Descending (D) node	Duration since last transit (years and months)
6 December 1631	A	
4 December 1639	A	8 yrs
6 June 1761	D	121 yrs 6 months
3 June 1769	D	8 yrs
9 December 1874	A	105 yrs 6 months
6 December 1882	A	8 yrs
8 June 2004	D	121 yrs 6 months
5 June 2012	D	8 yrs
11 December 2117	A	105 yrs 6 months
8 December 2125	A	8 yrs

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A brief history of the Transit of Venus

- First predicted by Johannes Kepler in the early 17th century
- First scientifically observed transit in 1639 by Jeremiah Horrocks
  - using a telescope to project the image of the Sun onto a piece of paper
  - an estimation of the Astronomical Unit was made, but based on assumptions of the size of Venus
- Early in the 18th century, Edmund Halley proposed a method of calculating the distance from Earth to Sun using transits of Mercury or Venus.
- The transits of 1761 and 1769 were observed by many people, in different locations around the world.
- The 1769 transit is the one observed notably by Captain James Cook in Tahiti.
- In Australia in 1874, a team of men led by Government Astronomer Henry Chamberlain Russell, scientifically observed transit of Venus in various locations around New South Wales. The 1882 transit was not observed.
- A re-enactment at Woodford in the Blue Mountains on 8 June 2004

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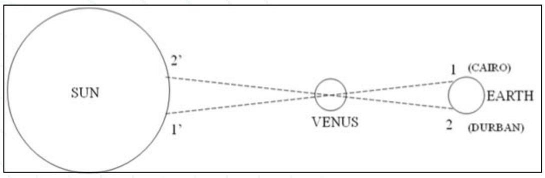
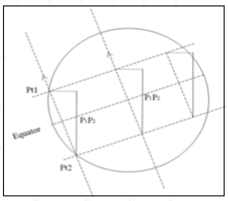
Transit of Venus - geometry

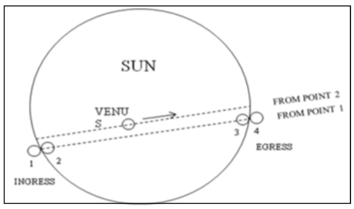
Stern (2004) presents a simplified method to calculate 1 AU based on Halley's method



Observing locations:	Lat	Long
Cairo (1)	30° N	32° E
Durban (2)	30° S	31° E



Dist between pts 1 & 2 due to plane of the ecliptic

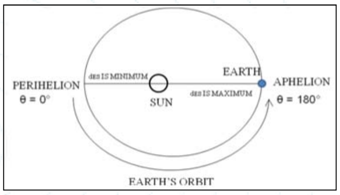


Path of transit across face of the Sun

Transit of Venus - geometry

Cairo: 19,526 seconds
Durban: 20,055 seconds

Average *L* = 19,790.5 seconds   Difference in *L* = 529 seconds

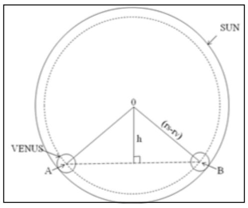


Elliptical revolution of Earth around the Sun

$$d_{es} = AU \frac{(1-e^2)}{1+e\cos\theta}$$

e – eccentricity of Earth's orbit

θ - angular position of Earth in its orbit around the Sun



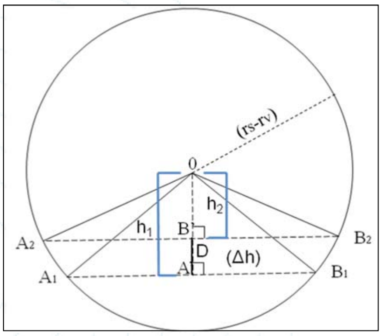
Geometry of transit of Venus on the face of the Sun

Apparent radius on Earth of:

Sun: 15.75 arc minutes

Venus: 0.5 arc minutes

Transit of Venus - geometry



At Cairo, the transit of Venus follows the line A_1B_1

At Durban, the transit follows the line A_2B_2

At Durban, the distance h_2 (centre of sun to transit line) is slightly smaller than h_1 at Cairo, because Venus, as it appears in the sky relative to the Sun at Durban, is slightly higher up. D = Δh

D is the apparent parallax shift of Venus relative to the Sun between Durban and Cairo, measured in minutes and seconds of arc

Using an approximation for the apparent velocity of Venus relative to the Sun and the durations recorded for the transit at each location, the apparent lengths A_1B_1 & A_2B_2 can be calculated. $l_{AB} = \omega_{VS} * L$

$$D = l_{OA} - l_{OB} = \sqrt{(r_S - r_V)^2 - \left(\frac{l_{A_1B_1}}{2}\right)^2} - \sqrt{(r_S - r_V)^2 - \left(\frac{l_{A_2B_2}}{2}\right)^2}$$

D = 0.3132'

Transit of Venus - geometry

Using some known data the distance P_1P_2 can be derived relative to the ecliptic.
Average radius of the spherical Earth (R_E) = 6371km,
Venus' orbital period (T_V) = 0.616 Earth years,
Eccentricity of Earth's orbit (*e*) = 0.01673,
Eccentricity of Venus' orbit = 0 (Venus' orbit has a very small eccentricity and is ignored).

$$\text{Chord } P_1P_2 = R_E \sin(lat(1)) - R_E \sin(lat(2))$$

Due to the Earth's tilt of 23.5°

$$\text{Dist } P_1P_2 = \text{Chord } P_1P_2 * \cos(23.5^{\circ})$$

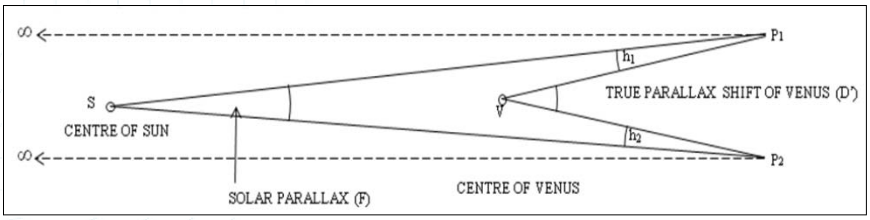
This perpendicular distance stays constant regardless of the rotation angle of the Earth due to the symmetry of the chosen latitudes.

$$\text{Chord } P_1P_2 = 6371 \text{ km}$$
$$\text{Dist } P_1P_2 = 5842.6 \text{ km}$$

Transit of Venus – solar parallax

During the last transit (8th June 2004) θ is nearly equal to 180°, therefore d_{ES} = 1.01673 AU & d_{EV} = 0.291AU

Because the Sun is not infinitely far away, the location of its centre will shift slightly (with respect to distant stars) when viewed from two separate locations on Earth. This Solar parallax impacts on the parallax shift of Venus because the parallax of Venus is measured relative to the Sun.



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Transit of Venus – simulated results

- Using Stern's values for the transit times at Durban and Cairo, results in an estimation for 1 AU = 157,302,177km
- The current accepted value is 149,597,870.691 (NASA, 2009)
- Benefit of Stern's method is simplicity.
- Blatter's method accounts for pairs of stations that do not lie on same meridian.

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Transit of Venus – a modern measurement

- A video of the event would leave a lasting record and allow accurate timing of the ingress and egress times
- Cooper lists problems with fitting videos to theodolites
- Recommends partnering with amateur astronomers using astronomical telescopes with an accurate tracking and timing mechanism
- David Gault's telescope (amateur astronomer) can video the transit event and insert GPS time stamps

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We need you!

2012 Transit of Venus

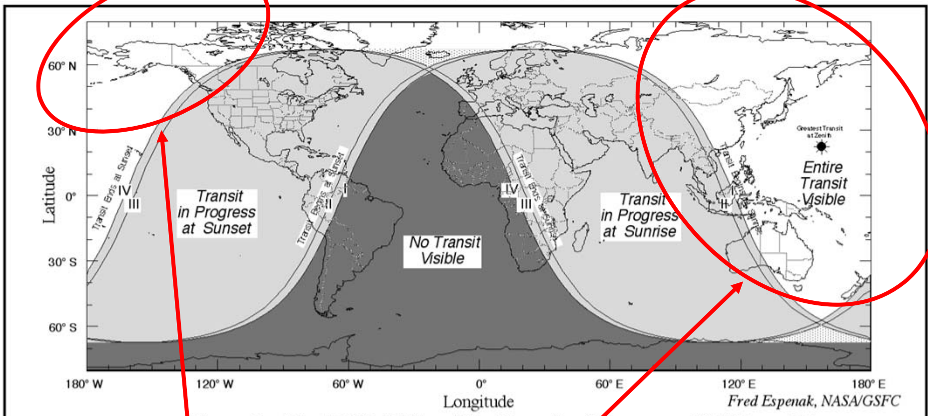

Figure 3 - World Visibility of the Transit of Venus — 2012 June 06

…. or here….

If you live here …

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