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.
June 8, 2004

... and later that day!
The Transit of Venus

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

(Courtesy Hyperphysics, 2006)

List of Transits and intervals

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

Transit of Venus - geometry

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

<table>
<thead>
<tr>
<th>Observing locations</th>
<th>Lat</th>
<th>Long</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cairo (1)</td>
<td>30° N</td>
<td>32° E</td>
</tr>
<tr>
<td>Durban (2)</td>
<td>30° S</td>
<td>31° E</td>
</tr>
</tbody>
</table>

Dist between pts 1 & 2 due to plane of the ecliptic
Path of transit across face of the Sun
Transit of Venus - geometry

At Cairo, the transit of Venus follows the line A₁B₁.
At Durban, the transit follows the line A₂B₂.
At Durban, the distance $h₂$ (centre of sun to transit line) is slightly smaller than $h₁$ 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 $A₁B₁$ & $A₂B₂$ can be calculated.

\[ l_{AB} = \omega_{VS} \times L \]

\[ D = l_{AB} \]

\[ l_{AB} = \sqrt{(r₅ \cdot r₇)^2 + \left(\frac{r₅n}{2} \right)^2 + \left(\frac{r₇n}{2} \right)^2} \]

$D = 0.3132°$
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°

\[
\text{Dist } P_1P_2 = \text{Chord } P_1P_2 \times \cos(23.5°)
\]

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

Chord $P_1P_2 = 6371$ km
Dist $P_1P_2 = 5842.6$ km

Transit of Venus – solar parallax

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

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.
Transit of Venus – simulated results

- Using Stern’s values for the transit times at Durban and Cairo, results in an estimation for 1 AU = 157,302,177 km
- 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.

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
We need you!

2012 Transit of Venus

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

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Title: Transit of Venus
Author: Craig Roberts & Matthew Cooper
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References