Australian Astronomy

ASA Factsheet No.15

Transit of Venus
8 June 2004

<u>Warning</u>: It is very dangerous to look directly at the Sun, especially through binoculars or telescopes. SERIOUS EYE DAMAGE MAY RESULT. A safe method of indirectly observing the Sun's disc is described below.

On the afternoon of Tuesday 8 June Venus will cross in front of the Sun. As we see Venus's dark silhouette move across the disc of the Sun we will be witnessing one of the rarest and most famous events in astronomy, a transit of Venus. This will be the first transit of the planet in over 120 years.

What is a transit?

A transit occurs when, as seen from Earth, a planet appears to move across the disc of the Sun. Only the two inner planets, Mercury and Venus, can ever be found between the Sun and the Earth and therefore be seen in transit. A transit does not occur each time the planets are in the same direction as the Sun because usually they pass above or below the Sun in the sky.

A transit is somewhat like an eclipse of the Sun. However, Mercury and Venus only appear as small dark spots against the disc of the Sun instead of covering the disc as the moon does in an eclipse. This is because the planets are much more distant than the moon.

Transits of Venus are very rare. They occur twice eight years apart and then not for over a century. They are more famous than the relatively common transits of Mercury as scientists in the 18th and 19th century used them to establish the scale of the Solar System. They are of especial interest to Australians since Lieutenant James Cook's voyage to Tahiti to observe the 1769 transit of Venus led to the European settlement of the continent.

The transit in 2004

This year's transit of Venus will be the first since 1882. It will be best seen in Europe, Asia and most of Africa where the transit will be seen from beginning to end – from Venus appearing to enter the Sun's disc, to leaving the disc just over six hours later. In Australia we will see the start of the transit, but everywhere on the continent the Sun will set before the end of the event. We are more fortunate though than people in New Zealand where the Sun will set before the beginning of the transit.

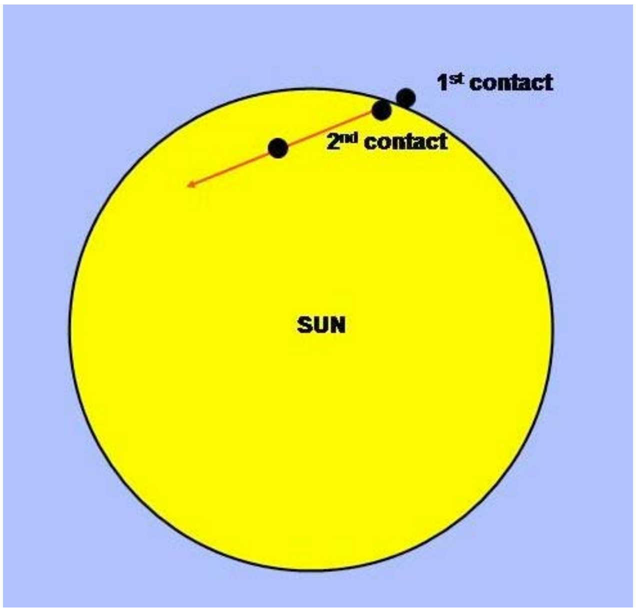

Figure 1 – the path of Venus across the Sun as seen from Australia. First contact refers to the time Venus just touches the edge of the Sun's disc. Second contact is when Venus is completely inside the disc, but still touching the edge.

The table below gives the times of the transit for the major cities in Australia. Observers elsewhere can estimate their local times from these. For all Australian observers the transit is still underway when the Sun sets at their location.

Place	**First touches Sun (first contact)**	**Just inside Sun (second contact)**	**Sunset**
Adelaide	2:38 pm	2:57 pm	5:11 pm
Brisbane	3:07 pm	3:26 pm	5:00 pm
Canberra	3:08 pm	3:26 pm	4:58 pm
Darwin	2:39 pm	2:58 pm	6:28 pm
Hobart	3:08 pm	3:26 pm	4:43 pm
Melbourne	3:08 pm	3:26 pm	5:07 pm
Perth	1:10 pm	1:28 pm	5:19 pm
Sydney	3:07 pm	3:26 pm	4:53 pm
All times in local time			

If you miss this transit, your next chance will be on 7 June 2012. After that, it's a long wait until 2117 and 2125!

History

Edmond Halley

It was Edmond Halley, of Halley's Comet fame, who in 1716 pointed out the feasibility of using transits for measuring the distance from the Earth to the Sun and suggested a method of observation.

If Venus is observed during a transit from widely separated locations there will be a slight shift in the track across the Sun as seen from each place. This is due to parallax - in the same way that a finger held in front of your face will appear to jump from side to side as you open and close your eyes in turn. Once astronomers have measured this slight shift they can use simple geometry to obtain the distance of the Sun.

Halley realised that this shift was so slight that it was not possible to measure it directly. Instead he suggested timing the instants when Venus first appears to touch the Sun's disc and when Venus is first completely inside the disc as well as the two corresponding instants when Venus leaves the disc. With the timings of what are known as first, second, third and fourth contacts, astronomers could compare the path of Venus across the Sun as seen from different locations.

Prior to Halley the only people to have observed a transit of Venus were a young English astronomer Rev. Jeremiah Horrocks in the village of Much Hoole and a friend in Manchester who saw one in December 1639. The next transit in 1761 was more extensively observed with expeditions to places far from Europe. Some of these did not go smoothly, partly due to the war between Britain and France at the time.

The transit of 1761: Mason and Dixon

In one British 1761 expedition the astronomer Charles Mason and the land surveyor Jeremiah Dixon set out to observe the transit from Sumatra. While still in the English Channel their ship was involved in a disastrous clash with a French frigate. After the ship returned to port Mason and Dixon were so shaken that they wanted to abandon the trip, but were persuaded to resume the expedition by threats of legal action from the Royal Society. After all that drama they did not reach Sumatra as the French had taken over their destination port. Instead they successfully observed the transit from Cape Town in South Africa where they had stopped on the way. If the names Mason and Dixon sound familiar it is because a few years after the transit they surveyed the boundary between two states in North America that became known as the Mason-Dixon Line. During the American civil war an extension of that line became the division between free and slave states.

The transit of 1769: James Cook

The most celebrated transit of Venus is that of June 1769, which was observed from many places. One of the observers was Lieutenant James Cook who sailed to the newly discovered island of Tahiti with the astronomer Charles Green in the ship HMS *Endeavour*. They arrived six weeks before the transit so as to have time to prepare. Cook had a small fort, called Fort Venus, built to protect the observing equipment from the natives. The fortification did not seem to help as a native soon managed to remove the astronomical quadrant that was crucial to establish their geographical position. Fortunately, it was quickly recovered.

Cook and Green found that timing the important second and third contacts was difficult due to the "black drop" effect. A dark thread appeared to join the edge of Venus to that of the Sun making the instants of second and third contacts hard to establish. In spite of this Cook and Green agreed exactly on one of the times and only differed by six seconds on the other.

The voyage to observe the 1769 transit is especially significant to Australians for, after successfully completing the observations, Cook opened sealed orders from the Admiralty to search for the unknown southern continent. He did not find this mythical land, but did claim New Zealand and New South Wales for the British Crown.

The transit of 1874: Henry Chamberlain Russell

As recorded by Henry Chamberlain Russell, NSW Government Astronomer, excitement was high before the next transit over a century later:

"Never perhaps in the world's history did morning dawn on so many waiting astronomers as it did on the 9th of December, 1874."

In addition to observing from Sydney Observatory, Russell organised three observing stations at Woodford in the Blue Mountains, Eden and Goulburn. These stations were staffed by the leading scientific men of the day such as PF Adams, the Surveyor-General, and Professor Archibald Liversidge from Sydney University.

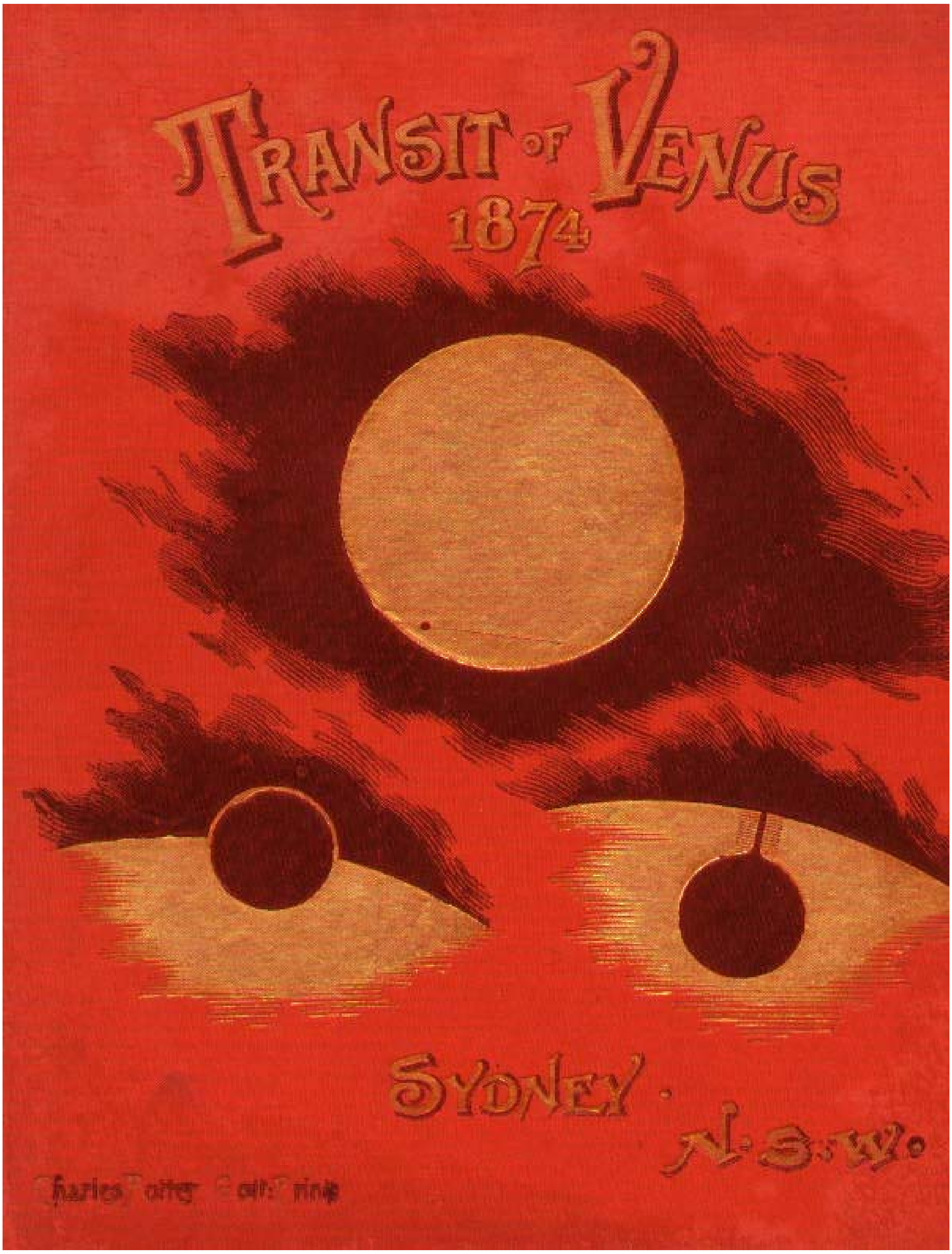

Figure 2 – The cover of a book published by HC Russell in 1890 reporting the results of his and his colleagues' transit of Venus observations in 1874.
Courtesy of the Powerhouse Museum

Russell and his observers were fully expecting to see the notorious black drop effect. Surprisingly, it was only seen by the two observers with small size telescopes. However, numerous other optical effects were seen such as a halo around the planet and ‘vibrations’ of its edge. Satisfactory results were obtained though in spite of the effects. When the NSW results were included with other “British” transit observations they helped to ensure a near agreement with the modern value for the Sun’s distance.

The transit of 1882: Henry Chamberlain Russell

By the time of the next transit in 1882 scientific interest had waned as astronomers had other methods of gauging the Sun’s distance. Russell still intended to make observations, but on the day clouds covered Sydney and much of NSW preventing any observation of the event.

Explanation of the black drop effect

Since the time of James Cook scientists have offered many explanations for the black drop and other optical effects that impede timing Venus on the Sun’s disc. Among their obvious suggestions are that the effect is due to the atmosphere of Venus and that it is an illusion. However, the planet’s atmosphere is too thin to be responsible and we know that it is not an illusion since the black drop has been photographed in recent years during transits of Mercury. During the transit of Mercury on 15 November 1999 the TRACE spacecraft even imaged the black drop from space.

As seen from Earth, light from planets or stars is always somewhat blurred by its passage through moving air currents in the atmosphere. In daytime the heating from the Sun causes extra turbulence close to the ground, leading to even greater blurring. Present day astronomers explain the black drop effect as the combining of this blurring with the dimming of the Sun’s disc near its edge. (A slight blurring of the image from the TRACE spacecraft led to the black drop from space as well, albeit less obvious than that seen from Earth.)

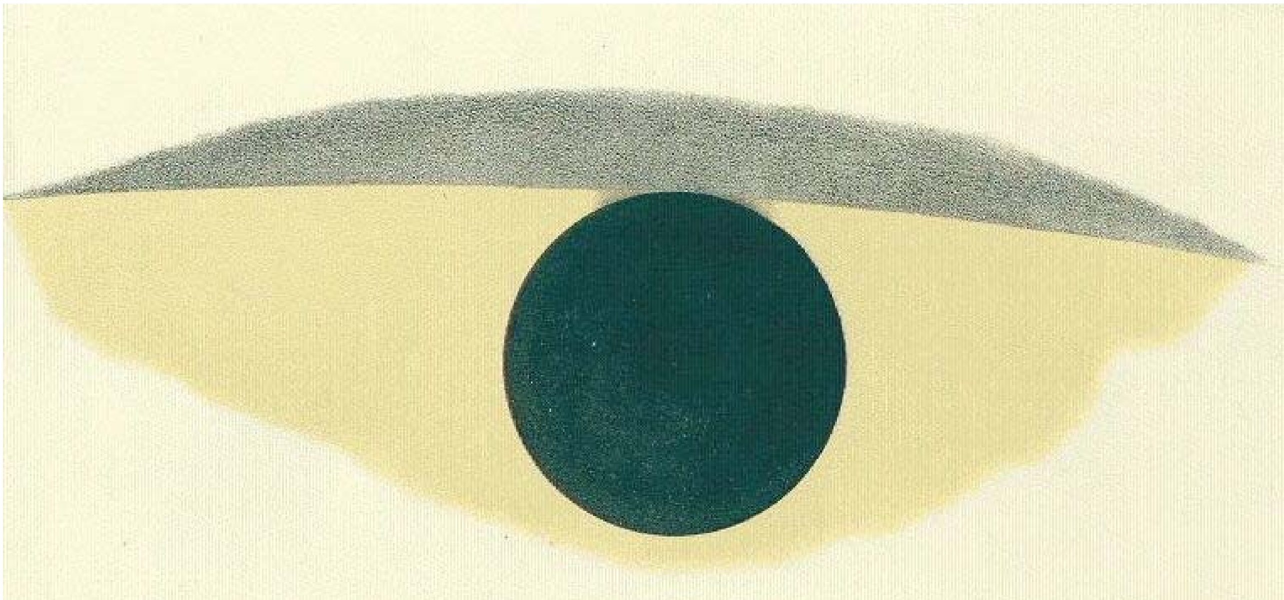

Figure 3 – A drawing by HC Russell of a slight haziness before second contact.
Courtesy of the Powerhouse Museum

A little maths
(ignore this section if you are not mathematically minded)

How did 18th and 19th century astronomers obtain the distance of the Sun from a transit of Venus?

Let us first work out the ratio of the distances of Earth and Venus from the Sun. That is given by Kepler's third law, which states that the cube of a planet's distance from the Sun (a) is proportional to the square of the time a planet takes to circle the Sun (the period T) or $a^3 \propto T^2$. Putting Venus' period of 225 days and Earth's period of 365 days into the formula we find a ratio of distances of approximately 0.7. We can then say that the ratio of the distances Earth to Venus and Venus to the Sun is in the proportion 3 to 7.

What is the separation of the tracks of Venus across the Sun seen from two places on Earth? Let us assume that the two places are separated by 4,000 km in the north-south direction (see figure 4). Then the separation on the Sun is given (with the help of similar triangles) as 4,000 km x 7/3 $\approx$ 9,000 km.

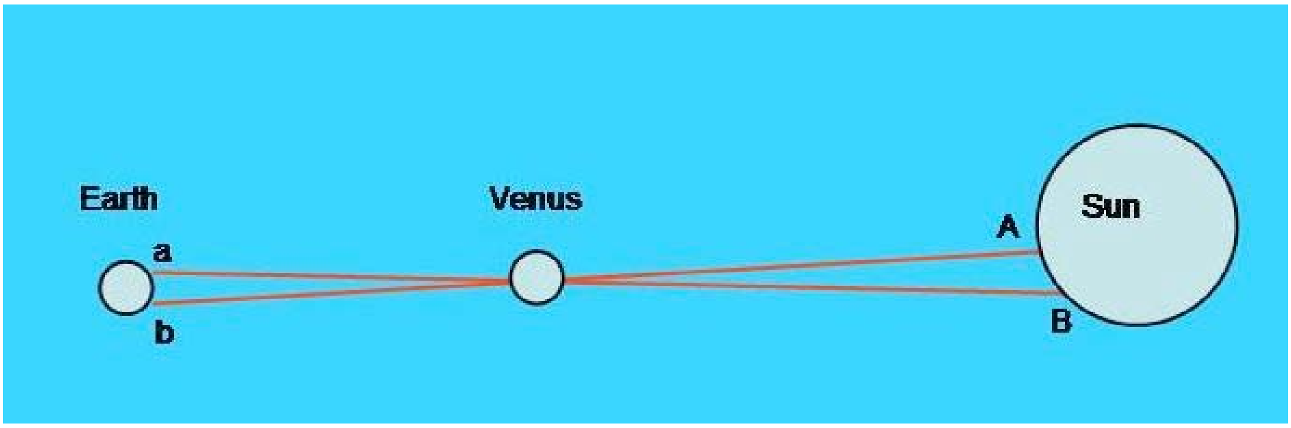

Figure 4 – the separation of the track as seen from two points a & b on Earth leads to a larger separation A & B on the Sun. Note that the diagram is not to scale.

If we obtain the separation of the tracks in angular measure from the timings in the two places then it is a simple exercise in trigonometry to determine the distance of the Sun.

What separation in angle do we expect? If we assume an approximate value of 150 million km for the distance of the Sun then the separation is the inverse tan of 9,000/150,000,000 $\approx$ 12 seconds of arc. This very small angle is about 1/5th of the size that Venus will appear when crossing the disc of the Sun. No wonder that Halley suggested obtained this shift by timing the crossing instead of trying to measure this tiny shift directly.

Finding the distances to stars and galaxies

Today's astronomers use the distance from the Earth to the Sun as the fundamental step in obtaining the distances of objects in the Universe. Instead of waiting for Venus to transit the Sun they bounce radar waves off the planet to obtain the Sun's distance to high accuracy.

The distances of nearby stars form the next rung in the astronomical distance scale. These are found by looking at the very small shift in the position of nearby stars with respect to distant ones as Earth orbits the Sun. Knowing the distance from the Earth to the Sun, we can use simple trigonometry to give the distance. Until recently astronomers had only managed to precisely measure the distances of about 100 stars in this way. In 1997 the results from the *Hipparcos* satellite boosted the number of precise star distances to over 100,000.

A type of star that changes its light output in a regular cycle of a few days called a Cepheid variable provides the next rung in the scale. Astronomers have found that the true brightness of these stars is related to the period of their brightness variation. By calibrating the technique with the help of Cepheids with directly measured distances astronomers can measure the distance of Cepheids in galaxies tens of millions of light years away.

There are a number of other rungs in the distance scale. It ends with the use of supernovae or exploding stars as standard candles. Astronomers know how bright these supernovae truly are and can compare this true brightness with how bright they appear when seen from Earth. In this way astronomers have measured distances almost to the edge of the visible Universe.

How to watch the transit safely

The best way is to visit your local observatory, planetarium or local amateur astronomical society, which is likely to be running public viewing sessions.

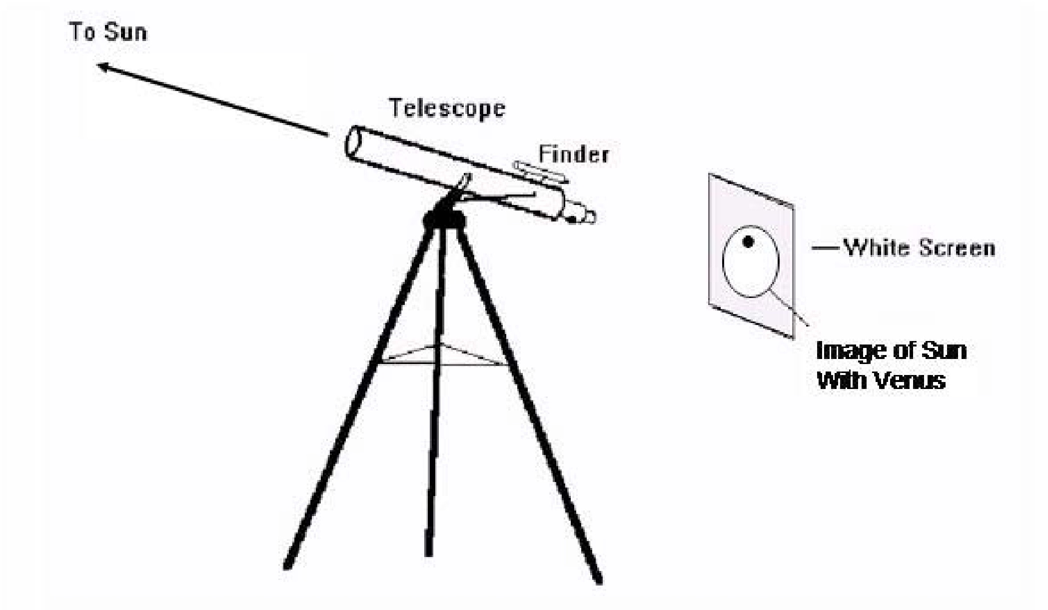

Figure 5 – How to use a telescope to project an image of the Sun. NEVER look through the telescope or its finder!

It is possible to safely watch the transit yourself if you have a small telescope or a pair of binoculars. Use the telescope or the binoculars to project the image, as shown in figure 5. With your back to the Sun aim the telescope towards it (this is not as difficult to do as it sounds – use the shadow of the telescope) and focus its image onto a white card held about 20 cm behind the eyepiece. Venus will appear as a black spot with a width of 1/33rd of the Sun's width and should be easily seen.

DO NOT LOOK THROUGH THE TELESCOPE OR ITS LITTLE FINDERSCOPE! Never leave the telescope unattended and ensure that children are supervised at all times. Viewing the projected image is quite safe, but looking through the telescope will cause almost instant blindness.

Observing programs during transit

Schools in Australia have the opportunity of cooperating with schools in the northern hemisphere in observing the transit. The schools and amateur astronomers at different locations will be trying to duplicate the observations of the past by timing the four contacts that Venus makes with the Sun. It will be fascinating to find out if effects like that of the black drop reported in the 18th century and the various other effects reported in the 19th will occur with modern telescopes. Also by exchanging results from different places it will be possible for students to make their own estimate of the Sun's distance.

One cooperative effort is being coordinated by Arkan Simaan, a physics teacher at a French High School near Paris. Contact him at arkan.simaan@free.fr. Another is by Dr Robert Walsh of the Centre for Astrophysics, University of Central Lancashire, UK. Contact him at rwwalsh@uclan.ac.uk.

More information

http://www.venus-transit.de/
http://sunearth.gsfc.nasa.gov/eclipse/transit/venus0412.html
http://www.melbourneobservatory.com/19thCentury.htm

This information was prepared for the ASA by Nick Lomb of Sydney Observatory (http://www.sydneyobservatory.com.au) and Martin George of Launceston Planetarium (http://www.qvmag.tased.edu.au/planetarium.html). This sheet may be freely copied for wide distribution provided the Australian Astronomy and ASA logos are retained.

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