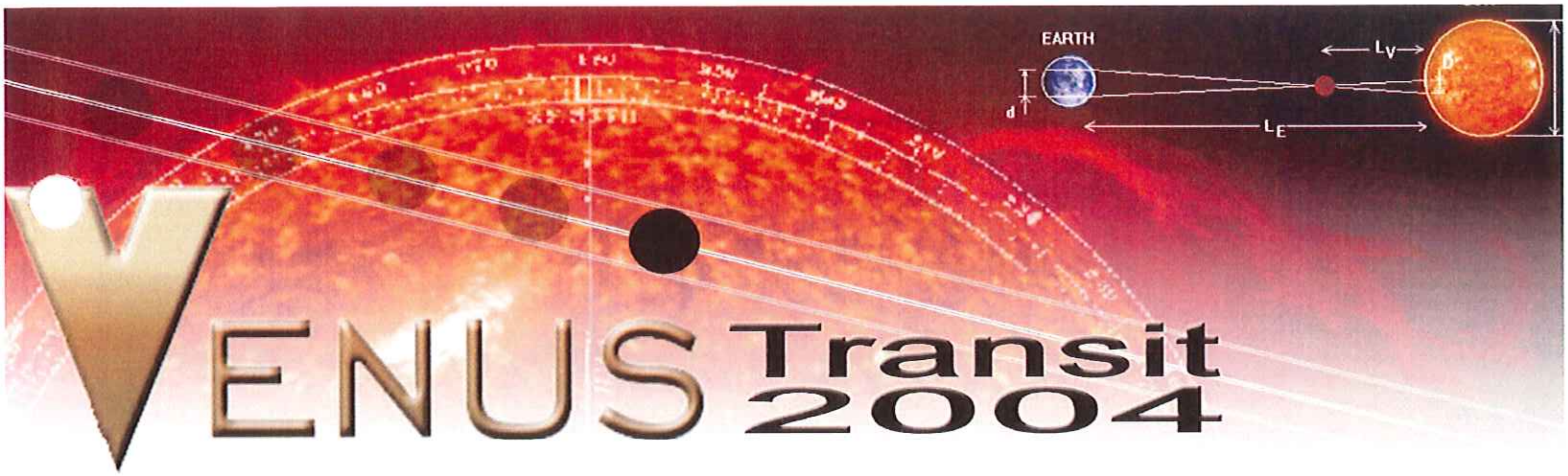


NASA / Astronomical League Transit of Venus Certificate Observing Program

Applied for Certificate 7/5/04

OBSERVATIONAL COMPONANT

1. **Derive the distance to Venus:** The distance to Venus can be derived by measurement of the parallax angle as observed by two observers spaced widely in latitude. To do this, the astronomer shall take observations from widely spaced observatories from the NASA SECEF Venus Transit web site (http://sunearthday.nasa.gov). Basically, the apparent linear separation of two positions of the planet Venus across the disk of the sun is measured and ratioed to the diameter of the sun to get an angular separation, "a" (see figure 1c). Then, knowing the distance between the two Earthly observers/observatories, one can calculate the distance to Venus using the formula: $d = [\, r / \tan(b)]$ where b is the parallax angle (= a/2) and is expressed in degrees, r is half the distance between the two observers, and d is the distance from the Earth to Venus. Each observatory will display a set of images of the transit taken over time. Your job will be to overlay these images and fit a straight line between the centers of each set of Venus images and then to measure the distance between two sets of lines. You can do this either by printing out the images or overlaying them on your computer. Remember to adjust the size of the images so the sun is the same size throughout. Figure 1a shows how each observatory's set of Venus images is slightly displaced. Figure 1b shows a line being fitted to two sets of transit observations. Figure 1c shows the geometry involved in the calculations.

2. **Calculate the A.U.**: Once the distance to Venus is known, you can derive the A.U. through observations of Venus at its greatest elongation from the sun. This is accomplished by constructing a diagram depicting a right triangle with the Earth, Venus, and the Sun at its three end points. At greatest elongation, Venus makes a right angle with the Earth and Sun. For this exercise, you can either wait for Venus to be at greatest elongation and measure the angle yourself or accept the already measured value of about 46 degrees for your calculations. Figure 2 outlines the process of computing the A.U. once the angle of greatest elongation is known.

3. **Calculate Venus' Orbital Period:** In the previous exercise, you derived the distance from Venus to the Sun. Now, use Kepler's 3rd law of planetary motion to derive Venus' orbital period via:

$$P^2 = A^3$$

0.723

Where P = Venus' orbital period (in years) and A = Venus' semi-major axis (in A.U.) which is roughly equivalent to the radius of its orbit. Venus actually has the smallest eccentricity of any planet (e~0.007) so its distance from the sun varies by only about 1 million miles over the course of its year.

4. **Just for fun:** Calculate the mass of the sun via:

$$M_{sun} = (4\pi^2 * A_v^3) / (G * P^2)$$

This equation is just a restating of Kepler's 3rd law of planetary motion, where A_v is the mean distance from the sun to Venus, G is the gravitational constant, and P is Venus' orbital period. Make sure to express your units of time in seconds and distance in centimeters. Your answer will be expressed in grams.

5. **Detect the Venusian atmosphere and the black drop effect:** Using a telescope and solar filter, the astronomer will observe and sketch/photograph the "Halo effect" which occurs both at entrance and exit from the sun's disk. This optical phenomenon, first viewed in 1761, is caused by the scattering of light through the planet's dense atmosphere as was suggested by the Russian astronomer, Lomonosov in that year. The halo should be visible between 1st and 2nd contact and again between 3rd and 4th contact when Venus' disk is partly on and partly off the Sun. One can also view the "Black Drop effect" apparent near 2nd and 3rd contact where the disk of Venus appears to bleed into the solar limb. This effect is due to difficulties in resolving features of high contrast such as a dark Venus silhouette and a bright sun and made accurate timings of the transit next to impossible contributing significantly to error in the Earth-Venus distance calculation. For some reason, perhaps related to the optical quality of the telescope or magnification of the image, the black drop is not always observed. Additionally, since observations in hydrogen alpha light were not available in 1882, the black drop effect has never been observed in H alpha light though it is believed that it will be observable at that frequency.

6. **Time the transit (1st, 2nd, 3rd, and 4th contact):** Using a telescope and a clock standardized to the official U.S. time as specified by NIST, observe each contact (US observers will be able to see only 3rd and 4th contact) and note the time of contact.

OUTREACH COMPONENT

To satisfy the requirements for the outreach component, A.L. members must satisfy item 1, below, and then any one of items two through four.

1. **Register for Sun-Earth Day at http://sunearthday.nasa.gov.**
2. **Participate with school, museum, or community groups:** Give a presentation in a school, museum, or civic group (e.g. Girl and Boy Scouts) on some aspect of the Transit of Venus.
3. **Hold a SUN PARTY:** Sponsor a solar observing event on the day of the transit. Get at least 15 people to actually view the sun with Venus in transit either directly through a telescope or suitable projection device or via the Venus Transit web images or web cast available at http://sunearthday.nasa.gov.
4. **Work with a local school to create and bury a time capsule**. The capsule can be dug up in either 2012 or 2117. GPS coordinates of the capsule must be provided.

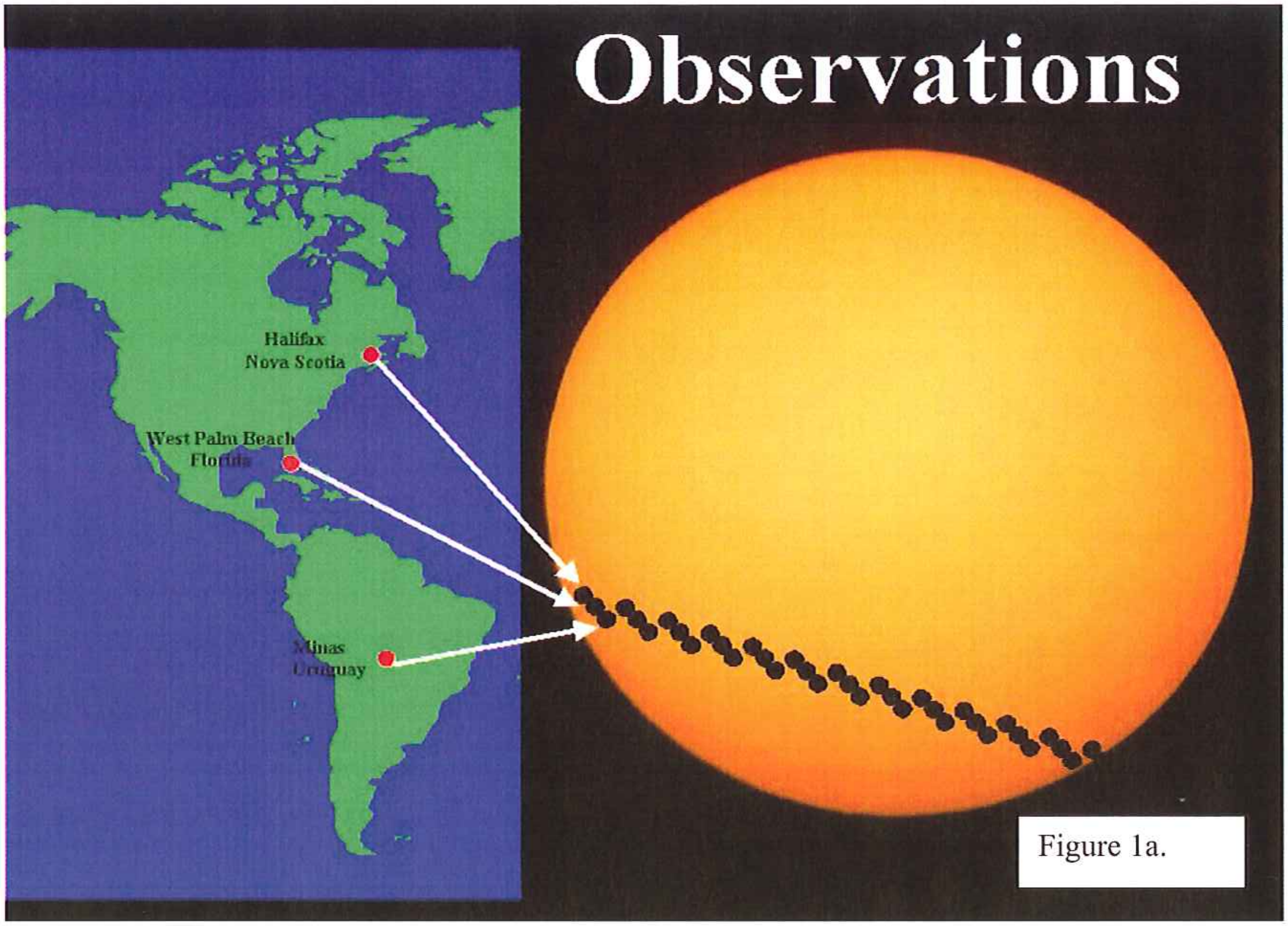


Figure 1a.

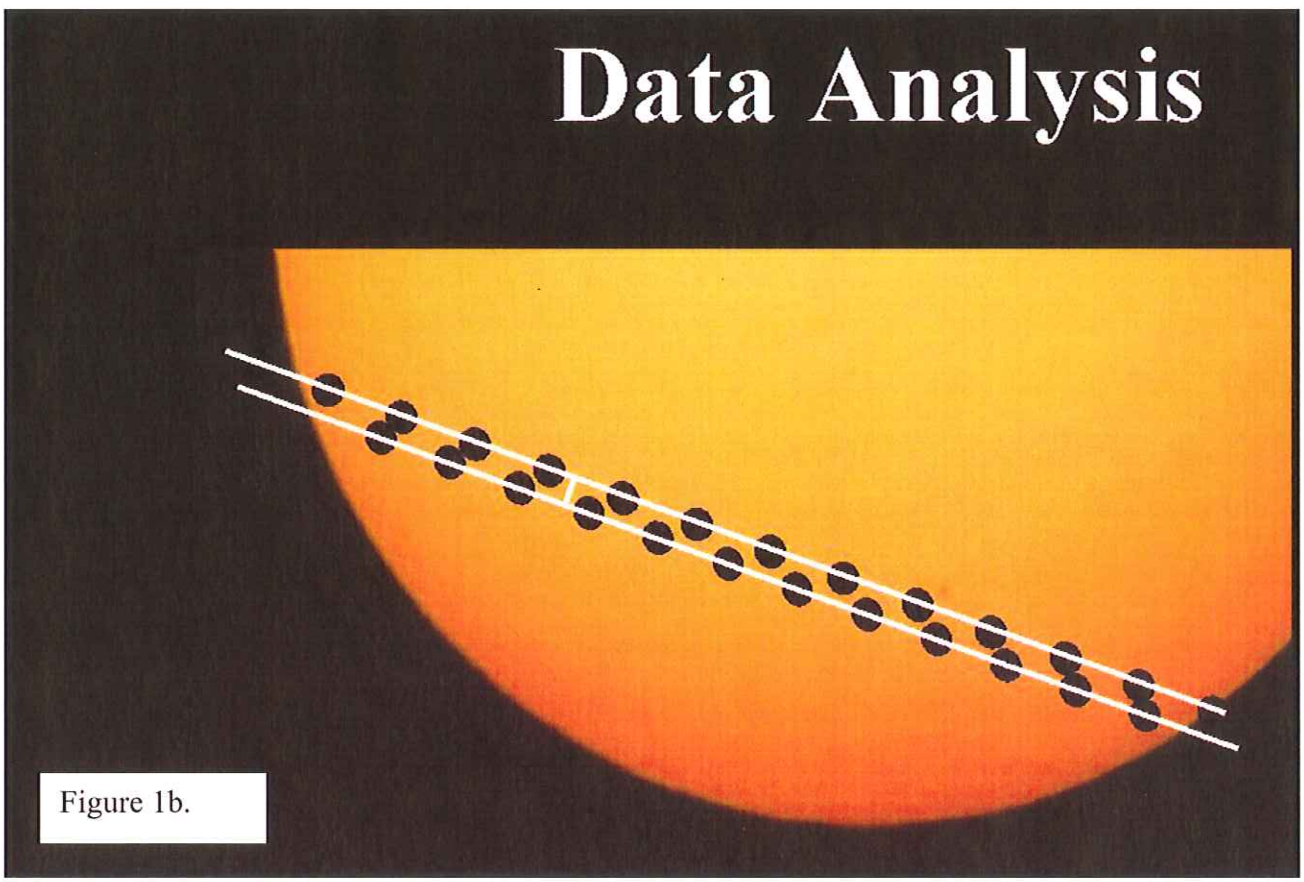
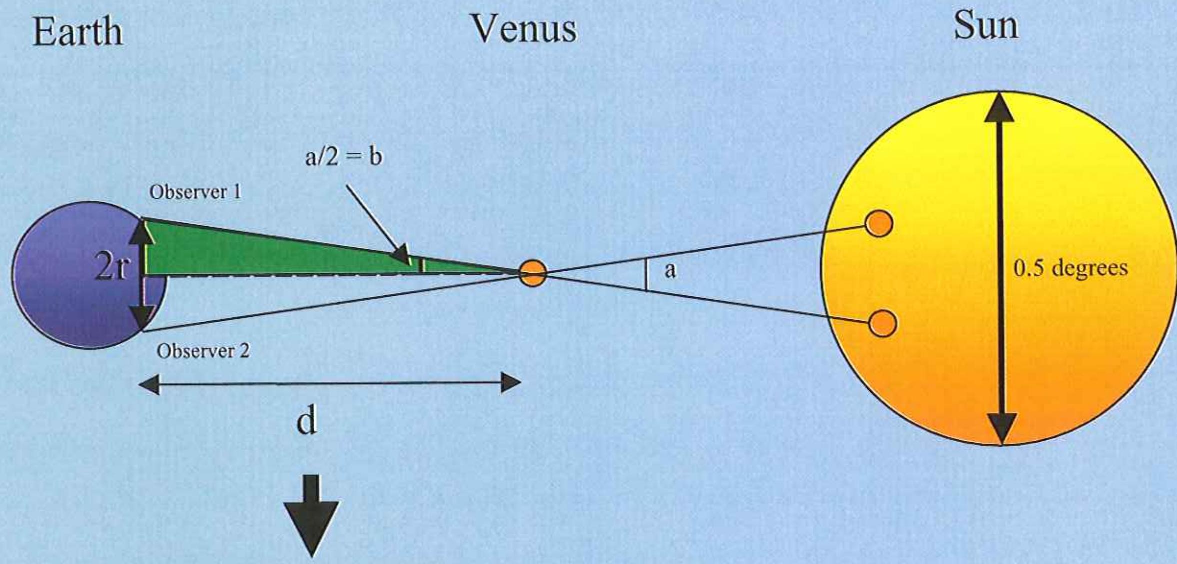


Figure 1b.

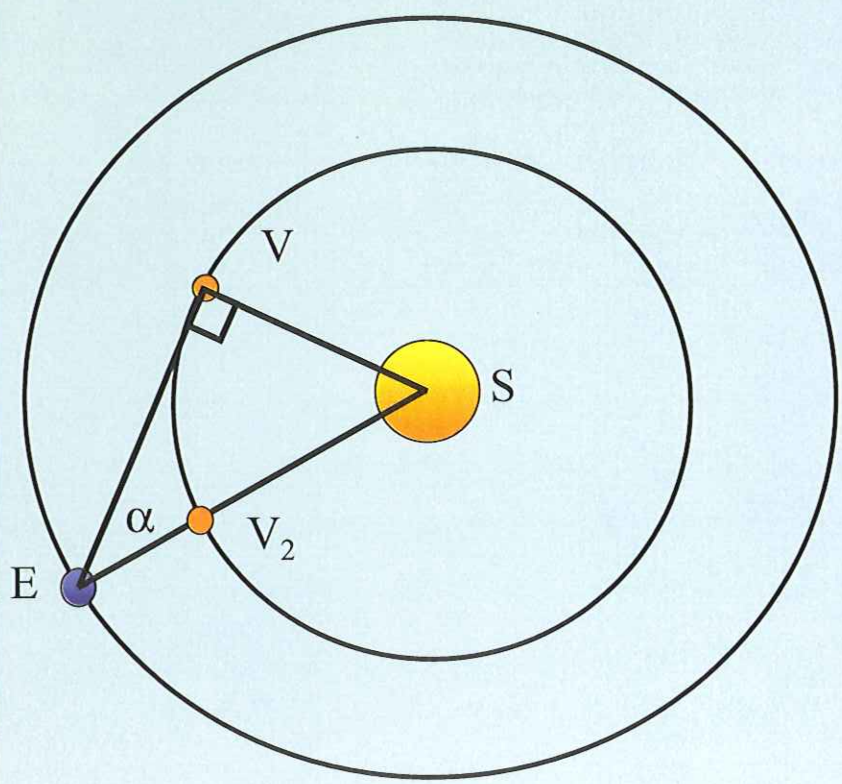
How to calculate the AU
Step 1: Calculate the distance to Venus



$d = r / \tan(b)$

Figure 1c.

How to calculate the AU
Step 2: Venus at Greatest Elongation



$VS / ES = \sin(\alpha)$

(α ~46 deg)

$VS/1\ AU = \sin(\alpha)$

$VS = 0.72\ AU$

so…

$EV_2 = 1 - 0.72\ AU$
$= 0.28\ AU$
$\sim 26M$ miles

$$\frac{0.28AU}{26M} = \frac{1AU}{X}$$

Figure 2.