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.

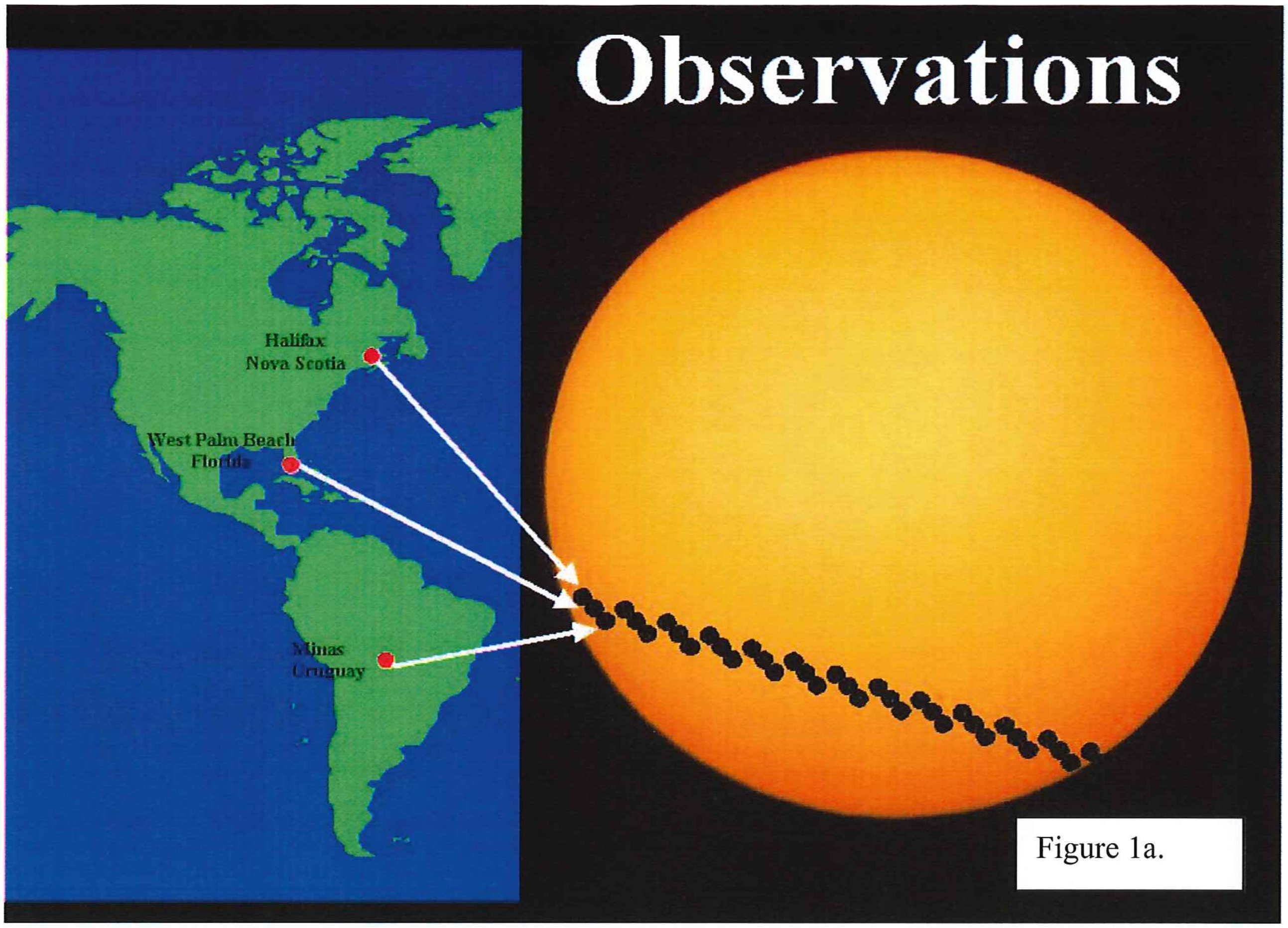


Figure 1a.

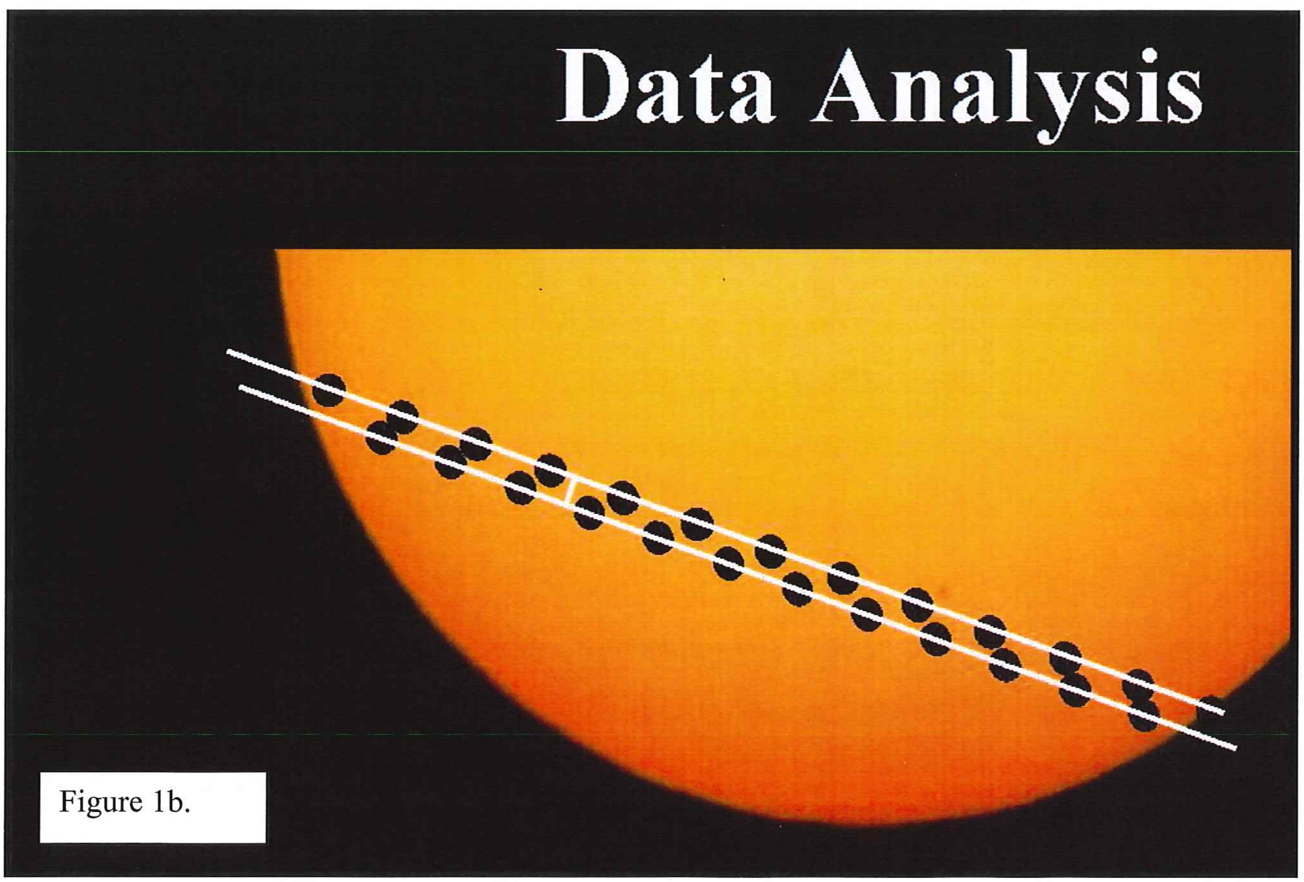
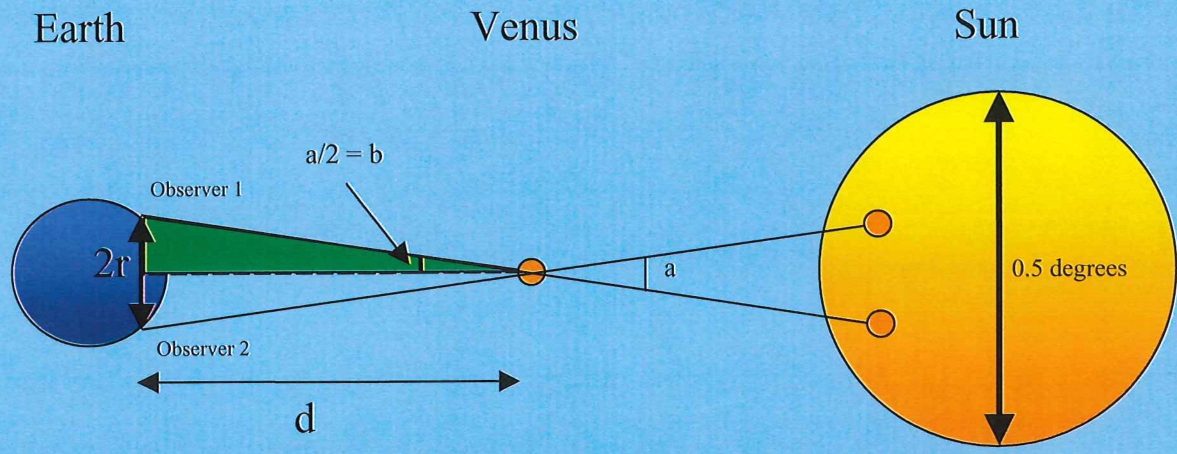


Figure 1b.

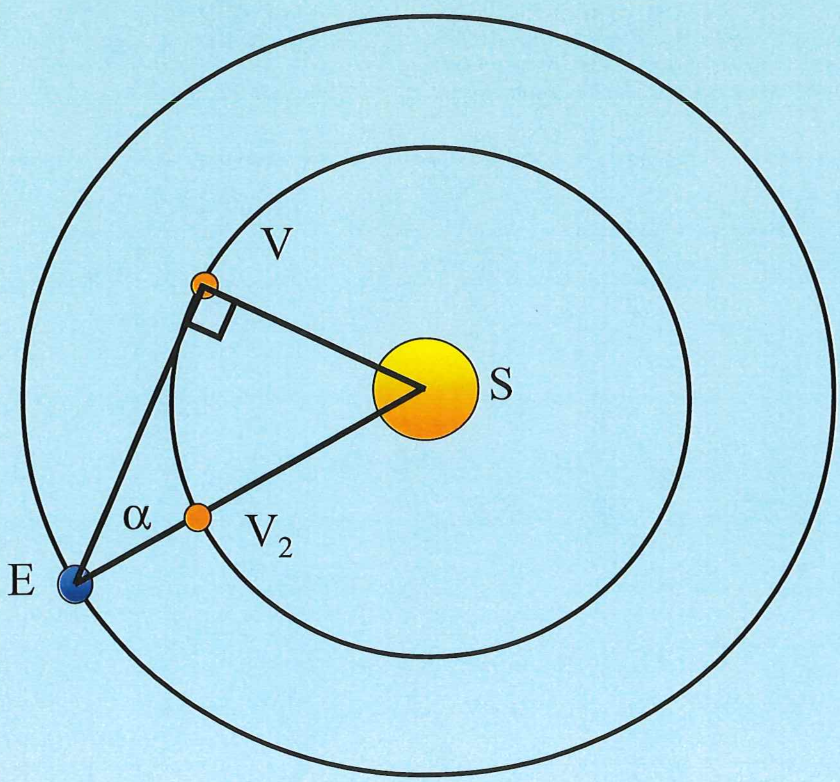
How to calculate the AU
Step 1: Calculate the distance to Venus



$$d = r / \tan(b)$$

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.

July 5, 2004

Dear lmayo@pop600.gsfc.nasa.gov,

I just completed all the calculations and would like to receive the NASA/Astronomical League's Transit of Venus Certificate Observing Program and pin. I found two different versions of the requirements for this program one on the Astronomical League's web site and one on the sunearthday.nasa.gov web site, so I finished all the calculations on both versions of the requirements.

The Astronomical League's requirements.

1) Derive the distance to Venus.

   I used the pictures from Howard University and from Australia to superimpose the two images of Venus and get a distance between them by measuring the distance between the two paths on the photographs made as Venus moved across the Sun. By taking into account the latitudes yielding an angular separation of the two observing sites of 71.326 degrees, and a distance between the two paths of .381 inches, I calculated the distance to Venus as 4.955×10^8 km. This is off by a factor of 10 and I cannot figure out where my error is. But if you take the actual value of $.414 \times 10^8$ km, my magnitude difference has a 17% error. Very close.

2) Derive Venus's orbital velocity at the time of transit.

   From using the Howard University photographs, I calculated an angular velocity of 1.16×10^{-5} degrees/second. Then I used the equation to calculate the orbital velocity and got a value of 30.374 km/sec. The actual value is 35.0 km/sec, which is an error of 13.2% in my value.

3) Detect the Venusian Atmosphere

   I thought I saw this between the 1st and 2nd contact. It was obvious near the limb of the Sun where the silhouette of Venus was eating into the disc of the Sun. Once, I saw a hint of a ring around part of the planet. Thereafter, I only saw a sliver of it on the bottom (top) of where the planet was part way onto the disc of the Sun. On 3rd contact, using a H-alpha filter, I might have seen the black-drop effect, but clouds were obscuring the Sun and it was difficult to see.

   Since then transit event, I have seen photographs on the internet clearly showing the Venusian atmosphere (the halo effect) and the black drop effect.

4) Time the Transit

I watched the transit event live on NASA TV from Athens, Greece and timed the transit using my WWV radio. Here are my contact times:

1st contact = 11:19:54 MDT - June 7th, 2004
2nd contact = 11:38:04 MDT - June 7th 2004
3rd contact = 5:04:07 MDT - June 8th, 2004
4th contact = 5:22:59 MDT - June 8th, 2004

From the certificate requirements on the web site http://sunearthday.nasa.gov,

1) Is the same as #1 from the certificate requirements found on the Astronomical Leagues' web site.

2) Calculate the A.U.

Using the value you supplied for Venus's greatest elongation of 46 degrees, I was able to calculate the value of the AU to be 92.857 x 10^6 miles.

3) Calculate Venus's Orbital Period

Using the equation provided, I calculated a value of P = .6147626 yrs or 224.39 days. The actual value is 224.7 days or less than a 1% error in my value.

4) Calculate the Mass of the Sun

Using values from my astronomy books and the equations provided, I calculated the mass of the Sun to be 1.9892 x 10^{30} kg. Converting a Newton to (km)(m)/sec^2 allowed me to cancel units nicely to be left with only kg.

5) Detect the Venusian atmosphere and black drop effect

Done in previous Astronomical League section #3.

6) Time of Transit

Done in previous Astronomical League section #4.

I have all my sketches I did during the transit, along with the actual calculations I did. I can FAX them to you if you need to see my work. Just send me a FAX number and I will send them to you.

As for Part 2 of the requirements,

1) I registered with the Sun-Earth Day event on April 12, 2004.
2) I gave a Friday night seminar (April 16, 2004) at the Little Thompson Observatory (www.starkids.org) to the people who attended this event about the upcoming Venus Transit event. There were 30 people in attendance, 18 of which were girls. I am also a JPL Solar System Ambassador, so I gave a discussion of the telecom we received about this event and also discussed how people might incorporate an early June vacation to the east coast to watch this event. I also identified several locations along the eastern seaboard that were hosting events on the morning of June 8th. I discussed my plans to see the Venus Transit event from Iowa City, IA (which was cloudy the entire transit). I can email you my power point presentation I gave the folks if you would like to see what I discussed. I also discussed safe sun observing techniques. The entire presentation took almost an hour.

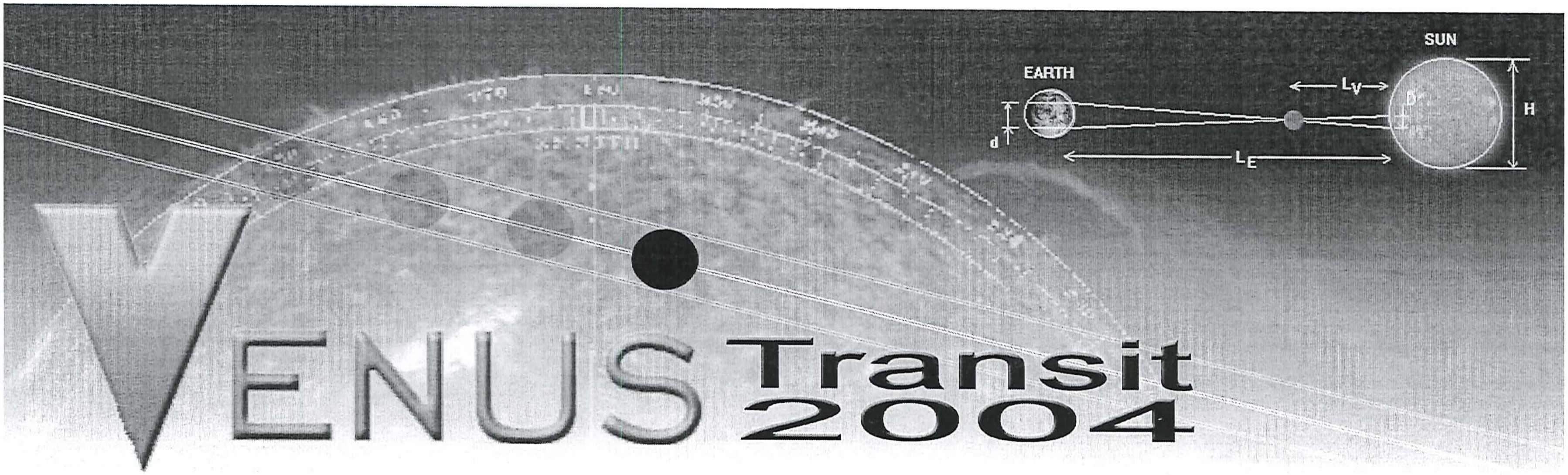
I am a member of the Longmont Astronomical Society, a member society of the Astronomical League. Please print my name on the certificate as Michael Hotka. You can mail my certificate and pin to:

Michael Hotka
1425 Snowberry Lane
Broomfield, CO 80020

Thank you for providing a program to recognize my participation in the Venus Transit event. I enjoyed doing the calculation as those astronomers did back in the 1800's. I am anxiously awaiting the 2012 event, for I will be able to see this from my backyard, here in Colorado.

Sincerely,

Michael Hotka



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Information about the Venus Transit Certificate:

- You must be a Astronomical League member to receive this certificate.
- When you have completed all criteria send it to: lmayo@pop600.gsfc.nasa.gov
- For more information about the Venus Transit go to: http://sunearth.gsfc.nasa.gov

Observing the Sun:

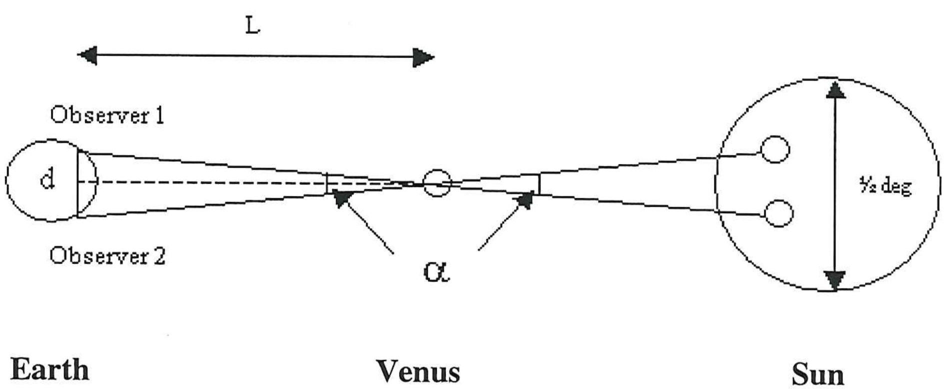
Before you start any solar observing program, make absolutely certain that you have safe filters and a safe set-up.

Only use filters from reputable sources, and never use a "solar filter" that screws into an eyepiece. As Richard Hill states in Observe and Understand the Sun:

"Observing the sun is the only inherently dangerous observing an amateur astronomer can do. Be aware of this at all times and take all necessary precautions. If you do not know a filter or procedure is safe then do not use it! Always err on the side of safety. An eye once damaged is forever damaged. Filters that let too much INFRARED light through can burn an eye if used visually. There is NO PAIN when this happens. Burned retinas can not be repaired. Excessive ULTRAVIOLET light has been shown to cause cataracts. So be very careful."

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 SECEF Venus Transit web site (http://sunearth.gsfc.nasa.gov). Basically, the linear separation of two paths of the planet across the sun is measured and ratioed to the diameter of the sun to get an angular separation, Alpha. Then, knowing the distance between the two observers/observatories, one can calculate the distance to Venus using the small angle formula: $L = [(d/2) / \tan(\alpha/2)] \sim d / (\alpha/2)$, where alpha is expressed in radians and $\alpha/2$ is the angle of parallax..



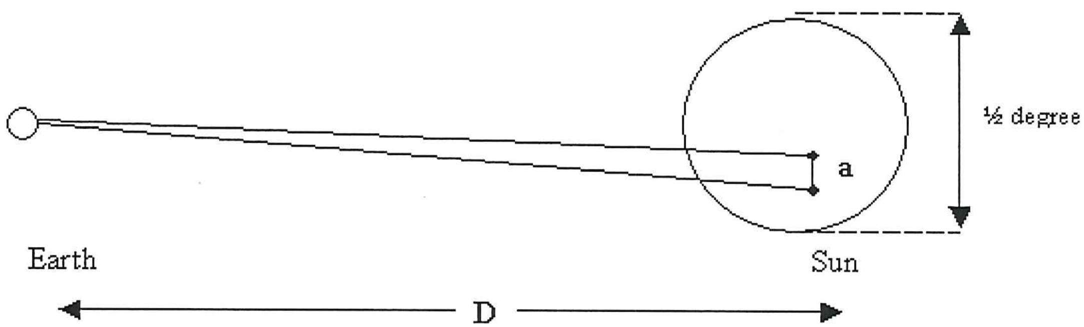
2. Derive Venus' orbital velocity at the time of transit: Once the distance to Venus is known, its orbital velocity can be estimated by first calculating an angular velocity and then using the small angle formula above. Using a telescope, estimate the angular movement of Venus across the sun over a given time period. The transit lasts about six hours in its entirety but East Coast observers will have less than two hours to view the transit after sunrise. If your own observations are not possible, refer to the sunearth.gsfc.nasa.gov web site and derive an angular motion from two different images spaced in time from the same observatory using the sun's angular diameter as a reference.

Angular Displacement = $a = (x_2 - x_1) * \Omega_{sun} = \Delta x * \Omega_{sun}$; where Ω_{sun} = angular diameter of the sun ~ 0.5 degrees or 0.0087 radians and Δx is the length of a line between two observations of Venus spaced in time, expressed as a percentage of the diameter of the solar disk.

** (then Angular Velocity = $\omega = a / (t_2 - t_1) = a / \Delta t$)

To calculate orbital velocity, use the following formula:

Orbital Velocity = $v = [(D * \tan(a)] / \Delta t$; where D = 1 A.U.



Just for fun: Calculate the mass of the sun via:

$M_{sun} = (4\pi^2 * A_v^3) / (G * P^2)$ 1.9891 x10^30 kg

Where Av is the mean distance from the sun to Venus, G is the gravitational constant, and P is Venus' orbital period. Make sure to use similar units of time and distance.

3. Detect the Venusian atmosphere: 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. One can also view the "Black Drop effect" apparent near 2nd and third 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.

Saw this between 1st & 2nd contact. Obvious near limb of Sun. Once, saw a hint of ring around planet, thereafter, just prominent on lower side of planet. On 3rd contact, well, just before, saw in Hα what might be black drop effect. Clouds in front of Sun obscured the effect but it started to happen for just an instant, then 3rd contact occured.

✓4. 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.

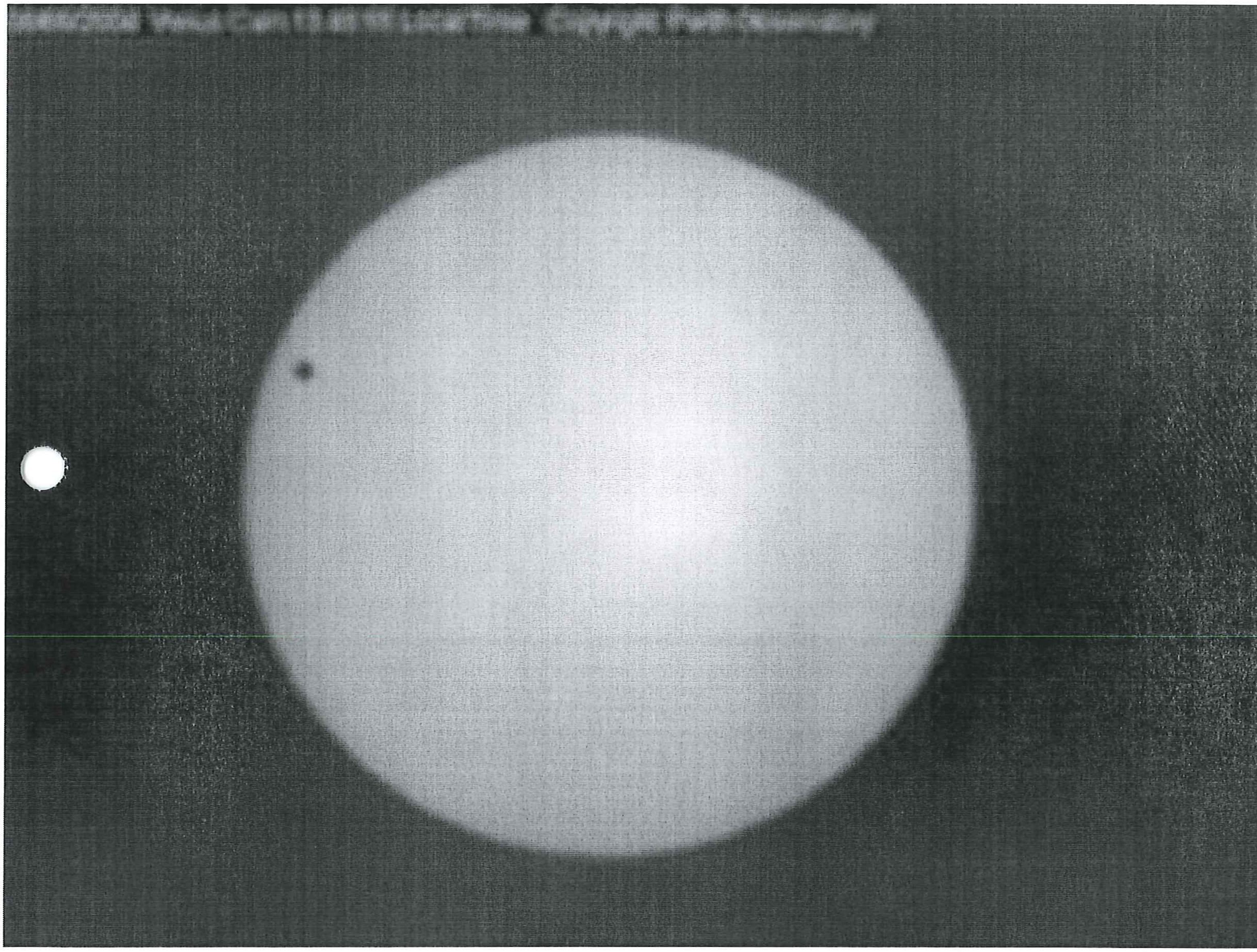
OUTREACH COMPONENT

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

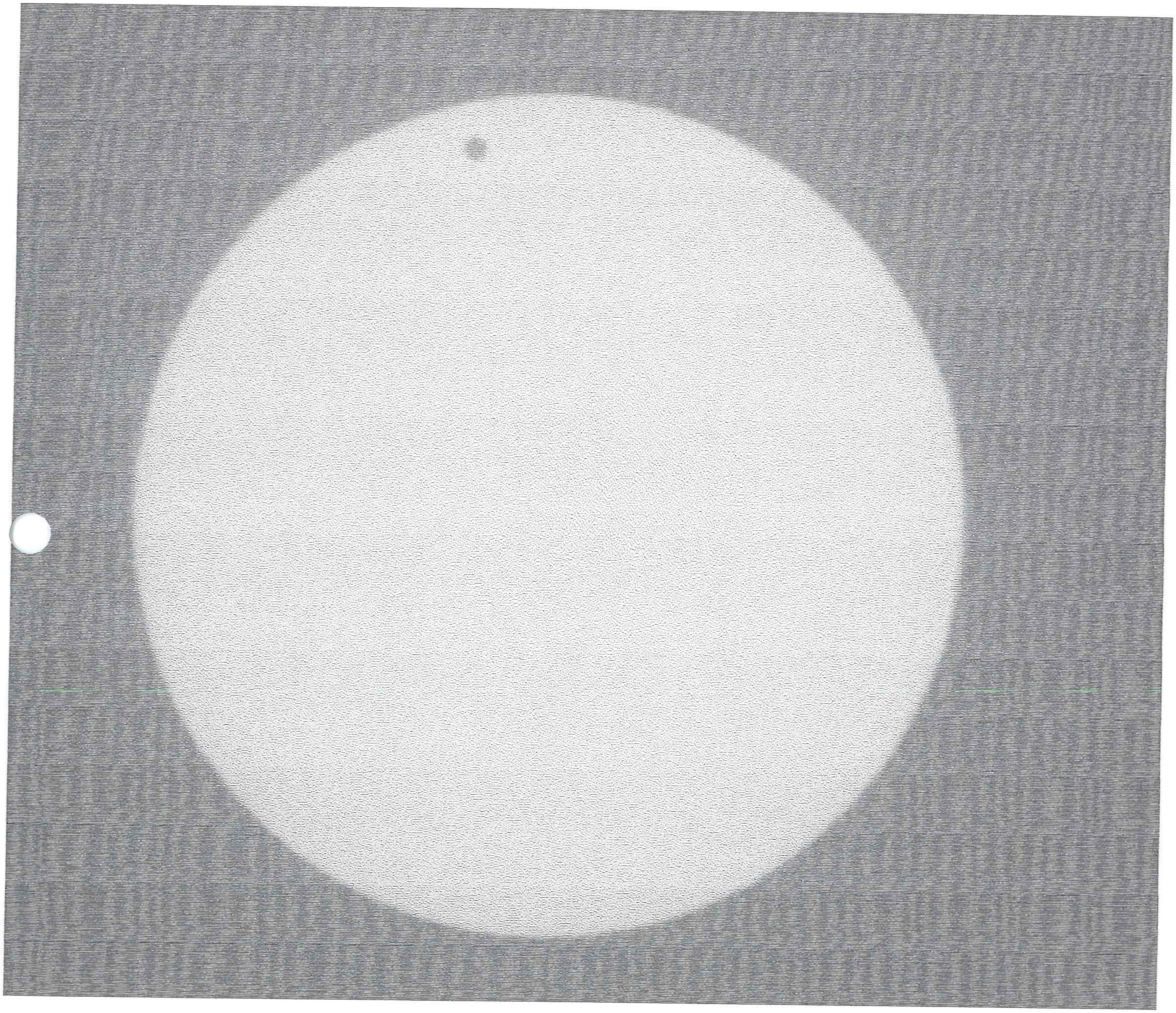
✓1. Register for Sun-Earth Day Registered 4/12/04
✓2. Participate with school, museum, or community groups: Give a presentation in a school, museum, or civic group (e.g. Girl and Boy Scouts) on some aspect of the Transit of Venus. Presentation 4/16/04 @ LTO 30 people - 18 girls
3. Hold a SUN PARTY: Sponsor a solar observing event on the day of the transit. Get at least 25 people to actually view the sun with Venus in transit either directly through a telescope or via the Venus Transit web images or web cast (http://sunearth.gsfc.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.

To see a Microsoft Word version of this document, click here

Australia



Howard University



Howard University