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Don’t Miss the Transit of Venus in 2012: It’s Your Last Chance Until 2117

by Chuck Bueter (www.transitofvenus.org)

The Travails of Le Gentil

Imagine your country is sending you on a quest to resolve one of the era’s biggest questions in science. At this moment in history, the solution, the technology, and the alignment of planets have come together. For your part of the mission, all you have to do is record the instant when the edge of one small circle touches the edge of a second larger circle.

Such were the fortunate circumstances of Guilliame Hyacinthe Jean Baptiste Le Gentil. The French astronomer eagerly set sail for India to witness the 1761 transit of Venus, a rare celestial alignment in which the silhouette of Venus appears to pass directly across the sun. A fleet of astronomers spread out across the globe in response to Edmund Halley’s call to time the event from diverse locations, from which the distance to the sun—the highly valuable Astronomical Unit—could be mathematically derived.

Upon Le Gentil’s arrival, the intended destination was occupied by hostile English troops, so his ship turned back to sea, where he could not effectively use a telescope. He missed the 1761 transit of Venus. Committed to (or obsessed by) his task, LeGentil hung around the Indian Ocean for eight years awaiting the next transit of Venus. He returned to India to view the 1769 transit of Venus, but on the morning of the transit a “fatal cloud” momentarily brought brief yet harsh weather to the normally placid region, and he missed it again! Le Gentil was numb with dejection.

Centuries of Intrigue

Transits of Venus occur in pairs eight years apart, with a span of more than a century between each pair. The telescope was in its infancy for the pair of transits prior to Le Gentil’s effort. In the early years of the 17th century,

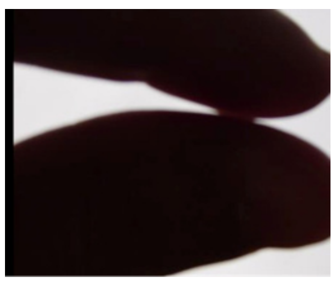
Expeditions were sent around the world to observe the transit of Venus.
Image courtesy of Chuck Bueter

Johannes Kepler showed the relationship between a planet’s orbital period and its distance from the sun. Kepler then derived tables of unprecedented accuracy that predicted the motions of the planets, including transits of Venus in 1631 and 1639. Poring over one such table, the young English astronomer Jeremiah Horrocks caught one of Kepler’s mistakes within weeks of the 1639 transit of Venus and mathematically predicted its imminent appearance. Horrocks projected an image of the 1639 transit of Venus and noted the planet’s size and path—the first time in recorded history.

What surprised Horrocks’ contemporaries most—and equally surprised many observers during the 2004 transit of Venus—was how small Venus appeared relative to the sun. Rather than being a disappointment, though, this size discrepancy should be recognized as a stunning visual comparison. A planet the size of Earth, Venus' diminutive profile highlights the immensity of the distant Sun, which could hold the volume of a million earths!

Mathematics again served science well when Edmond Halley announced one could quantify the distance to the Sun—and hence the true distance to each of the planets using Kepler's laws—merely by having observers from widely separated locations time the duration of the transit of Venus, which Halley would not live to see. For Venus to slice across the Sun takes about 6 hours, and observers needed to time that event to the second.

For the 1761 and 1769 pair of transits, nations mounted global expeditions, most famously James Cook's first major voyage to the Pacific, where Cook himself timed the 1769 apparition from Tahiti. Other 18th century expeditions demonstrated incredible commitment by globetrotting astronomers (like Le Gentil), who faced shipwreck, war, disease, angry mobs, isolation, and inclement weather in the first major international science collaboration. At stake in knowing the Sun's true distance included the opportunity for navigational supremacy—a great benefit for maritime commerce.



Demonstrating the black drop effect. Image courtesy of Chuck Bueter

Unfortunately, the limitations of the telescopes and other factors gave rise to a hindrance called the "black drop effect." When the edge of Venus appears just about to touch the inside edge of the Sun, an annoying ligament suddenly appears between the well-defined edges. This distortion confounded the accurate timing of the transit by a few seconds, and Halley's vision of accuracy plummeted. The effect can be simulated by holding your nearly-pinched thumb and index finger together in front of a bright light. Before they touch, a dark meniscus seemingly joins the two digits.

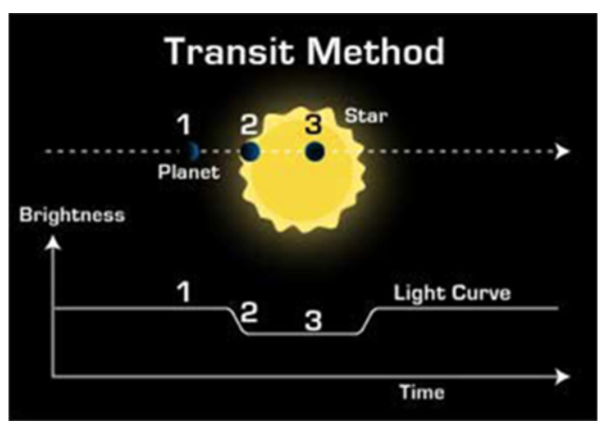
When the 19th century pair of transits rolled around, astronomers hoped the new tools of photography could help them to discern the exact instant of internal contact, which had been plagued previously by the black drop effect. Jules Janssen developed a "photographic revolver," a precursor to motion picture cameras, which captured a series of images near the critical moment. Again, ambitious expeditions set out to far-flung locales to await and to time the duration of the 1874 and 1882 transits of Venus. Alas, photography proved to have its limitations as well, and the accuracy in practice was again not what Halley had suggested was achievable.

Getting ready to observe the transit of Venus during a US Naval Observatory expedition in the 19th century. Image credit: USNO

In ensuing decades, developments like radar helped astronomers refine the true distance to Venus, and the transit method became a historical artifact. Nonetheless, the 2004 transit of Venus piqued the world's curiosity, and for the first time spacecraft could peer at the celestial phenomenon with unprecedented clarity. So many people were intrigued that Google's *Zeitgeist* feature deemed the Venus Transit to be the world's #1 Most Popular Event for the entire month of June 2004.

The Future of Transits

While transits of Venus were historically significant, today the spectacle illustrates how astronomers seek to answer one of the biggest questions in modern science: Are there distant worlds capable of sustaining life? A transit of Venus illustrates the method by which astronomers are now searching for planets in the "habitable zone" around distant stars. Here on earth we have a front row seat to a planetary transit on June 5–6, 2012. As we watch the planet Venus



If a planet passes directly between a star and an observer's line of sight, it blocks out a tiny portion of the star's light, thus reducing its apparent brightness. Image credit: NASA/JPL pass across the face of the Sun, the Sun's total brightness dips by a fraction of a percent. The decrease is not perceptible to the human eye, but it is certainly measurable by sensitive instruments. NASA's Kepler mission is looking at over 150,000 distant stars simultaneously to detect periodic yet discrete dips in stellar brightness, which hint at the presence of companion planets transiting their host stars. Early results from the Kepler mission suggest there may be over 50 billion planets in the Milky Way, of which 500 million would reside in the so-called habitable zone. A new quest using the transit method has just begun.

The 2012 Transit of Venus

The last transit of Venus in our lifetimes occurs June 5-6, 2012, with the date and time dependent on your location. For North American viewers, it begins shortly after 6:00 p.m. Eastern Daylight Time and continues through sunset. You can safely witness this rare sight only if you take proper steps to protect your eyes, for you will be looking at the Sun.

Location	Transit Begins	Sunset
Washington D.C.	6:03 p.m. EDT	8:26 p.m. EDT
Chicago	5:04 p.m. CDT	8:17 p.m. CDT
Denver	4:05 p.m. MDT	8:20 p.m. MDT
San Francisco	3:06 p.m. PDT	8:24 p.m. PDT
Honolulu	12:10 p.m. HST *	7:08 p.m. HST

*Note: Hawaii sees both the beginning and the end of the 2012 transit of Venus, with final contact around 6:44 p.m. HST.

How to Participate in 2012

With some preparation, you can safely witness the 2012 transit of Venus yourself. Popular "eclipse shades" are useful, but because the one-arc minute diameter of Venus is near the limit of the human eye's capability, the best views will be filtered and magnified. Experienced observers can use solar filters over the large, front end of their telescopes, or project an image onto a surface. A rear screen projection is a favored viewing technique, allowing a group of people to gather around the projected image while enclosing the path of the Sun's rays. Be safe, but seize the opportunity.

Unlike Le Gentil, a fatal cloud should not doom you. The beleaguered astronomer would have marveled at the capacity of our population to rally around his longtime objective, regardless of weather. If inclement weather occurs, or if you are in the zone where the transit is not visible, you can watch webcasts of the 2012 transit of Venus broadcast live from atop the Big Island of Hawaii. The NASA Edge team will feature transit of Venus programming and expert commentary throughout the 2012 event.

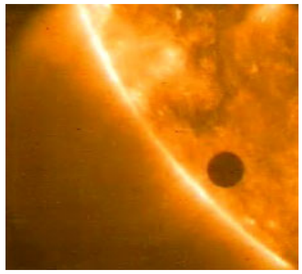
Timing the transit of Venus with the Transit of Venus phone app. Image courtesy of Steven van Roode

In a new twist of technological invention, the Transit of Venus phone app will likely allow observers to push a phone button at the perceived moment of internal contact, which sends the observer's location and recorded time to a common database. Will the modern public with digital riches do any better timing a transit of Venus than centuries of skilled predecessors?

The 2012 transit of Venus is also an opportunity to celebrate the Sun and marvel at its magnificence. During the preceding several years the Sun has been at a low point in its 11-year cycle of activity. However, as it rises from the depth of visual dullness, you will likely be able to see through filtered telescopes some emerging solar features like sunspots. Whereas fleets of nations once carried hopeful astronomers to distant lands to observe Venus transiting the Sun, today a fleet of spacecraft observe the intricacies of the Sun itself. The Solar Dynamic Observatory, for example, peers at the Sun with unprecedented clarity, while the STEREO pair of spacecraft maintain a vigil of all sides of the evolving Sun. As humans grow more dependent on technology, we also grow more vulnerable to the

Safe viewing of the transit is essential. Images courtesy of Chuck Bueter vagaries of solar weather.

As the 2012 transit of Venus concludes, envision how the 2117 and 2125 pair of transits might differ from our seemingly modern events. What new inventions or unforeseeable changes in world culture will transform the 22nd century experience? We will have to wait 105 ½ years to find out, which is more incentive not to miss this last transit of Venus in our lifetimes.



Venus Transit seen by NASA's Sun-observing TRACE spacecraft. More images and movies. Credit: NASA/LMSAL

Because the orbit of Venus is inclined to the Earth's orbit, at inferior conjunction Venus usually appears a little above or below the Sun. Transits occur only when the Sun-Venus-Earth alignment occurs at the orbital nodes. The next eight-year pair of transits occurs in December 2117 and 2125.

To demonstrate this in the classroom, check out this simple paper plate activity.

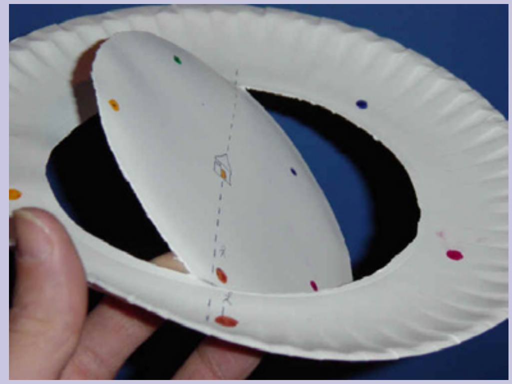
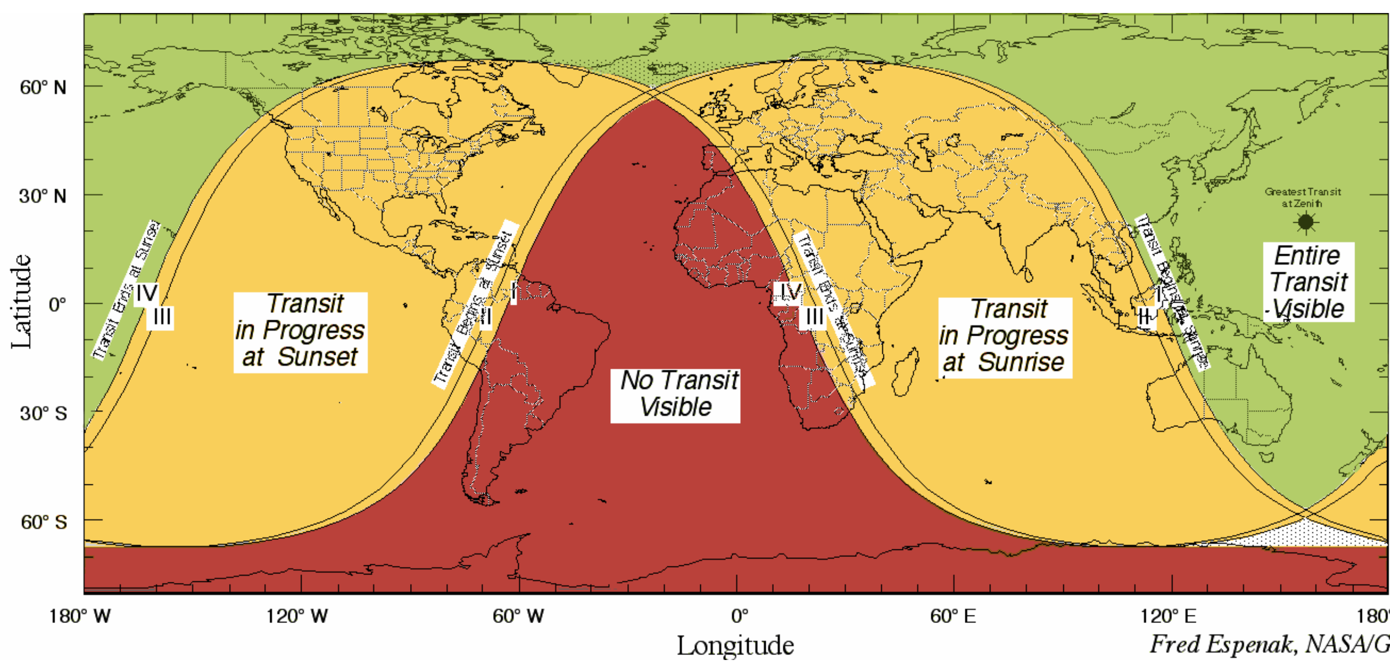


Image courtesy of Chuck Bueter

Transits of Mercury are much more common, occurring 13-14 times per century, mostly due to its more rapid orbit closer to the Sun. The next transit of Mercury will occur on May 9, 2016.



Fred Espenak, NASA/GSFC

Classroom Activities

Featured Activities:

Activity: Transit Frequency

An activity using paper plates to model the periodicity of transits of Venus:
http://analyzer.depaul.edu/paperplate/Transit%20of%20Venus/transit_frequency.htm

Activity: Transit of Venus Plot

Students plot the path of Venus on a paper plate as the planet's disk moves across the face of the sun:
http://analyzer.depaul.edu/paperplate/Transit%20of%20Venus/activity.htm

Other Activities:

Paper Plate Observation from the Smithsonian Institution Libraries: Students simulate the documentation of the Transit using paper plates and marking the path of the transit. This and other exercises and lesson plans were designed to accompany and enrich the study and discussion of the June 2004 Transit of Venus.
http://www.sil.si.edu/exhibitions/chasing-venus/teachers/lessonplan5.htm

Build a Sun Funnel for Group Viewing of Sunspots and the Transit of Venus
http://cdn.transitofvenus.org/docs/Build_a_Sun_Funnel.pdf

Activities from NASA's Kepler Mission, including the use of the transit method to detect exoplanets.
http://kepler.nasa.gov/education/activities/

Resources

Websites devoted to the Transit of Venus

Transit of Venus website featuring safe viewing techniques; teacher resources in a variety of areas including the arts, music, science, and math; videos and new media; history of transits; and many links to additional transit of Venus resources.
http://www.transitofvenus.org/

The Transit of Venus Project has periodically fresh content in its blog; coordinates the global experiment to measure the Astronomical Unit through the Transit of Venus phone app; calculates transit times for your location; addresses phenomena like the black drop effect and the aureole; and features transit of Venus history.
http://transitofvenus.nl/wp/

Transit Math from Sten Odenwald at NASA Goddard Space Flight Center. This large resource includes background information on transits, eclipses and occultations; problems and activities to provide connections and applications of math and geometry to astronomical phenomena; and many images and diagrams explaining the history and science behind the observations.
http://spacemath.gsfc.nasa.gov/SED12/TransitMathV2.pdf

A Transit of Venus workbook from Steven van Roode. This workbook contains classroom activities that demonstrate the mathematics of transits, including how to use a transit to determine the distance to the Sun, and thus the size of the solar system. Also included are problems using light curves such as those measured by the Kepler mission to find the size of extrasolar planets and the distance from their parent star.
http://www.transitofvenus.nl/files/TransitOfVenus.pdf

Downloadable software from Project CLEA for modeling transits of Venus and Mercury in the classroom. Students can use imagery of past transits to measure the Astronomical Unit.
http://www3.gettysburg.edu/~marschal/clea/Transitlab.html

An international resource for the 2004 transit of Venus, including information on the Venus Express mission, and classroom activities for finding the Earth-Sun distance. A featured link goes to an article by Robin Catchpole on the link between a Venus transit and the measurement of the Astronomical Unit.
http://www.venus2004.org/en/

The NASA Transit of Venus site
http://eclipse.gsfc.nasa.gov/transit/venus0412.html

Sun-Earth Day 2012 will have coverage of the transit and other resources for educators. For more information go to the Sun-Earth Day homepage:
http://sunearthday.nasa.gov

The theme for Sun-Earth Day 2012 is Shadows of the Sun
http://sunearthday.nasa.gov/2012/about/about.php

The 2004 theme was Venus Transit 2004
http://sunearth.gsfc.nasa.gov/sunearthday/2004/index_vthome.htm

A nice article on NASA Science News on James Cook and the transit of Venus
http://science.nasa.gov/science-news/science-at-nasa/2004/28may_cook/

YouTube video on the transit of Venus
http://www.youtube.com/watch?v=p1aAG2TUNY0

Observing the Sun Safely

Safely observing the transit of Venus from the NASA Sun-Earth Day website:
http://sunearthday.nasa.gov/2012/transit/viewing.php

Information and links on safe solar viewing, and a six-minute movie for kids, *Meet Your Star: Viewing the Sun Safely*
http://cse.ssl.berkeley.edu/cms/LearningResources/ViewingtheSunSafely/tabid/269/Default.aspx

Information from the NASA Eclipse website:
http://eclipse.gsfc.nasa.gov/SEhelp/safety.html

Safe Sun Viewing from Science@NASA and Spaceweather.com, including how to use binoculars to project an image of the Sun for groups.
http://www.spaceweather.com/sunspots/doityourself.html

The Black Drop Effect

The black drop effect occurs when Venus appears to "connect" to the edge of the Sun before actually reaching the edge. You can model the black drop effect by slowly pinching your index finger and thumb together. Your fingers seem to meet even before they touch. This optical phenomenon was originally thought to provide proof of Venus having an atmosphere. For an explanation of the black drop effect, check out the following links:

http://www.transitofvenus.org/history/black-drop

http://www.transitofvenus.nl/blackdrop.html

A YouTube video of modeling the black drop effect with your fingers:
http://www.youtube.com/watch?v=gm_kZd_wGkE

An online simulation of the black drop effect:
http://home.comcast.net/~erniew/astro/bd.html

The Kepler Mission and use of the transit method in the search for exoplanets

The Kepler Mission homepage:
http://kepler.nasa.gov/

PlanetQuest: Exoplanet Exploration from the Jet Propulsion Laboratory
http://planetquest.jpl.nasa.gov/

A site with animations of the primary techniques used to detect exoplanets
http://rml3.com/a10p/detecting.htm

Modeling a transit detection in the classroom using a LEGO orrery:
http://kepler.nasa.gov/education/ModelsandSimulations/LegoOrrery/
A PDF with details on the construction and use of the LEGO orrery:
http://kepler.nasa.gov/files/mws/LEGOorrery2011.pdf