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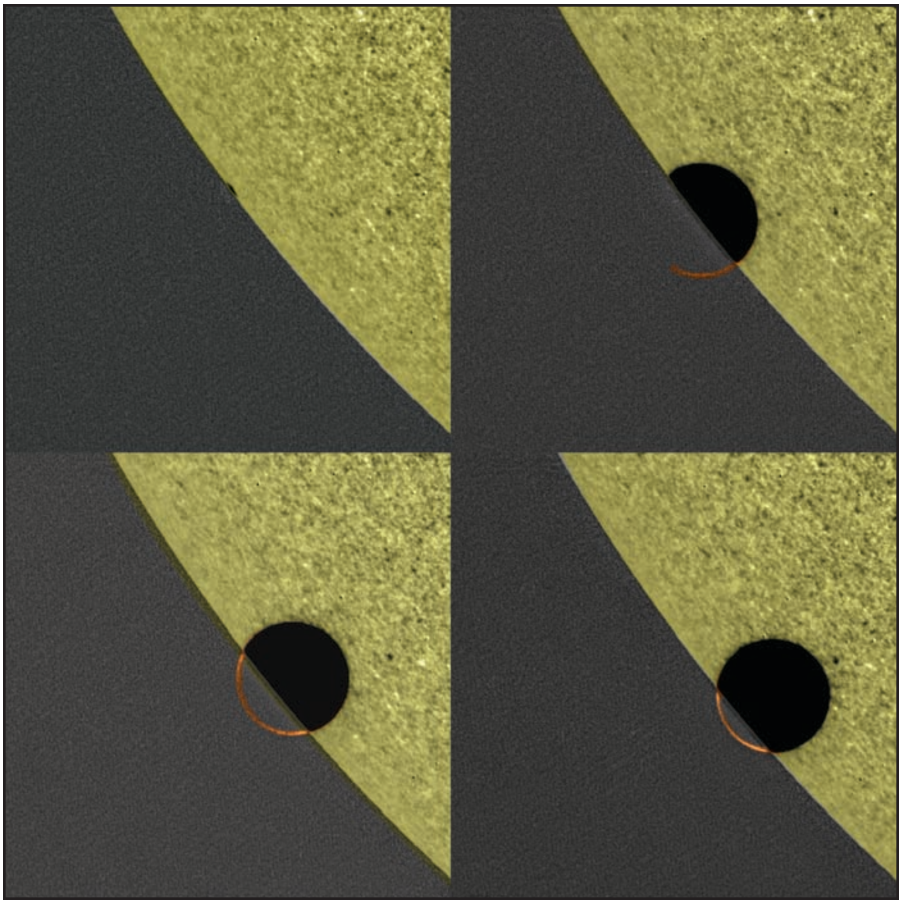
Catch a Pass!
(of Venus with the Sun)

by Jay M. Pasachoff



These colorized visible-light views of the 2004 Venus transit are a sample of 20 minutes of images taken by the TRACE spacecraft. Venus's atmosphere has an orange tint; the Sun's surface has a yellow tint.

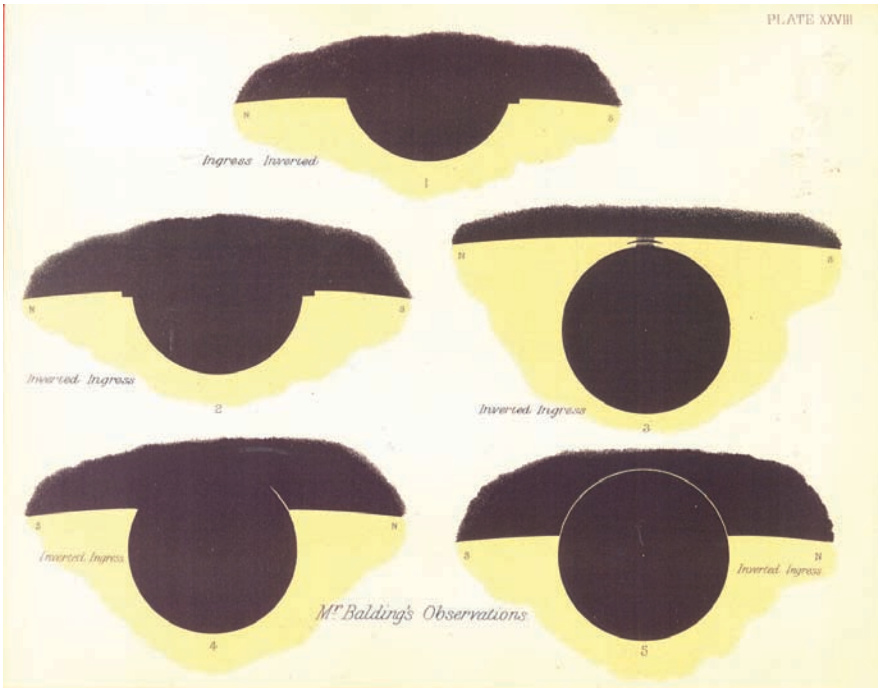
What are you doing on June 5, 2012? That's *just* a year away, so mark the date on your phone's calendar with a reminder. Why? Because a rare, predictable, astronomical event — a transit of Venus between Earth and the Sun — takes place on that day. And it won't happen again for 105 years!

All you need is a special kind of filter to cut down on the Sun's brightness to safely observe this event directly. Or you can use a device to project the Sun onto a wall, where you will see a small disk (Venus) move across the Sun. It will move slowly, taking about six hours to pass from one of the Sun's edges to the other.

Transit History

The story of transits of Venus goes back almost 400 years, to the great German astronomer Johannes Kepler. Kepler figured out that the planets' orbits around the Sun were ellipses, rather than circles. He also was the first to calculate the planets' positions accurately enough that he could predict a transit. But the transit he predicted, in 1631, wasn't visible in Europe, where he lived, and we didn't have telescopes then in California, where it would have been visible. So the important event came and went unobserved.

Soon, however, a young man named Jeremiah Horrocks, though only 20 years old, discovered a way to improve on Kepler's work. He figured out that there would be another transit in 1639, just eight



In these early drawings, the black-dr op effect is shown in the center right image. Venus's atmosphere is the arc above the Sun's edge in the lower-right image.

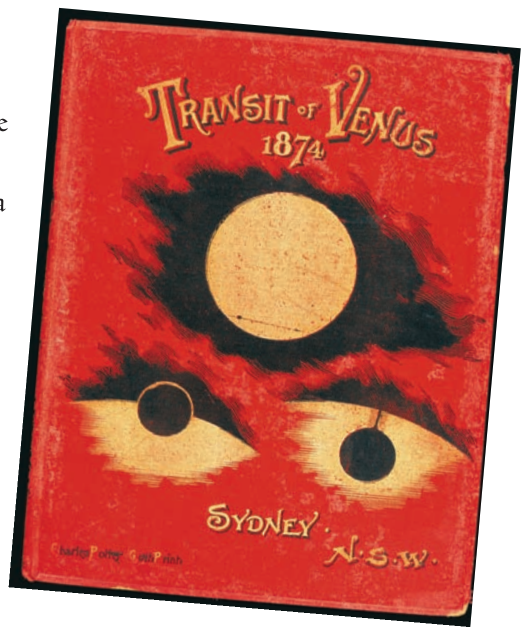
years after the first. (We now know that transits always occur in pairs eight years apart.) Only he and one friend saw that transit; they were surprised and amazed at how small Venus's black silhouette looked against the Sun's huge surface.

In 1716, Edmond Halley, of comet fame, figured out a way to measure the size of the solar system, something that wasn't yet known. His method used transits of Venus; he had people observe them from different positions around the globe, from far north to far south. If the observers recorded to within about a second of time when Venus entered the Sun's disk and when it left, using geometry they could then figure out how far away Venus and the Sun are from Earth. (Using triangulation, they would measure by what angle Venus appeared to change against the Sun in the background. One side of the triangle would be the known distance between the telescopes on Earth the farthest distance from each other.) The average distance from the Earth to the Sun is known as an *Astronomical Unit*, and this was the best way to determine it. Now we know it is about 93 million miles, but back then they had no way of measuring it. Only with that information could astronomers figure out how big and how far away are Venus and the other planets.

But transits of Venus don't come often. As we now know, transits come in pairs. The two transits in a pair are separated by eight years, followed by a gap of 105 or 122 years before the next pair occurs. That meant astronomers of the 18th century had to wait until 1761 and 1769 to observe the next transits.

On each of those occasions, over 100 expeditions were sent to various points around the world to make observations. The most famous expedition occurred in 1769, when a young lieutenant in the British navy, James Cook, was given a ship to command, which made him captain, and sent with an astronomer to observe a transit from the island of Tahiti in the South Pacific. After they observed the transit, they also explored Australia and New Zealand, simply because they were in the vicinity.

The plans of all the observers, however, were foiled by the *black-drop effect*, an apparent blackness that linked Venus's silhouette to the edge of the Sun and that lasted about a minute, 60 times longer than the one second the observers expected. The blackness pulled, like taffy, until it apparently popped, but by then it was too late for observers to get an accurate time. So the black-drop effect prevented astronomers from learning the scale of the solar system and the true sizes of the planets, as they had hoped and expected. At the transits of 1874 and 1882, they were foiled

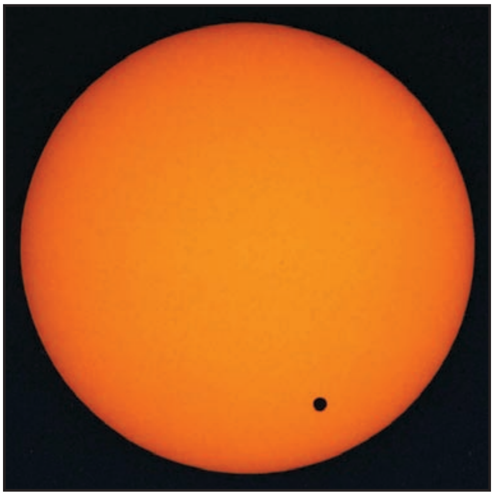


once again by the black-drop effect, even though photography was then available. Eventually, astronomers used a newly discovered asteroid that came near Earth to measure the size of the Astronomical Unit more accurately than they could using transits.

Observing Transits Today

About 10 years ago, I learned from a colleague's lecture that most people thought the black-drop effect was caused by Venus's atmosphere, which is really too thin to create the effect. Even most books and articles gave the incorrect reason. As someone who studies the Sun, I knew that spacecraft had made regular observations of our star, which must have included the 1999 transit of Mercury. So my colleague Glenn Schneider from the University of Arizona and I looked at the images of that transit. We knew that Mercury has no atmosphere and that the spacecraft taking the images was above the Earth's atmosphere. So when we still saw a black-drop effect, we knew that something other than an atmosphere was causing it. We were able to show that it has two causes: the inherent blurriness of the telescope's imaging and the rapid rate at which the Sun darkens in the tiny bit near its edge. The second reason hadn't been carefully considered in the past.

When the 2004 transit of Venus came, nobody on Earth had ever seen such an event. My astronomy students at Williams College and I went to Greece, so we could see the entire transit, including both black-drops, one at the beginning and one at the end. We arranged to use observations from two separate spacecraft, one that took photographs of the event and the other that measures the total amount of sunlight that hits Earth.



Tiny Venus against our star's orb

Our images were from NASA's Transition Region and Coronal Explorer spacecraft (TRACE). They showed the atmosphere of Venus appearing as a thin partial ring when the planet was about halfway onto the disk of the Sun, similarly showing it for a while as Venus exited. At each time, the atmosphere was visible for about 20 minutes out of the six-hour-long transit. Our measurements of the Sun's total brightness showed that it faded by about a tenth of a percent (0.1 percent) when Venus was silhouetted against the Sun. This made sense because Venus's disk is about 0.1 percent the area of the Sun's disk. Since this technique of looking for slight dimming of stars is the way that NASA's Kepler spacecraft has discovered hundreds of planets around other stars, it was interesting to see in detail with transits of Venus just how the method works.

Our successes on the ground and in space for the 2004 transit of Venus have made us eager for the transit of June 5, 2012. Although only part of it will be visible from most of the United States, we hope to observe from Hawaii, where the whole transit will be visible. Other observers will go to Tahiti, where Captain Cook and his astronomer, Charles Green, observed the 1761 Venus transit. We plan to use images from NASA's Solar Dynamics Observatory (SDO) to study Venus's atmosphere once again.

We definitely plan to make good use of the 2012 transit, because after that, the people of Earth will have to wait until the years 2117 and 2125 for the next pair. Let's all take the opportunity on June 5, 2012, to observe the last transit of Venus in the 21st century.

CAUTION: Be sure to observe the transit of Venus safely. You should never look at the Sun without using proper filters. Inexpensive ones (a few dollars) can be purchased from thousandoaksoptical.com or rainbowsymphony.com. You also can use one side of a pair of binoculars or a small telescope to project an image of the Sun onto a piece of paper or a wall. With this projection method, you don't look through the telescope; you face away from the Sun while pointing the telescope's or binocular's main lens or mirror at the Sun. The projected image is safe to look at. **Never look at the Sun through a telescope or binoculars unless they are safely filtered.**