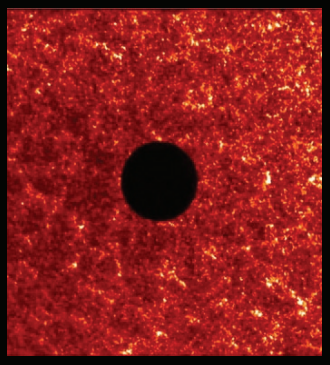
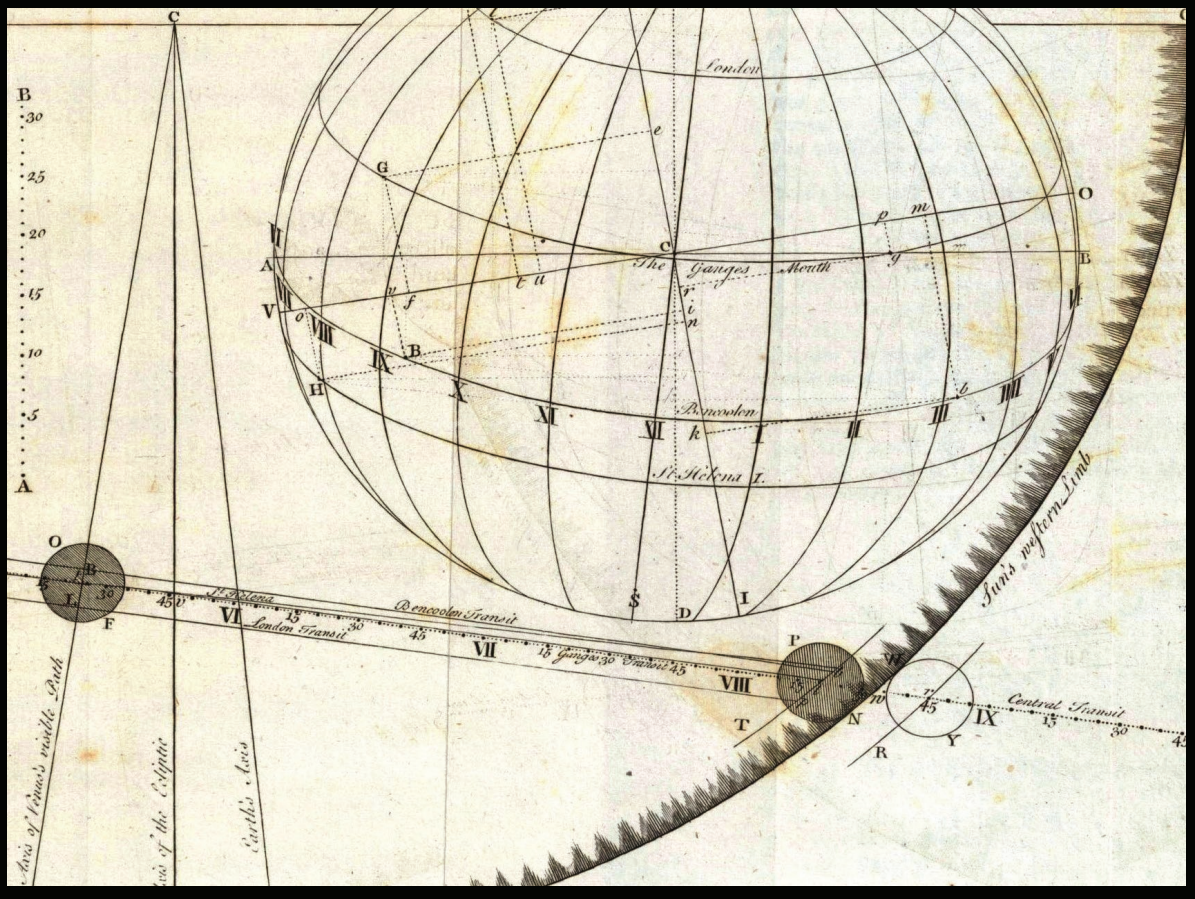
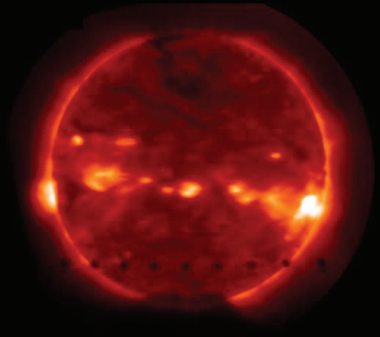
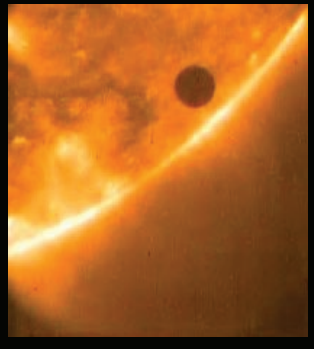
National Aeronautics and Space Administration









Transit of Venus 2012

Top Row – Left image - Photo taken by US Naval Observatory of 1882 transit of Venus. NOAA satellite x-ray image showing the Transit of Venus 2004. Middle image - cover of Harpers Weekly for 1882 showing children watching transit of Venus. Right image – Image from TRACE satellite of Venus, 2004.

Middle - Geometric sketches of the Transit of Venus by James Ferguson on June 6, 1761 showing the shift in the transit chords depending on the observer's location on Earth. The parallax angle is related to the distance between Earth and Venus.

Bottom – Left image **-** NOAA satellite x-ray image showing the Transit of Venus 2004. Middle image – An observer of the 2004 transit of Venus wearing NASA's Sun-Earth Day solar glasses for safe viewing. Right image – The Transit of Venus taken in 2004 by NASA's TRACE satellite.

During the 18th and 19th centuries, astronomers carefully measured the transits of Venus in order to determine a precise distance of the sun from Earth. This distance determined in units of kilometers would set the absolute physical scale for the entire solar system and beyond.

When do Transits of Venus happen?

Here is a table of the dates of the past ten transits.

Dec 7, 1631	Dec 9, 1874
Dec 4, 1639	Dec 6, 1882
June 6, 1761	June 8, 2004
June 3, 1769	June 5, 2012

Math Puzzler 1 – To the nearest year, how often do transits of Venus occur? What kinds of numerical patterns can you find among the transit years? When will the next transits occur between 2012 and 2600?

How far away from Earth is Venus?

The diameter of Venus is known to be 12,000 kilometers. At the time of the transit of Venus, its angular diameter is measured as 0.016 degrees.

Math Puzzler 2 - Using trigonometry, what is the distance from Earth to Venus in kilometers at the time of the transit?

Math Puzzler 3 - The duration of the transit depends on the relative speeds between the fast-moving Venus in its orbit and the slower-moving Earth in its orbit. This speed difference is known to be 5.24 km/sec. If the June 5, 2012 transit lasts 24,000 seconds, during which time the planet moves an angular distance of 0.17 degrees across the sun as viewed from Earth, what distance between Earth and Venus allows the distance traveled by Venus along its orbit to subtend the observed angle?

Determining the Astronomical Unit

Based on the calculations of Nicolas Copernicus and Johannes Kepler, the distances of the known planets from the sun could be given rather precisely in terms of the distance between Earth and Sun - known as the Astronomical Unit (AU). For instance, Mercury was located at 0.39 AU, Venus was at 0.72 AU, Mars was at 1.5 AU and Jupiter was at 5.2 AU from the sun. But no one had an accurate measure of the distance from Earth to the sun in physical units such as kilometers, to the true physical size of the solar system was not very well known.

In the 1600's, two astronomers realized that the the transits of Venus could be used to make this measurement.

Math Puzzler 4 - At the time of the Transit of Venus, what is the distance between Earth and Venus in terms of Astronomical Units?

Math Puzzler 5 - From your answers to Math Puzzler 2 and 3, what is the average distance between Earth and Venus in kilometers using these two methods?

Math Puzzler 6 - Using a simple proportion, what is your estimate for the Astronomical Unit in kilometers?

Note to Educators: *The answers to these Math Puzzlers can be found by visiting the Educator's area at the SpaceMath@NASA website and clicking on the Transit of Venus button.*

Visit the SpaceMath@NASA website at

http://spacemath.gsfc.nasa.gov

to register for access to over 400+ problems and their solutions that apply math to all types of 'far out' space topics including NASA press releases and videos!

Dr. Sten Odenwald
sten.f.odenwald@nasa.gov

Answer Key for Flyer

Math Puzzler 1

The transit years are

1631
1639 (1639-1631) = 8 years
1761 (1761-1639) = 122 years
1769 (1769 - 1761) = 8 years
1874 (1874-1769) = 105 years
1882 (1882-1769) = 8 years
2004 (2004-1882) = 122 years
2012 (2012-2004) = 8 years

There are pairs of transits separated by 8 years, and then the pairs repeats in alternating patterns every 105 years and 122 years. The months alternate between June and December between pairs. Following this pattern, the next transits will be in the years 2117, 2125, 2247, 2255, 2360, 2368, 2490, 2498, 2603, 2611. During these years, the transit months will alternate December, December, June, June, December, December, etc.

Math Puzzler 2

Distance = 12000 km / sin(0.016) = **43 million km**.

Math Puzzler 3

Orbital speed of Earth = 29.78 km/s
Orbital speed of Venus = 35.02 km/s
Difference = tangential speed across sky viewed from Earth = 5.24 km/s
Distance traveled in 24,000 seconds along Venus orbit = 5.24 x 24000 = 126,000 km.
Apparent angular size of this distance = 0.17 degrees
Distance to Venus = 126,000 km / sin(0.17) = **42 million km**

Math Puzzler 4

Distance = 1.00 – 0.72 = 0.29 AU

Math Puzzler 5

Average Earth-Venus distance = (43 million + 42 million)/2 = **43 million km**

Math Puzzler 6

$$\frac{43 \text{ million}}{0.29 \text{ AU}} = \frac{X}{1.0 \text{ AU}} \quad \text{so } X = \textbf{148 million km}$$

actual value = 149 million km