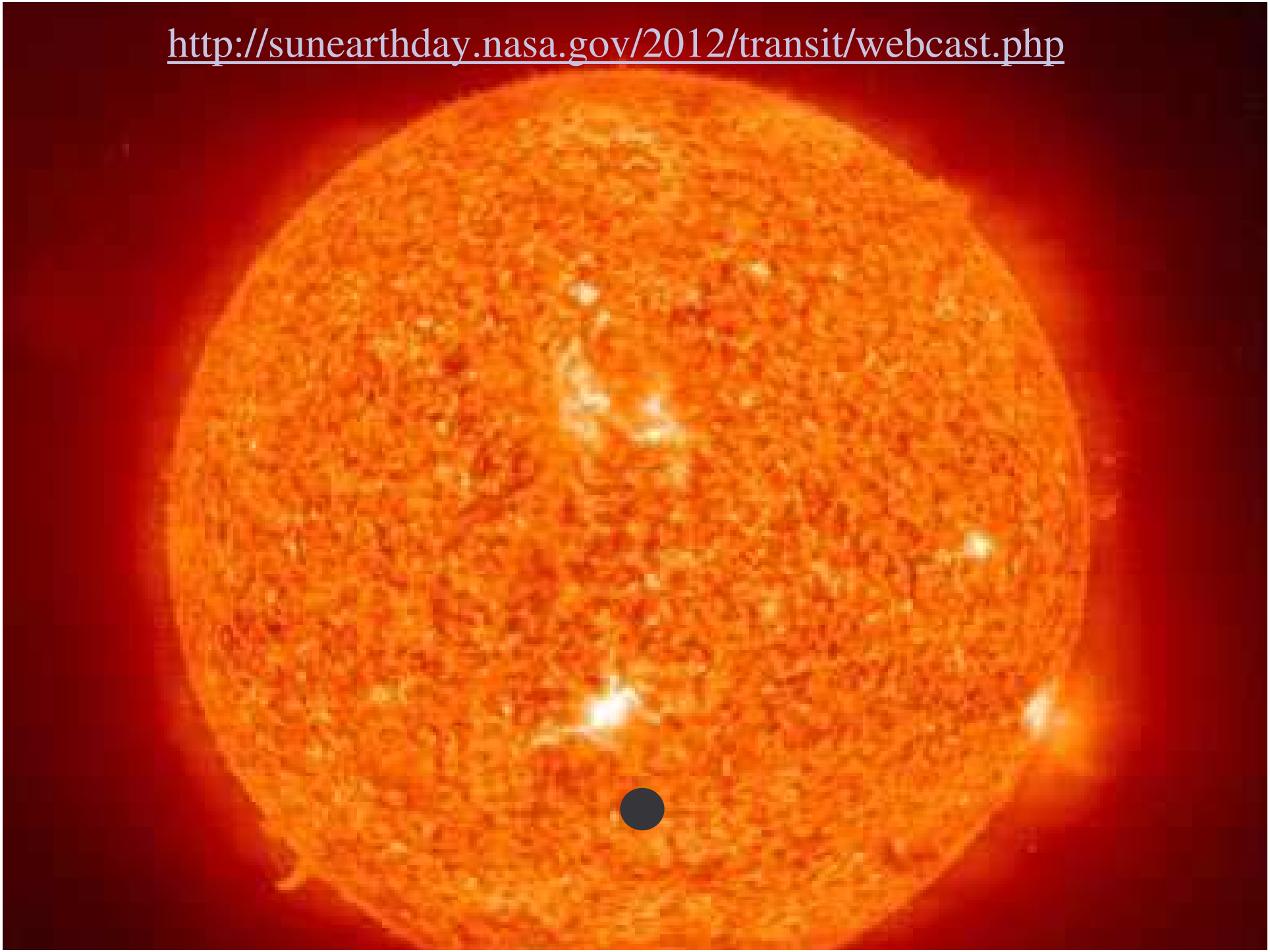
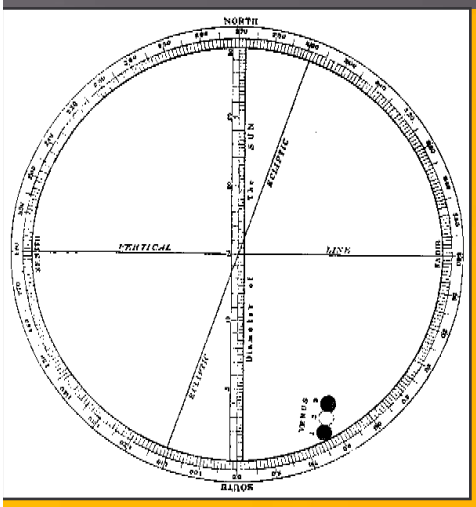
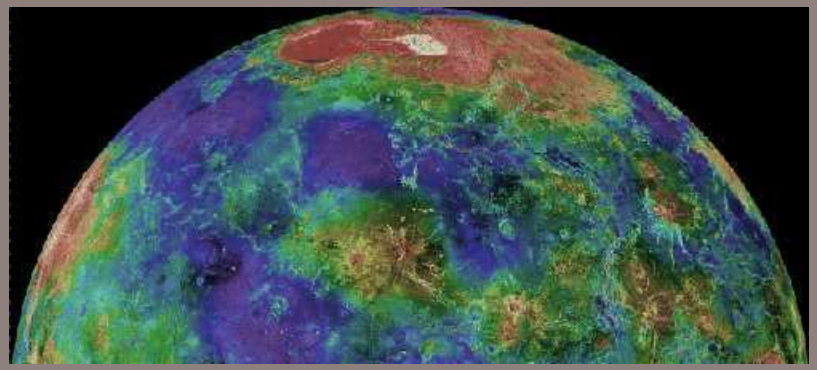
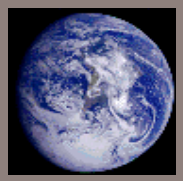

http://sunearthday.nasa.gov/2012/transit/webcast.php

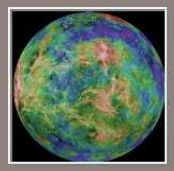

NORTH
SUN
ECLIPTIC
VERTICAL
NADIR
ECLIPTIC
SOUTH



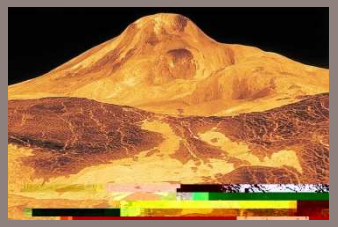
Venus



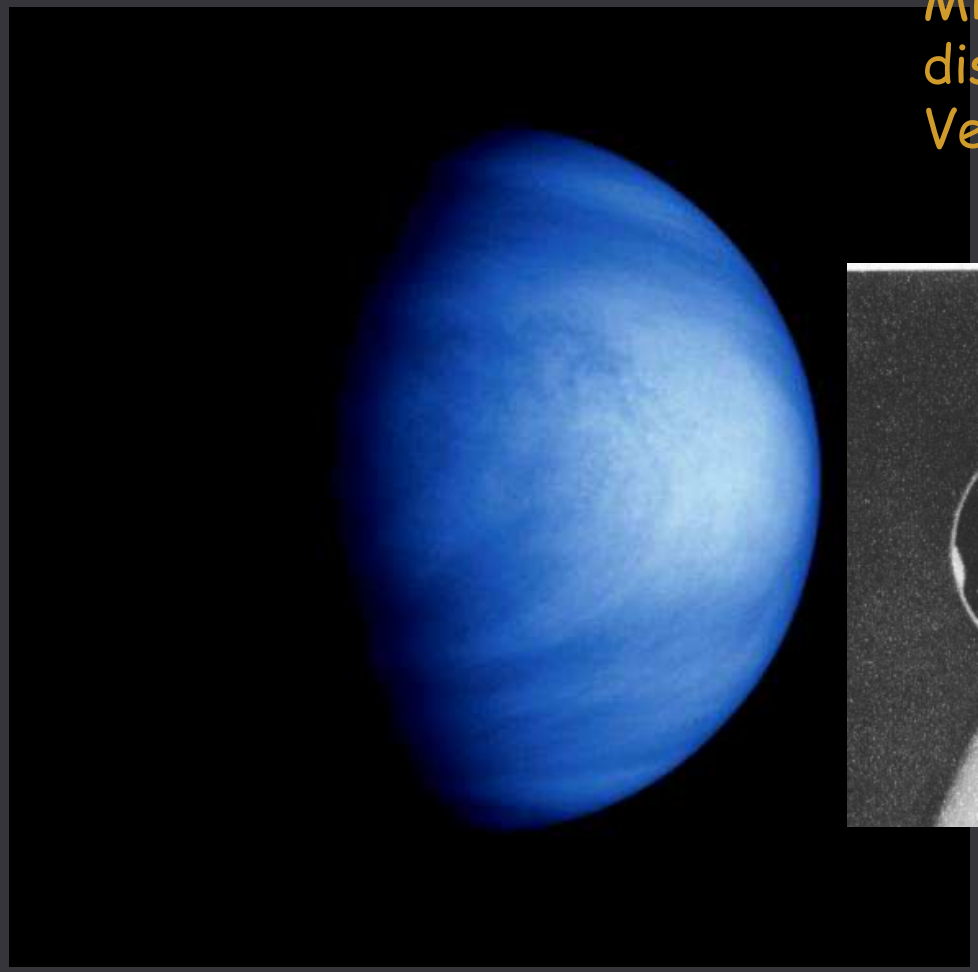
Earth



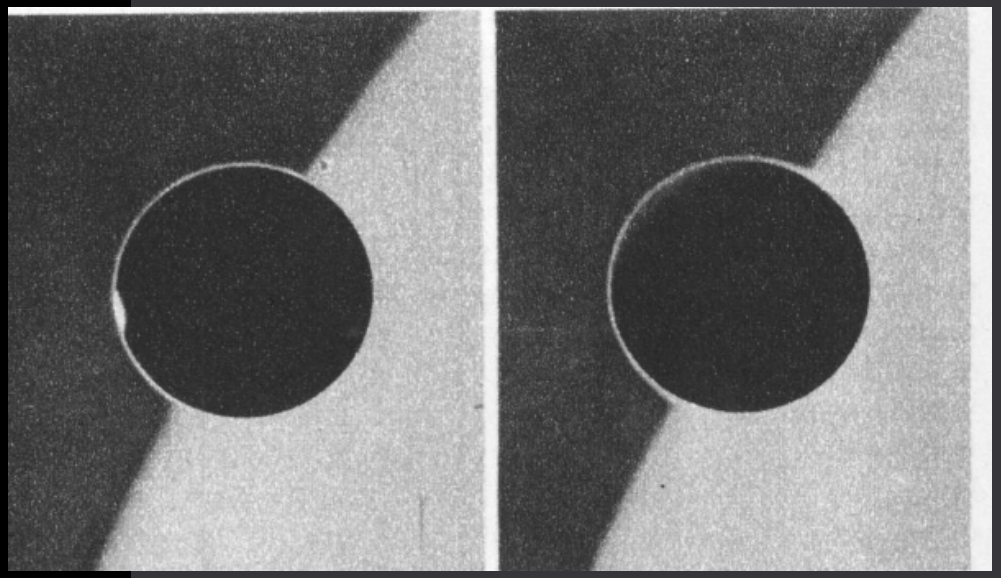
Venus visible with the unaided eye: **"morning star"** or the **"evening star.**



- Similar to Earth:
  - **diameter**: 12,103 km – **0.95 Earth's**
  - **mass 0.89 of Earth's**
  - few craters -- young surface
  - densities, chemical compositions are similar
- **rotation** unusually **slow** (Venus day = 243 Earth days -- longer than Venus' year)
- rotation **retrograde**
- **periods of Venus' rotation and of its orbit are synchronized** -- always same face toward Earth when the two planets are at their closest approach
- **greenhouse effect** -- surface temperature hot enough to melt lead

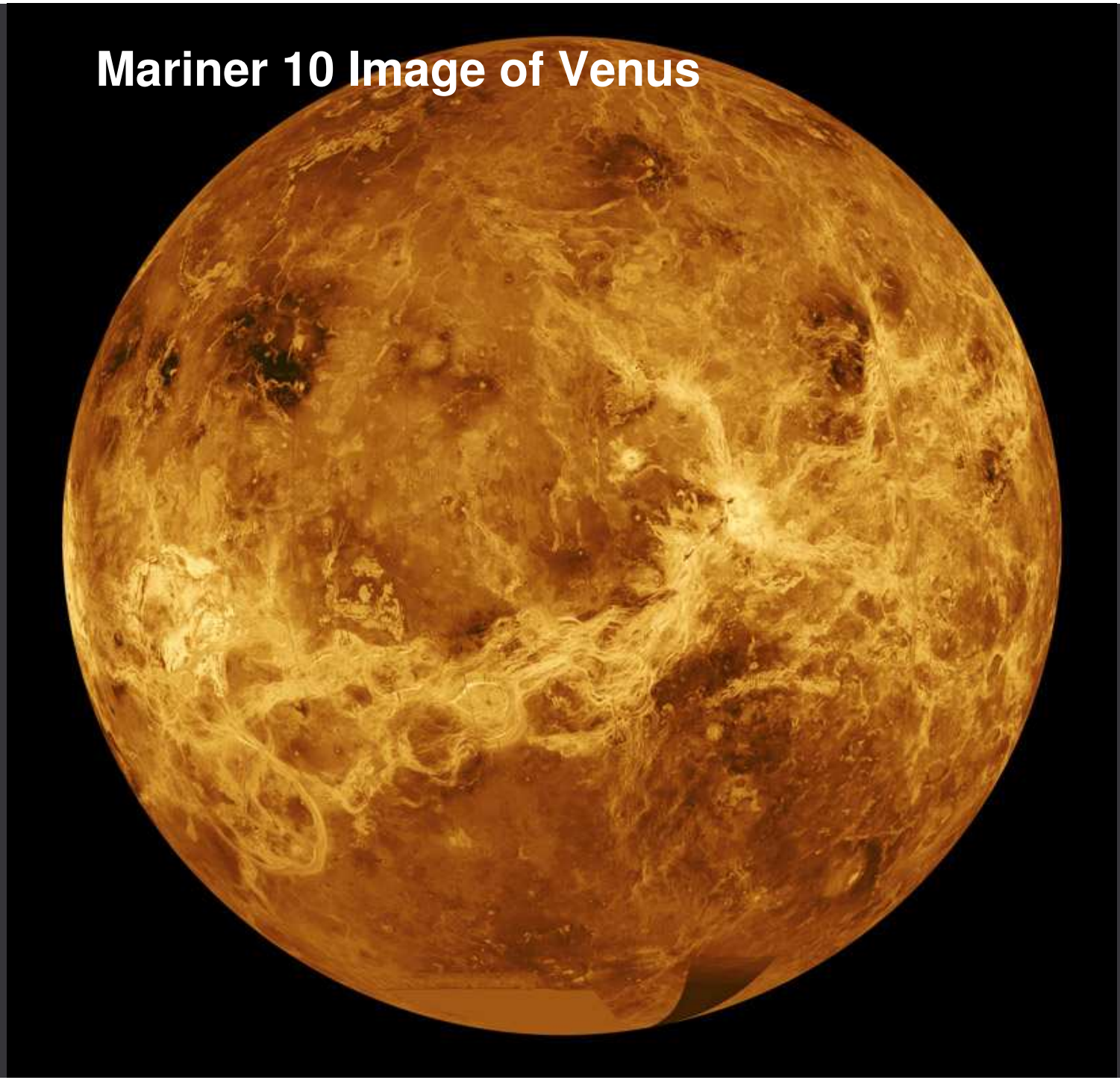


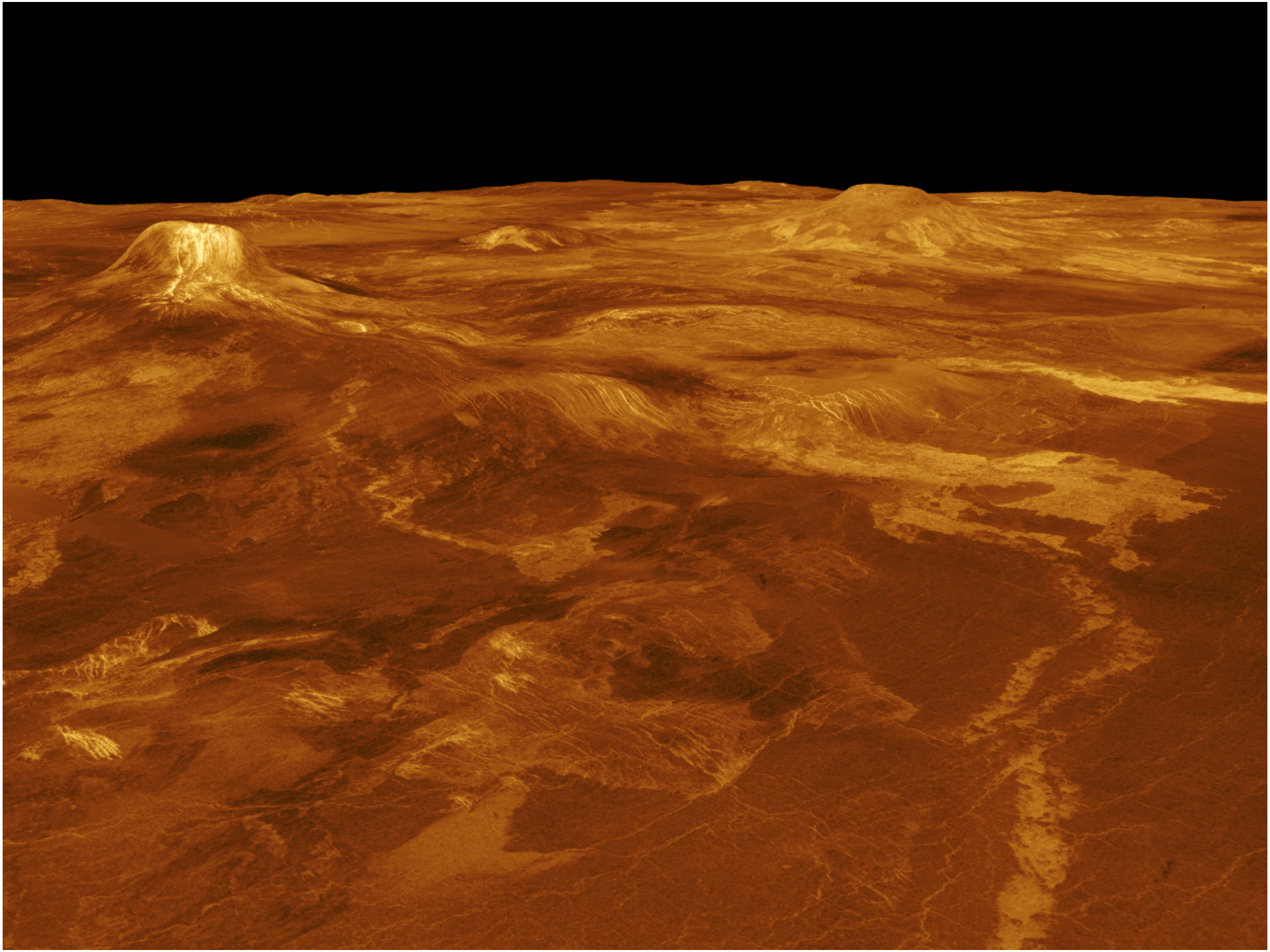
Mikhail Lomonosov, june 5, 1761 discovered, during a transit, that Venus has an atmosphere



The atmosphere is is composed mostly of carbon dioxide. There are several layers of clouds, many kilometers thick, composed of sulfuric acid.

Mariner 10 Image of Venus

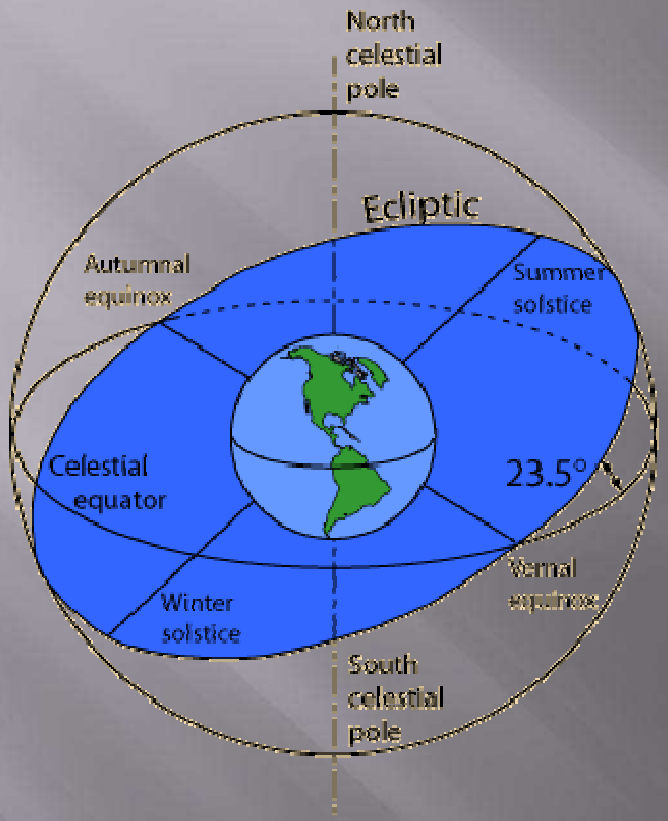


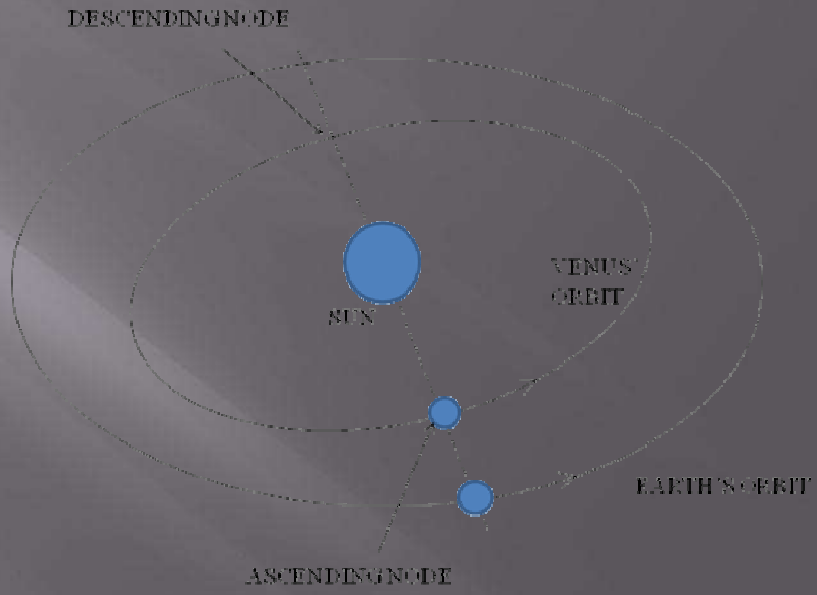



CCCP

Venera 13

The Transit of Venus





Venus' orbit is inclined (by 3.39 degrees) relative to the ecliptic

If in the same plane we would have 5 transits in 8 years

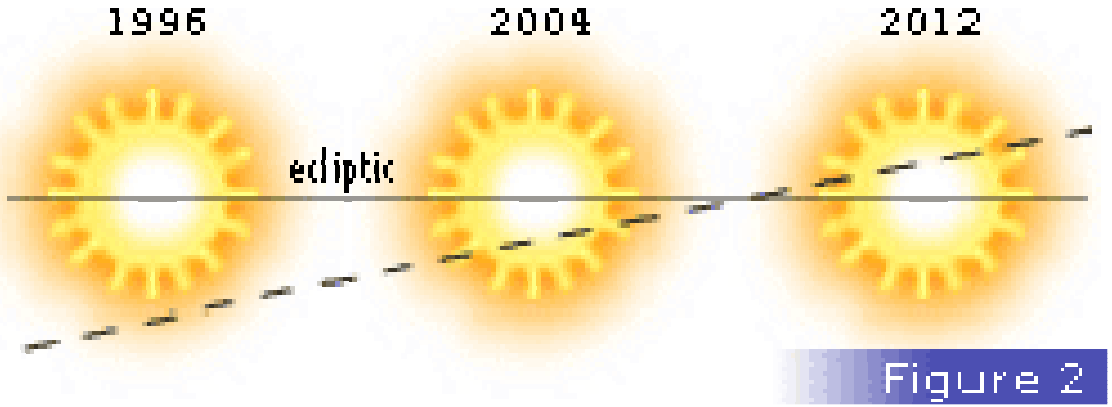
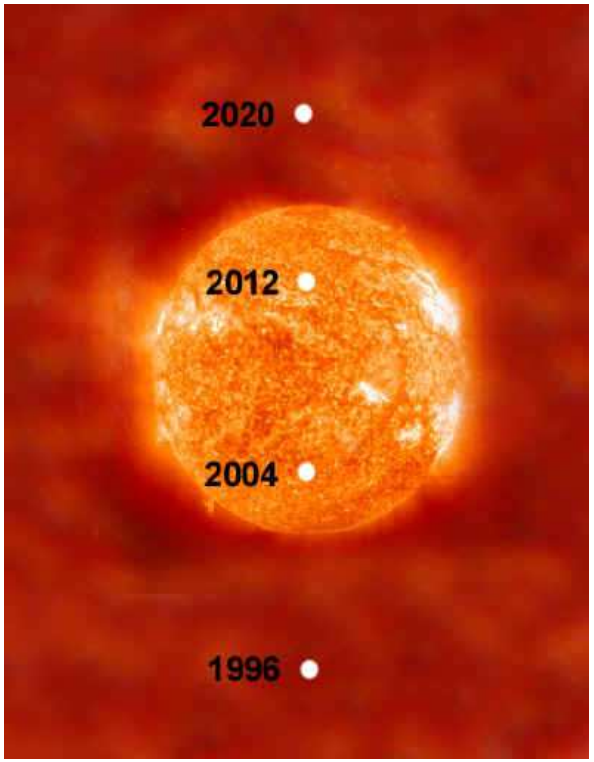
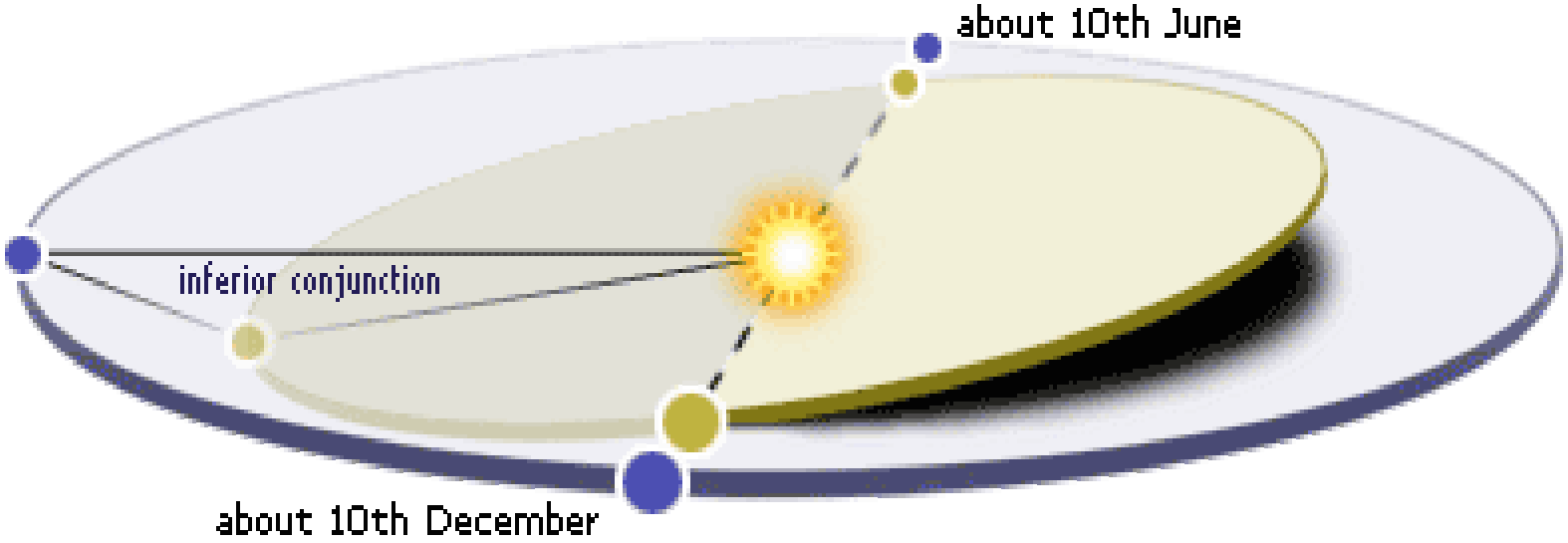


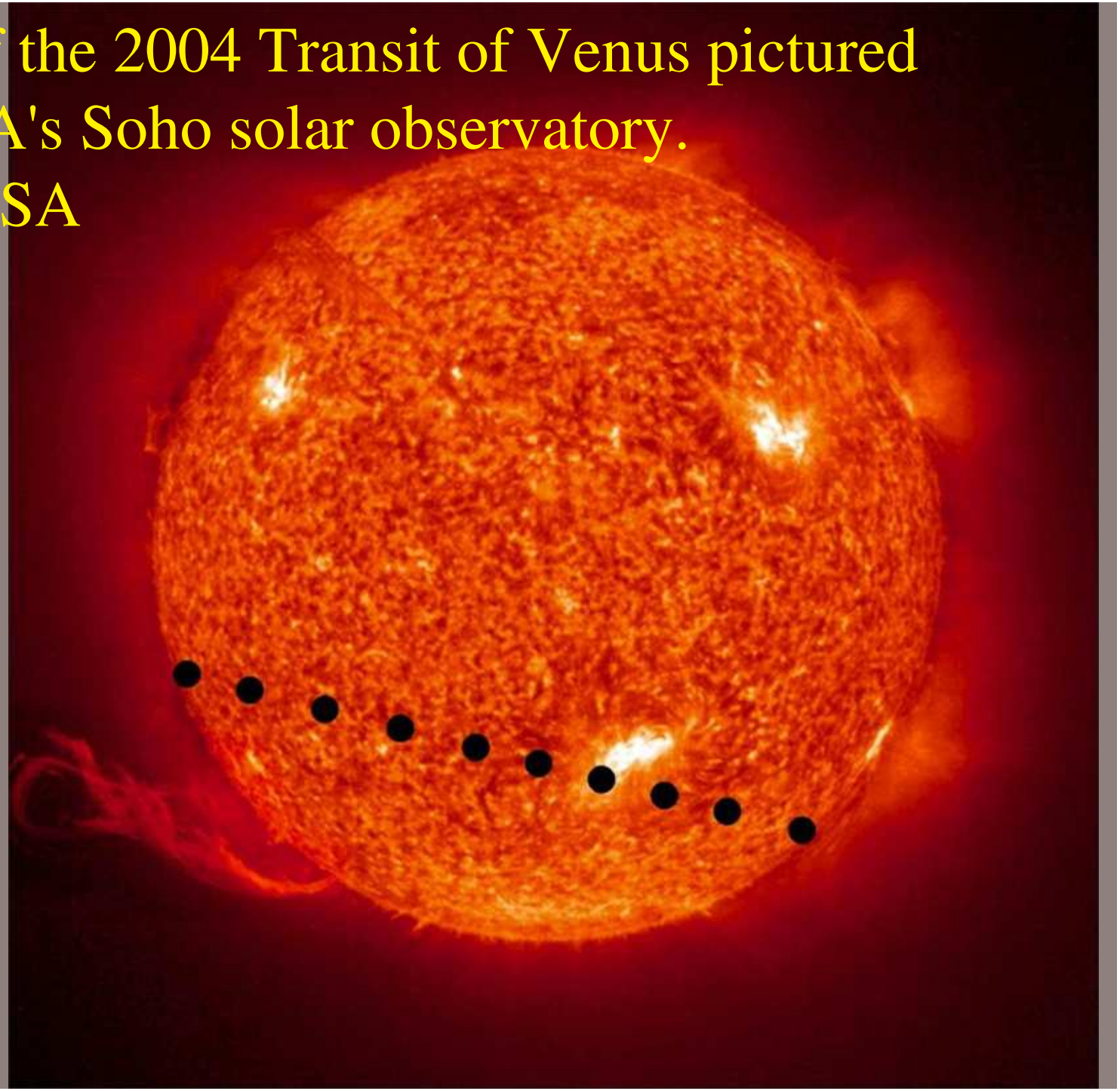
Figure 2



Venus: 13 years , Earth: 8 years
Each time Earth completes 1.6 orbits, Venus catches up to it after 2.6 of its orbits



Progress of the 2004 Transit of Venus pictured from NASA's Soho solar observatory.
Credit: NASA



List of Transits and intervals

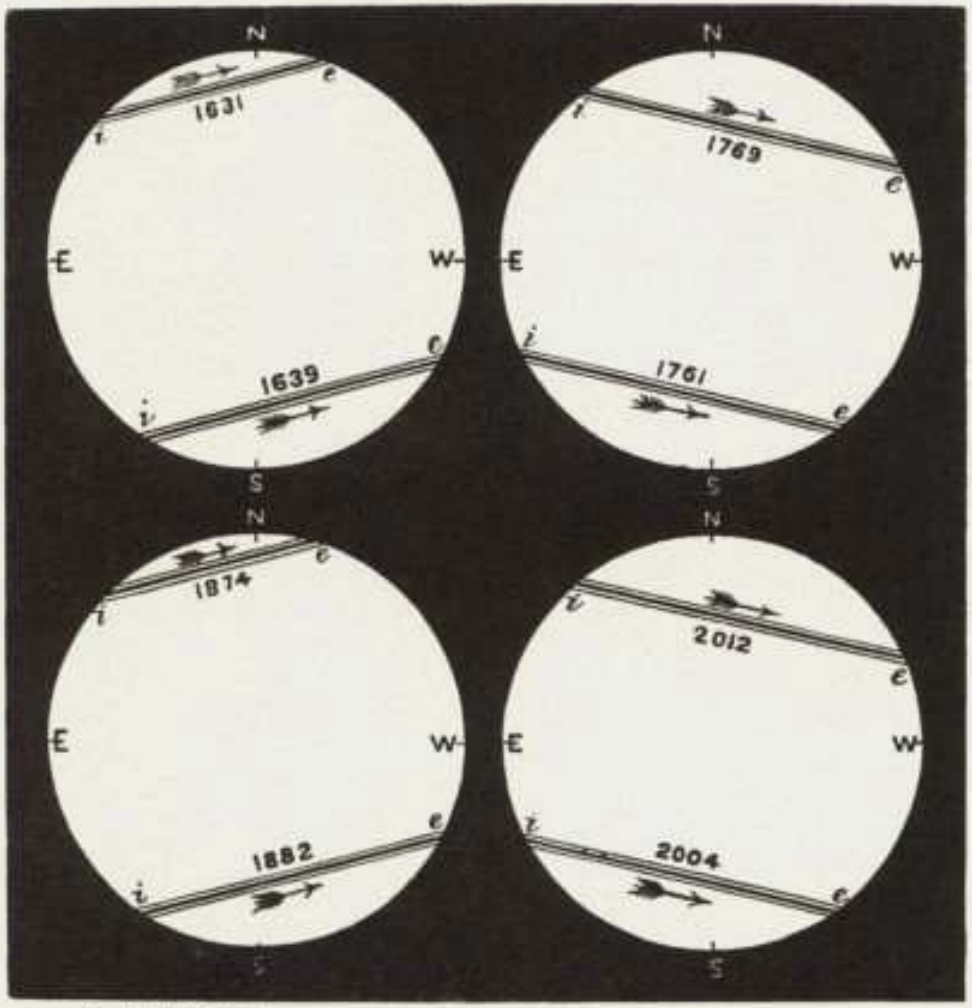
Date of transit	Ascending (A) or Descending (D) node	Duration since last transit (years and months)
6 December 1631	A	
4 December 1639	A	8 yrs
6 June 1761	D	121 yrs 6 months
3 June 1769	D	8 yrs
9 December 1874	A	105 yrs 6 months
6 December 1882	A	8 yrs
8 June 2004	D	121 yrs 6 months
5 June 2012	D	8 yrs
11 December 2117	A	105 yrs 6 months
8 December 2125	A	8 yrs

In 6000 years 81 transits only

PATHS OF VENUS

(MOST NORTHERLY, CENTRAL, AND MOST SOUTHERLY)

ACROSS THE SUN'S FACE

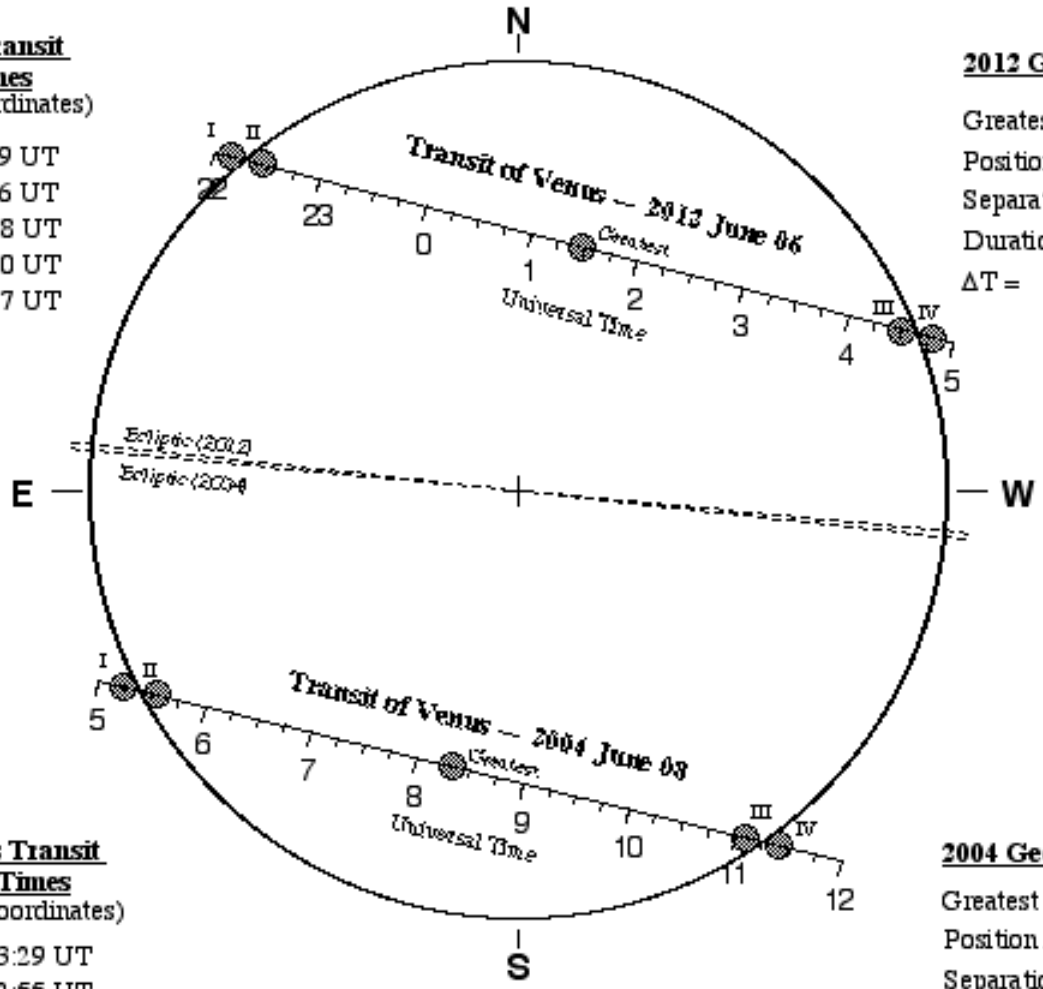


R. A. Proctor del.

DURING THE TRANSITS OF

A.D. 1631, 1639, 1761, 1769, 1874, 1882, 2004, AND 2012.

2004 and 2012 Transits of Venus



2012 Venus Transit Contact Times
(Geocentric Coordinates)

I	= 22:09:29 UT
II	= 22:27:26 UT
Greatest	= 01:29:28 UT
III	= 04:31:30 UT
IV	= 04:49:27 UT

2012 Geocentric Data

Greatest = 01:29:28 UT
Position Angle = 345.4°
Separation = 554.4"
Duration = 06h40m
ΔT = 75.0 s

2004 Venus Transit Contact Times
(Geocentric Coordinates)

I	= 05:13:29 UT
II	= 05:32:55 UT
Greatest	= 08:19:44 UT
III	= 11:06:33 UT
IV	= 11:25:59 UT

2004 Geocentric Data

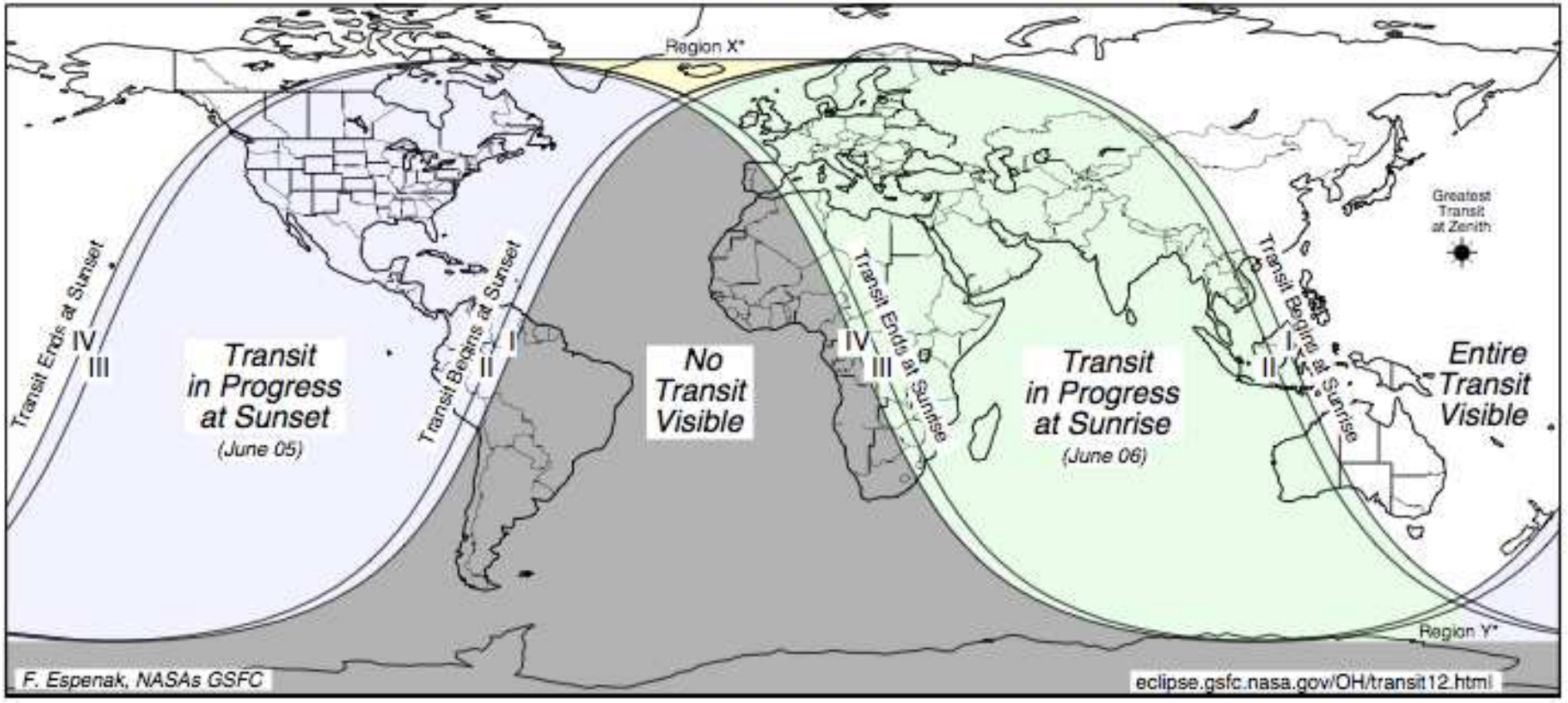
Greatest = 08:19:44 UT
Position Angle = 166.3°
Separation = 626.9"
Duration = 06h12m
ΔT = 65.0 s

Fred Espenak, NASA/GSFC

Figure 1 - Path of Venus across the Sun's disk on 2004 June 08 and 2012 June 06

FIGURE 1

Global Visibility of the Transit of Venus of 2012 June 05/06

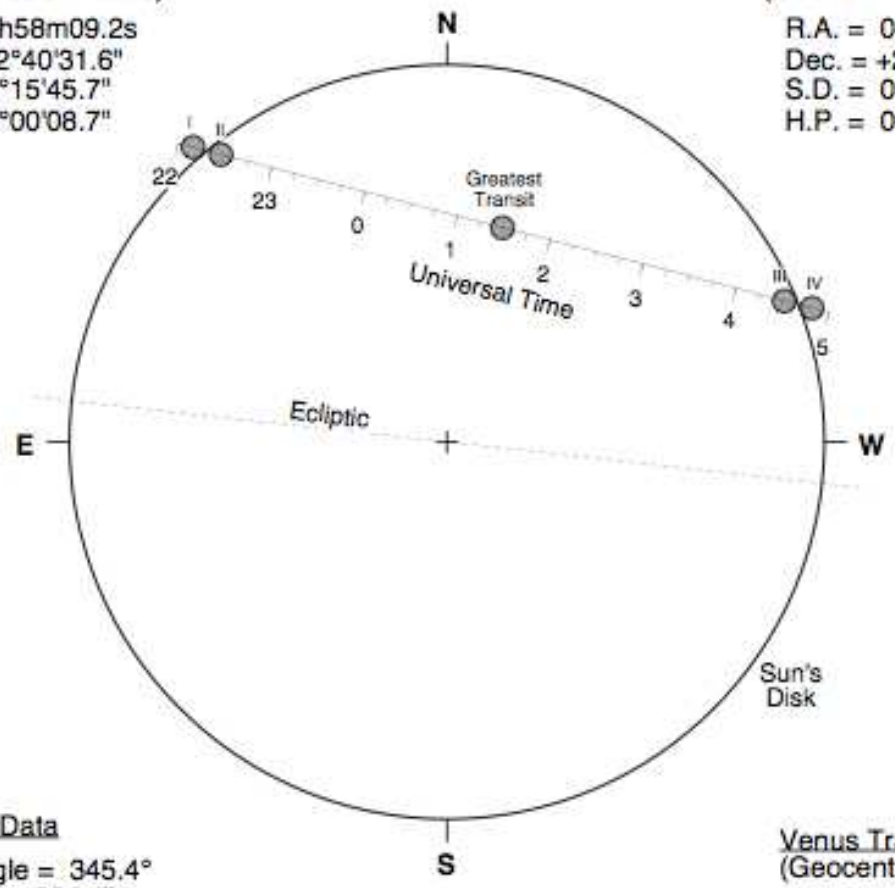


* Region X - Beginning and end of Transit are visible, but the Sun sets for a short period around maximum transit.
* Region Y - Beginning and end of Transit are NOT visible, but the Sun rises for a short period around maximum transit.

FIGURE 2

Transit of Venus of 2012 June 05/06

Greatest Transit = 01:29:36.3 UT J.D. = 2456084.562225



Sun at Greatest Transit
(Geocentric Coordinates)

R.A. = 04h58m09.2s
Dec. = +22°40'31.6"
S.D. = 00°15'45.7"
H.P. = 00°00'08.7"

Venus at Greatest Transit
(Geocentric Coordinates)

R.A. = 04h57m58.8s
Dec. = +22°49'25.9"
S.D. = 00°00'28.9"
H.P. = 00°00'30.5"

Geocentric Data

Position Angle = 345.4°
Separation = 554.4"
Duration = 06h40m

Ephemeris Data

Eph. = VSOP87
ΔT = 66.7 s

0 5 10 15
Arc-Minutes

F. Espenak, NASAs GSFC - 2011 Jun
eclipse.gsfc.nasa.gov/OH/transit12.html

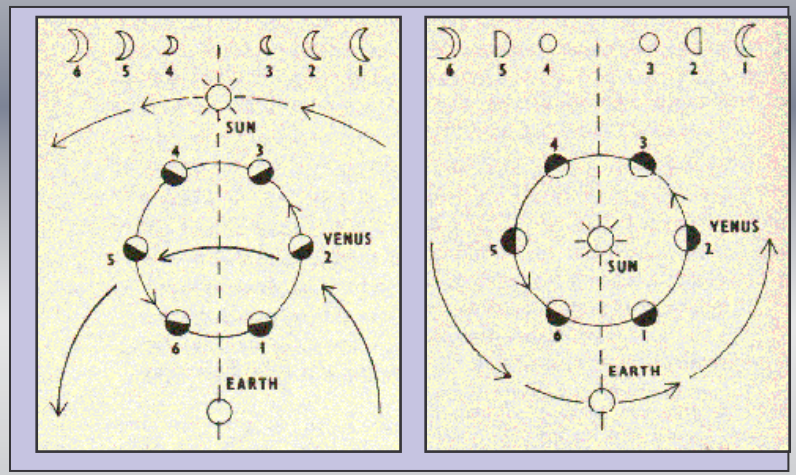
Venus Transit Contacts
(Geocentric Coordinates)

I = 22:09:38 UT
II = 22:27:34 UT
Greatest = 01:29:36 UT
III = 04:31:39 UT
IV = 04:49:35 UT

Venus' Role in History

Copernican System vs Ptolemaic System

- Earliest records of observation date back to Babilonians ~3000 B.C.
- First telescopic observations - Galileo, 1610.
  - Venus had a cycle which could not be explained by its rotation around the earth
  - Venus exhibited phases
  - Venus changed apparent size

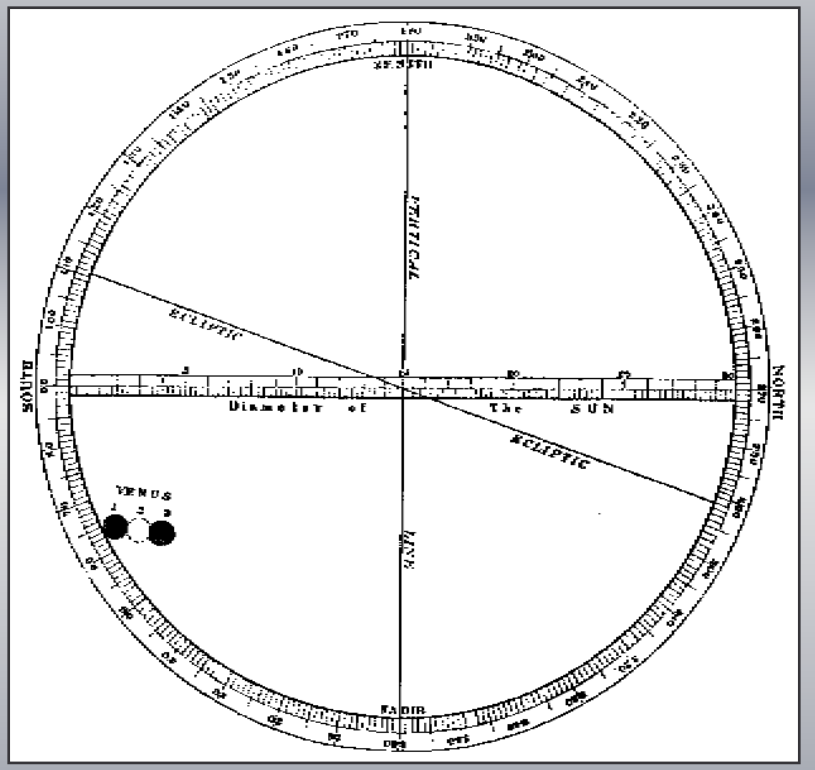


http://astro.unl.edu/classaction/animations/renaissance/venusphases.html

Venus' Role in History

Size of the Solar System - Revealed!

- Kepler predicted the transit of December 1631 (though not observed!) and 120 year cycle.
- Jeremiah Horrocks in 1639 predicts that a further transit of Venus would occur on 4th December 1639
- 1761 transit observations partly successful in determining value of A.U.
- Russian astronomer Mikhail V. Lomonosov, suggests Venus has an atmosphere.
- Captain James Cook et al., observed the 1769 transit from Tahiti.



Local Time	D (% of Sun's Diameter)
3.15 pm	48.06
3.35 pm	45.00
3.45 pm	43.33

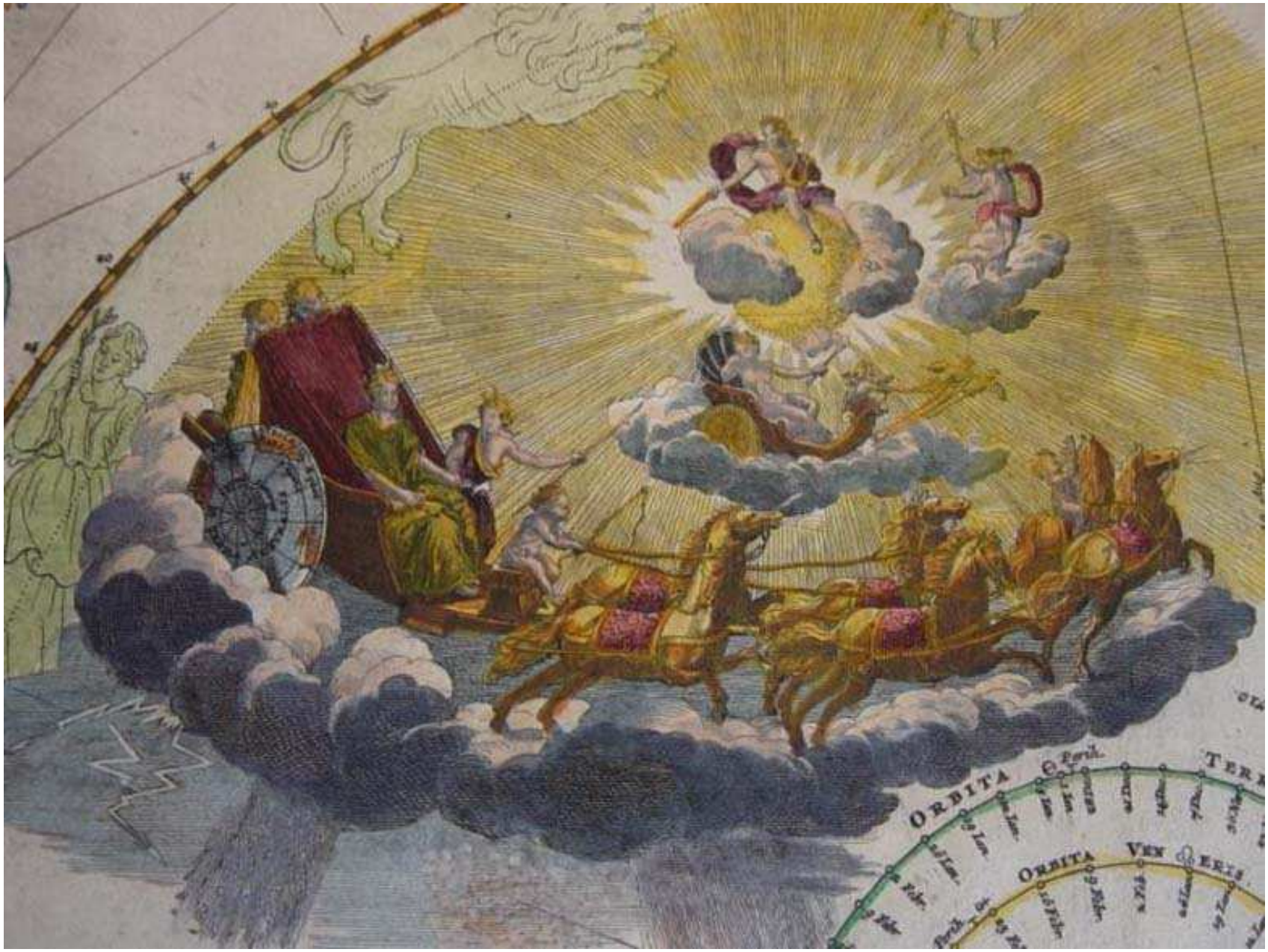
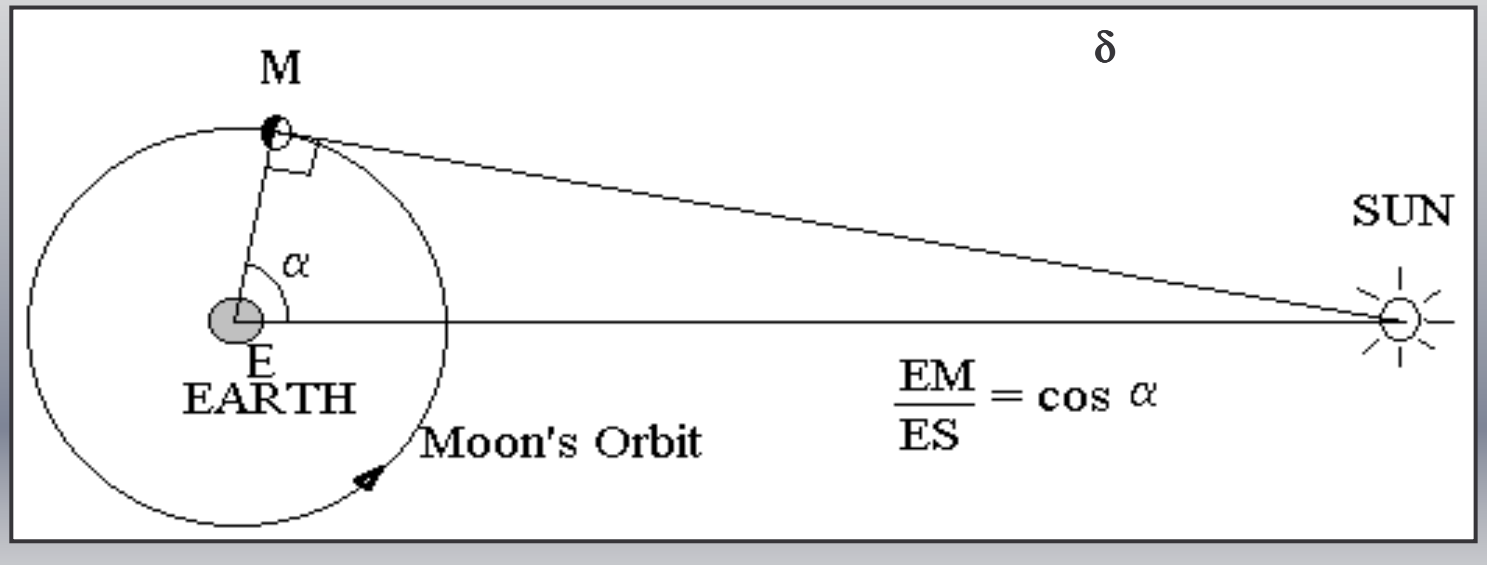


Figure from Johann Doppelmayer's Atlas Coelestis (1742)

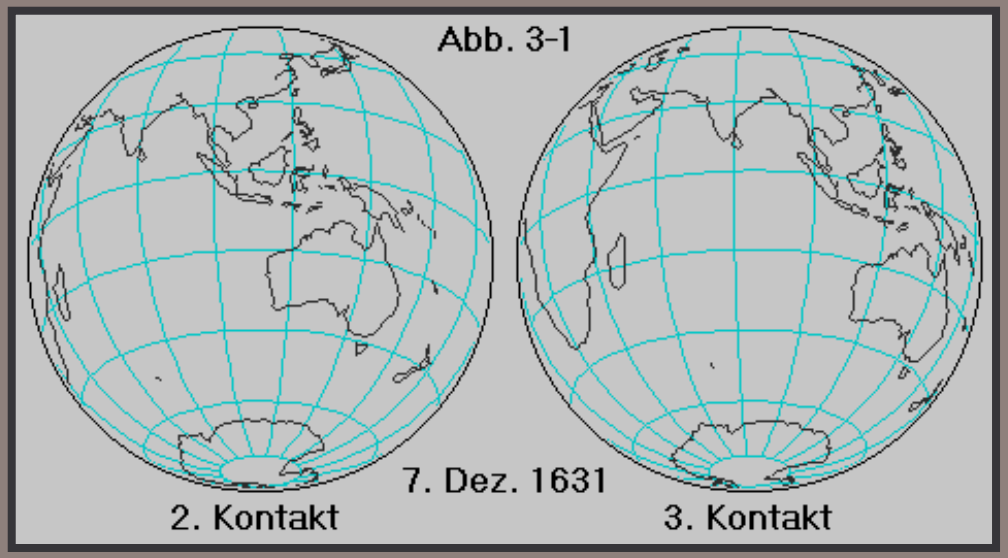
Early Estimate of the Astronomical Unit

Aristarchus of Samos (c.310 - 230 BC):
relative distances Moon, Earth, Sun

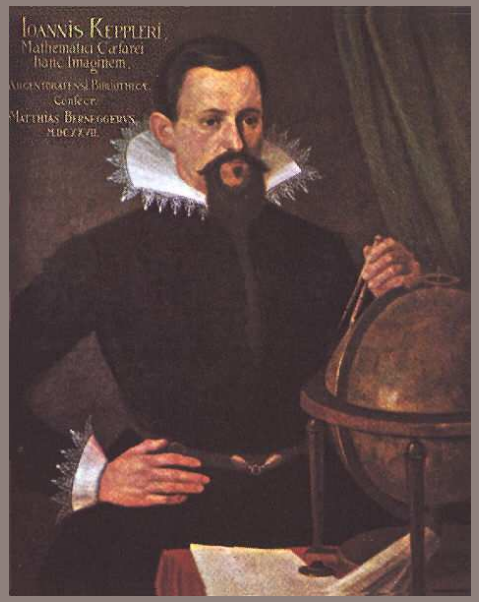
Astronomical unit AU = distance from Earth to the Sun



December 6, 1631



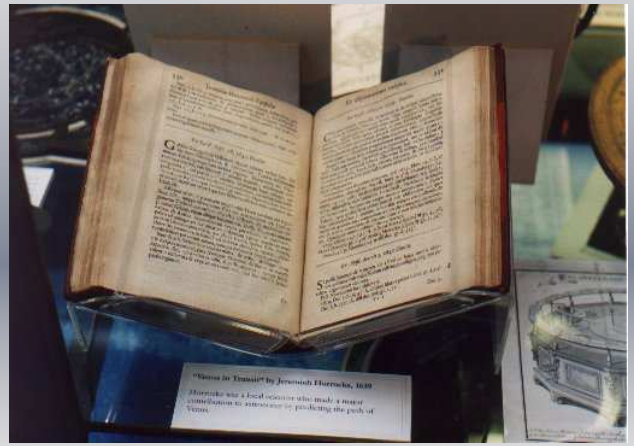
Pierre Gassendi
(1592-1655)



Johannes Kepler
(1571-1630)

- There are no records to suggest that anyone ever observed this event.
- Kepler predicted it would not be visible in Europe, so he requested that mariners keep a lookout for it.
- Pierre Gassendi (1592-1655) tries and fails to observe it

December 4, 1639



Horrocks' record of the 1639 transit

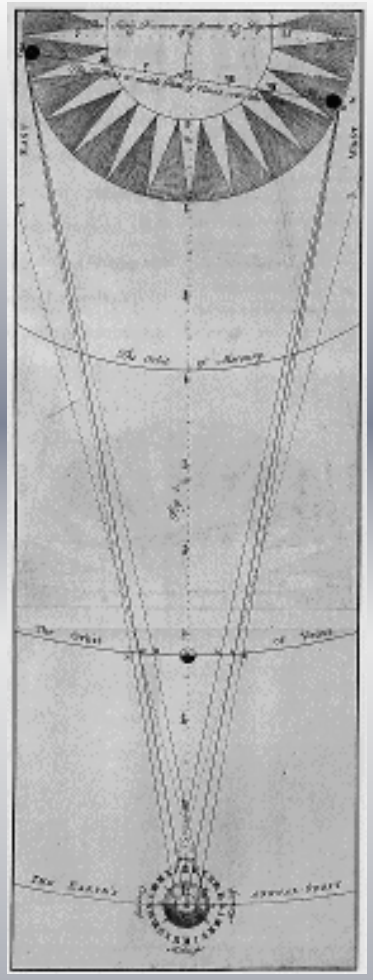
St Michael's Church Hoole, England →

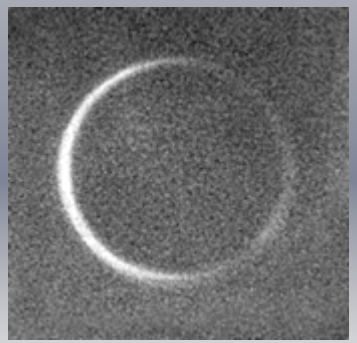
Jeremiah Horrocks (1618-1641)

Amateur astronomer Horrocks Calculated, predicted and observed 1639 transit.

Horrocks missed the start of the transit, but observed it until sunset.

His friend William Crabtree observed it for only 30minutes because it happened late in the day from England. There are no other known observers.





1761 and 1769

Edmond Halley came up with the idea of using the Mercury transit of 1677 to establish the sun-earth distance. He called for the first international multi-station study.

- **Observed from 70 stations.**
- **The first large-scale international scientific endeavor ever attempted.**
- **First measurement of Venus disk size**
- **Lomonosov detects atmosphere as a luminous ring at first contact**
- **AU = 150 million km, less than 1% difference from measurements today**

Edmond Halley (1656-1742)

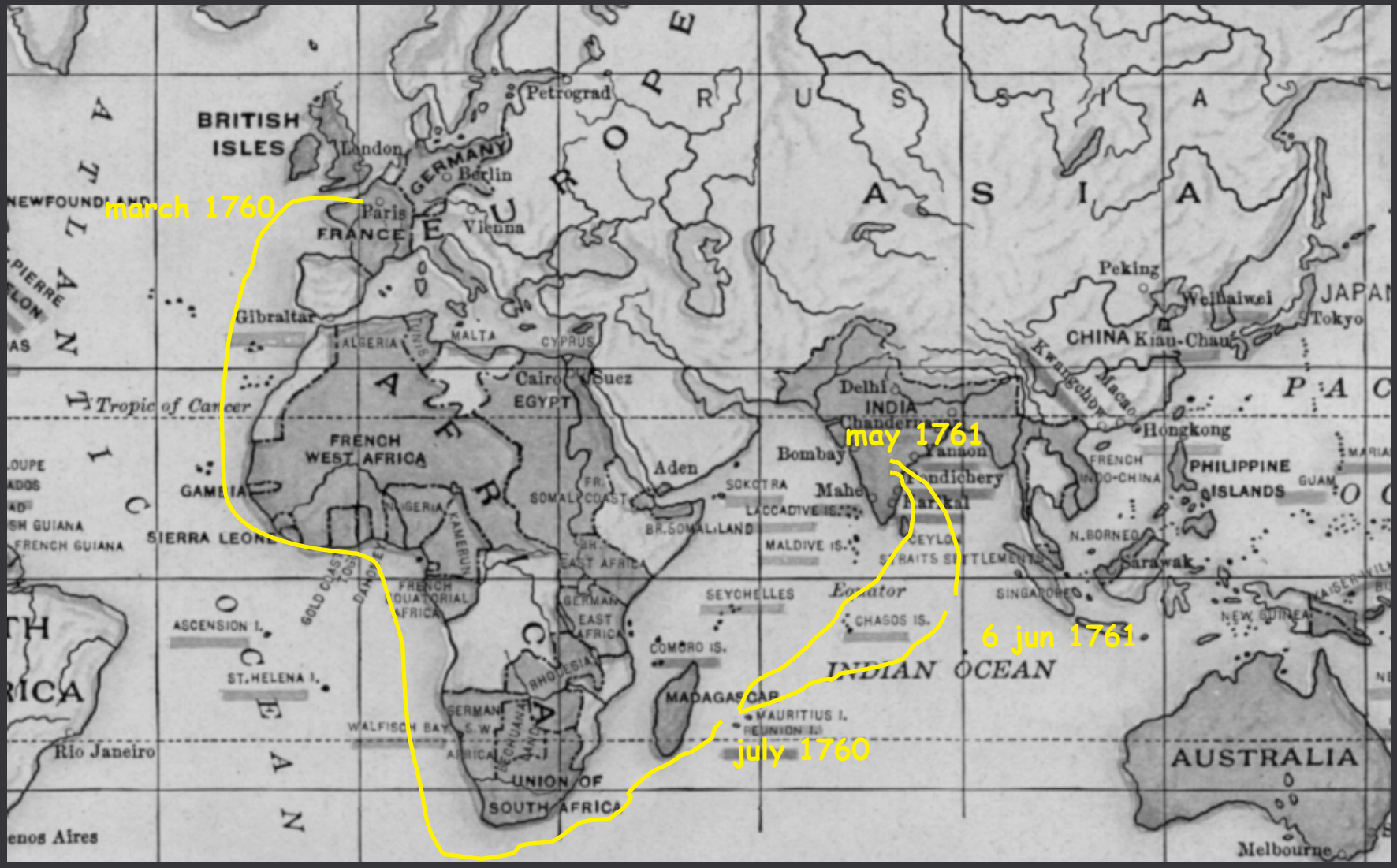
A new Method of determining the Parallax of the Sun

Edmond Halley

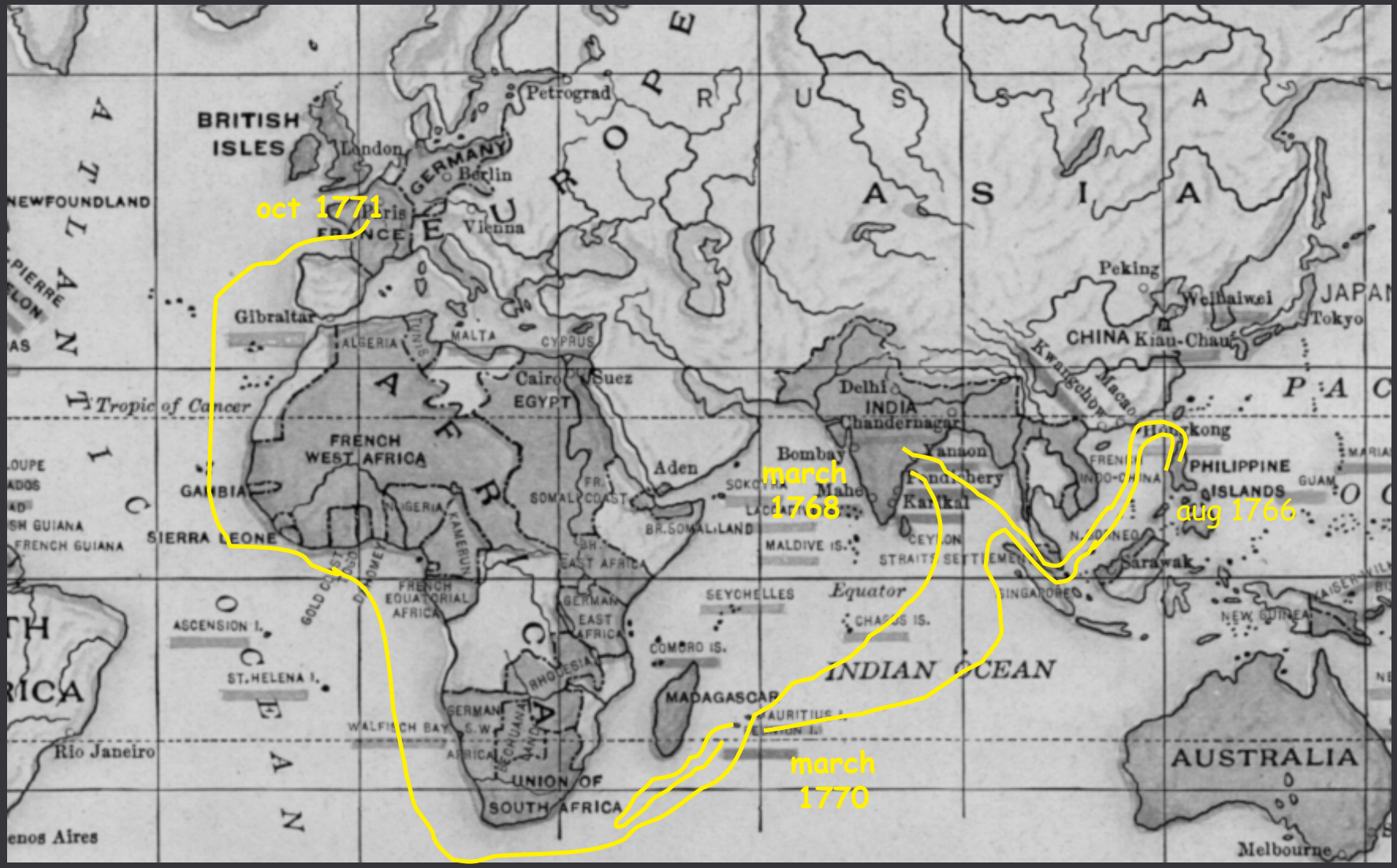
PHILOSOPHICAL TRANSACTIONS VOL. XXIX (1716) A new Method of determining the Parallax of the Sun, or his Distance from the Earth; by Dr. Halley, Sec. R. S. N0 348, p.454. Translated from the Latin.

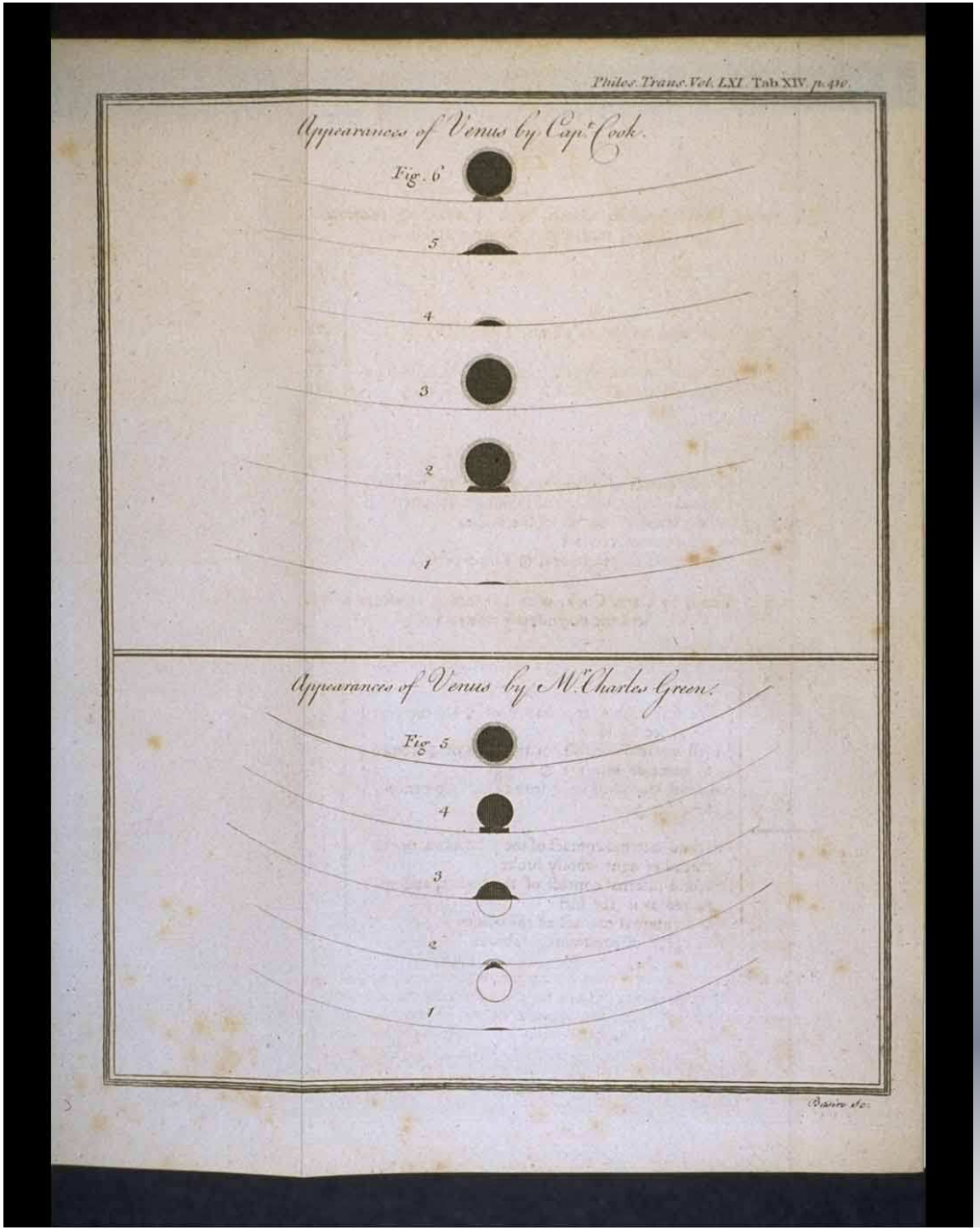
It is well known that this distance of the sun from the earth, is supposed different by different astronomers. Ptolemy and his followers, as also Copernicus and Tycho Brahe, have computed it at 1200 semi-diameters of the earth, and Kepler at almost 3500; Riccioli doubles this last distance, and Hevelius makes it only half as much. But at length it was found, on observing by the telescope, Venus and Mercury on the sun's disk, divested of their borrowed light, that the apparent diameters of the planets were much less than hitherto they had been supposed to be; and in particular, that Venus's semi-diameter, seen from the sun, only subtends the fourth part of a minute, or 15 seconds; and that Mercury's sem-diameter, at his mean distance from the sun, is seen under an angle of 10 seconds only, and Saturn's semi-diameter under the same angle; and that the semi-diameter of Jupiter, the largest of all the planets, subtends no more than the third part of a minute at the sun. Whence, by analogy, some modern astronomers conclude that the earth's semi-diameter, seen from the sun, subtends a mean angle, between the greater of Jupiter and the less of Saturn and Mercury, and equal to that of Venus, viz. one of 15 seconds; and consequently, that the distance of the sun from the earth is almost 14,000 semi-diameters of the latter.

Guillaume-Joseph-Hyacinthe-Jean-Baptiste Gentil de la Galaisière



Guillaume-Joseph-Hyacinthe-Jean-Baptiste Gentil de la Galaisière





Transit 1769

Transit of Venus (detail) from James Cook and Charles Green's "Observations Made ... at King George's Island in the South Sea" in *Philosophical Transactions of the Royal Society. Vol. 61, 1771.*

Finding the distance to the stars

•The first parallax shift of a star was detected in 1838 by an astronomer named F. W. Bessel at the Konigsberg Observatory in Prussia.

•The star was actually a binary called 61 Cygni, a gravitationally bound pair of red dwarf stars.

•Bessel found that these stars were making annual loops with a radius of .29 arcseconds, corresponding to a distance of 10.3 light years

Frederick W. Bessel

December 9, 1874

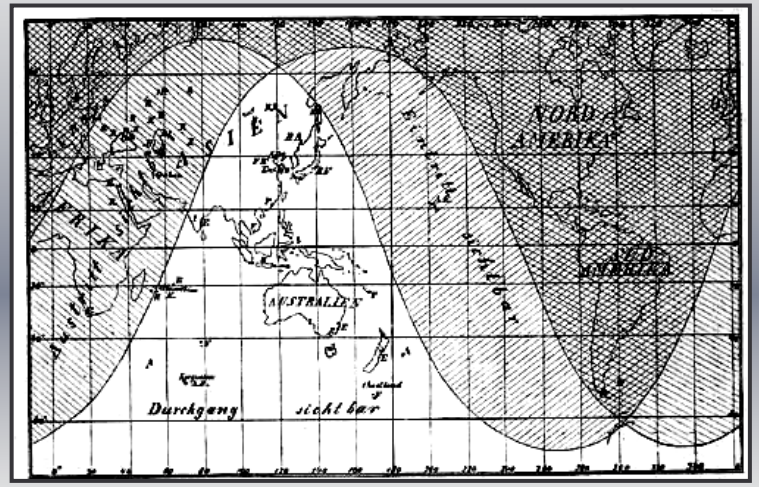
Venus described as identical to earth with animal and plant life.

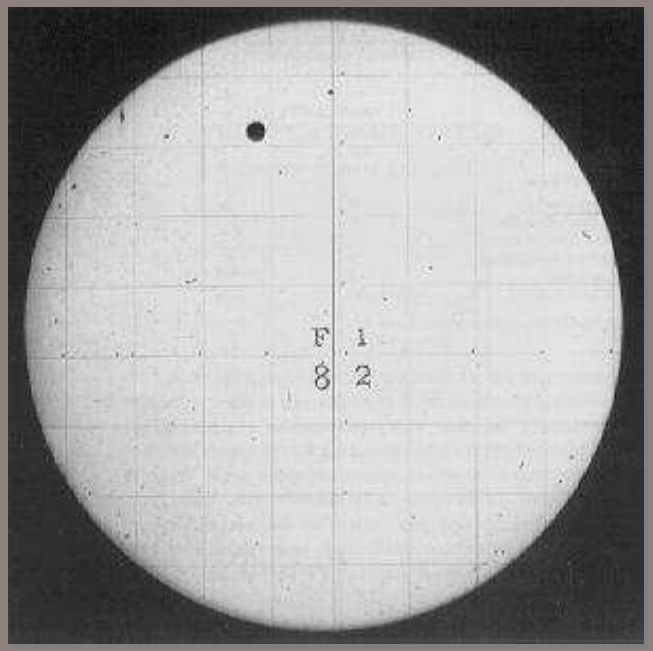
No natural satellites ever seen during previous transits.

Parallax distances to 20 stars were known

Extensive media coverage generated enormous public interest.

AU determined



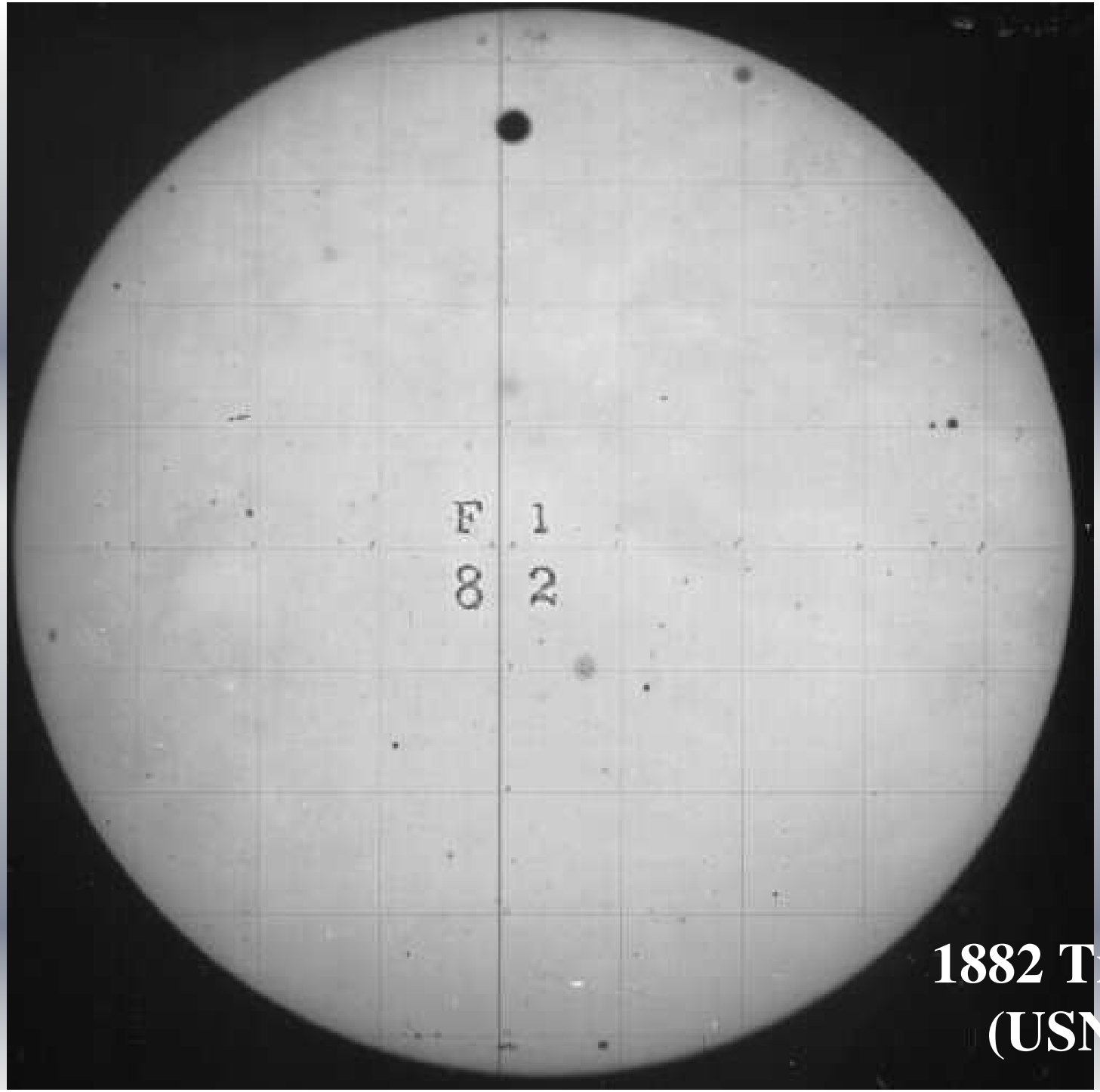


December 6, 1882

All 147 negatives of the 1882 Venus transit had lain patiently on a high-up, corner shelf at Lick Observatory for 120 years. Two astronomers decided to make a movie.

http://earthsky.org/space/bill-sheehan-and-tony-misch-video-of-1882-venus-transit

•William Sheehan, left, and Tony Misch at Lick Observatory in California during the 2003 opposition of Mars. Copyright Laurie Hatch. Used with permission.



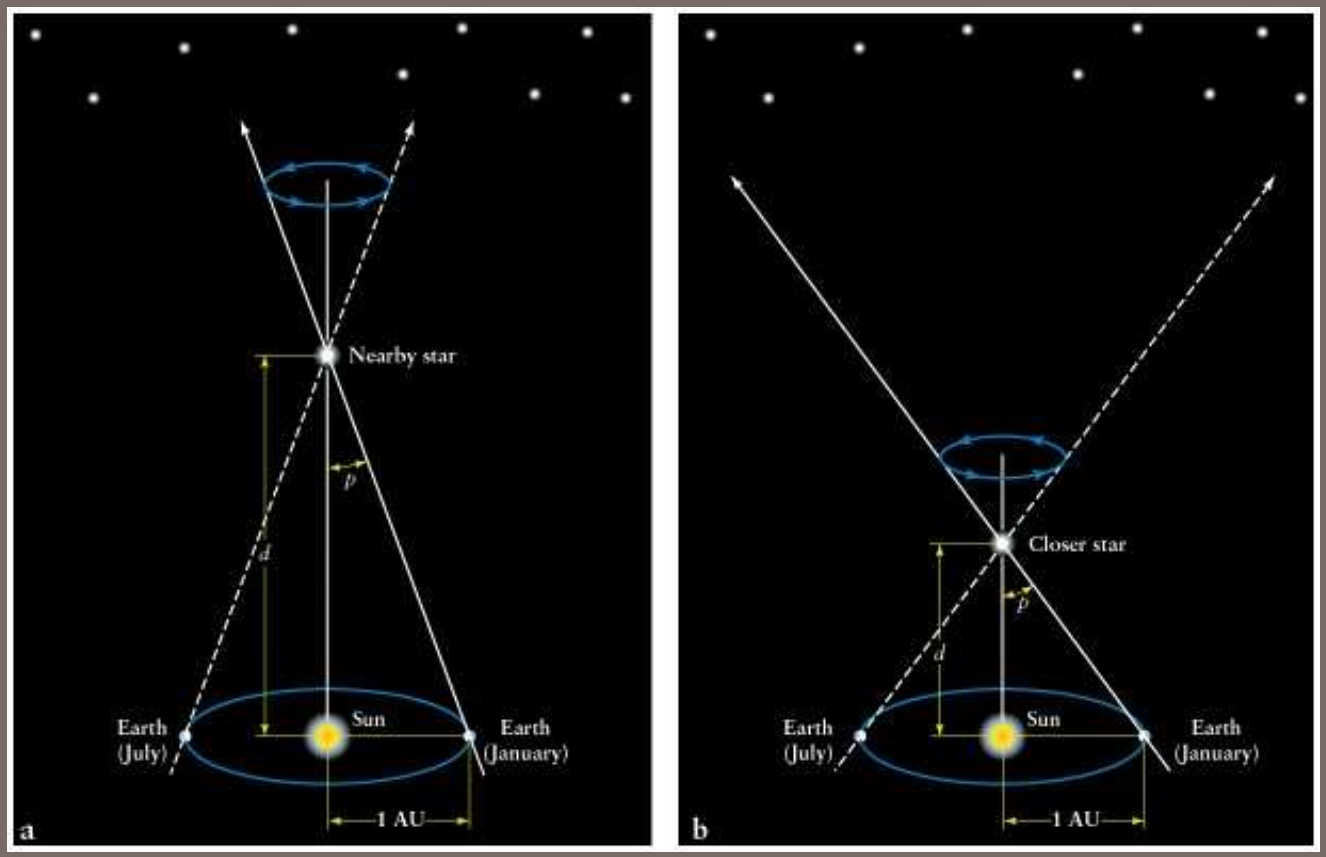
1882 Transit (USNO)

1882, the date of the last Venus transit, quote by William Harkness of the U.S. Naval Observatory (from Sky and Telescope, Feb. 1995):

We are now on the eve of the second transit of a pair, after which there will be no other till the twenty-first century of our era has dawned upon the earth, and the June flowers are blooming in 2004.

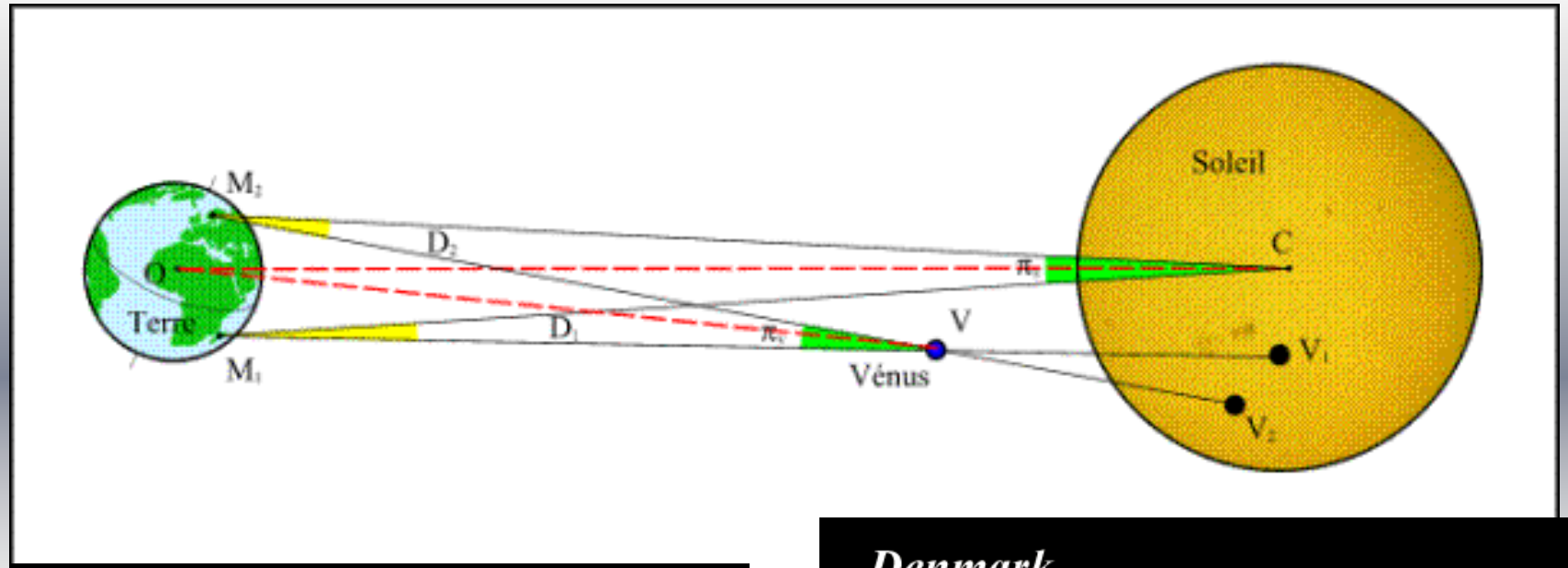
When the last transit season occurred the intellectual world was awakening from the slumber of ages, and that wondrous scientific activity which has led to our present advanced knowledge was just beginning. What will be the state of science when the next transit season arrives God only knows. Not even our children's children will live to take part in the astronomy of that day. As for ourselves, we have to do with the present.

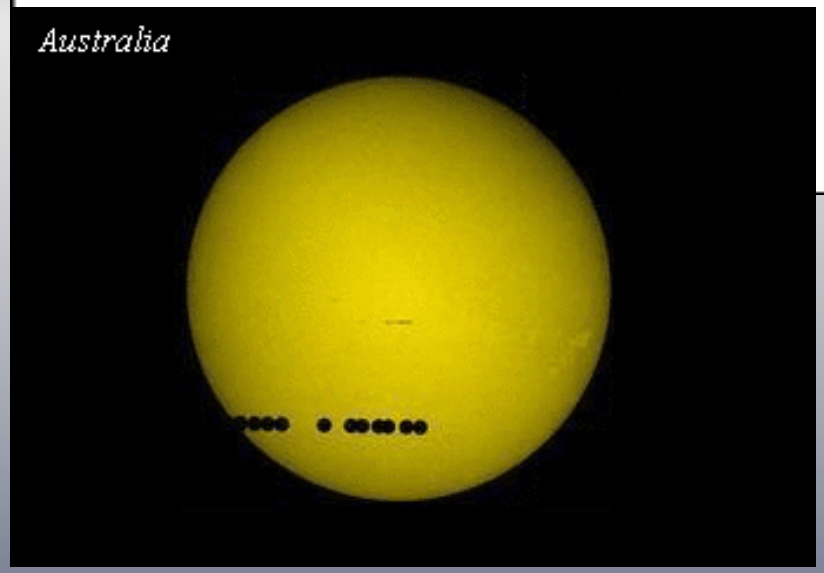
Parallax

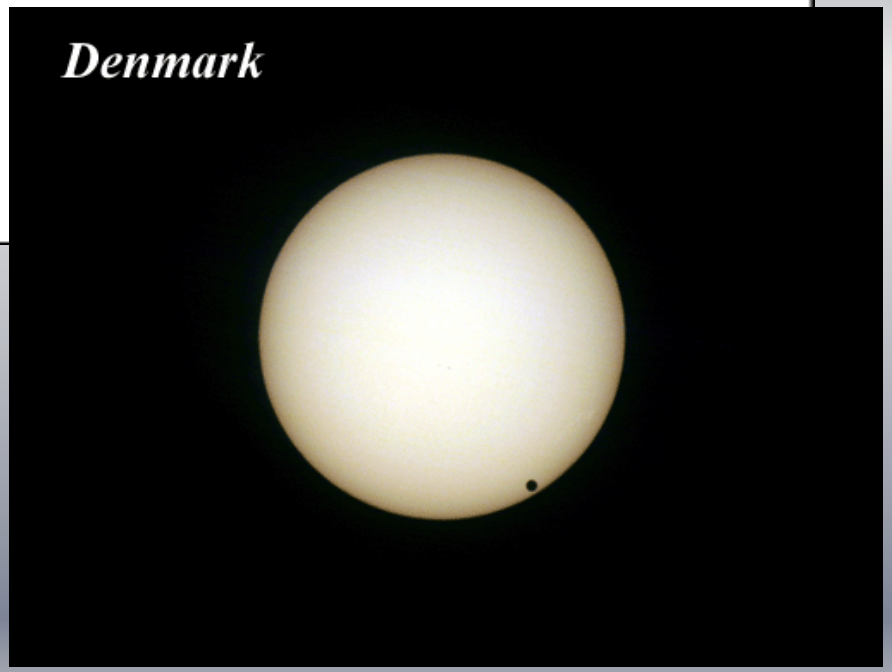


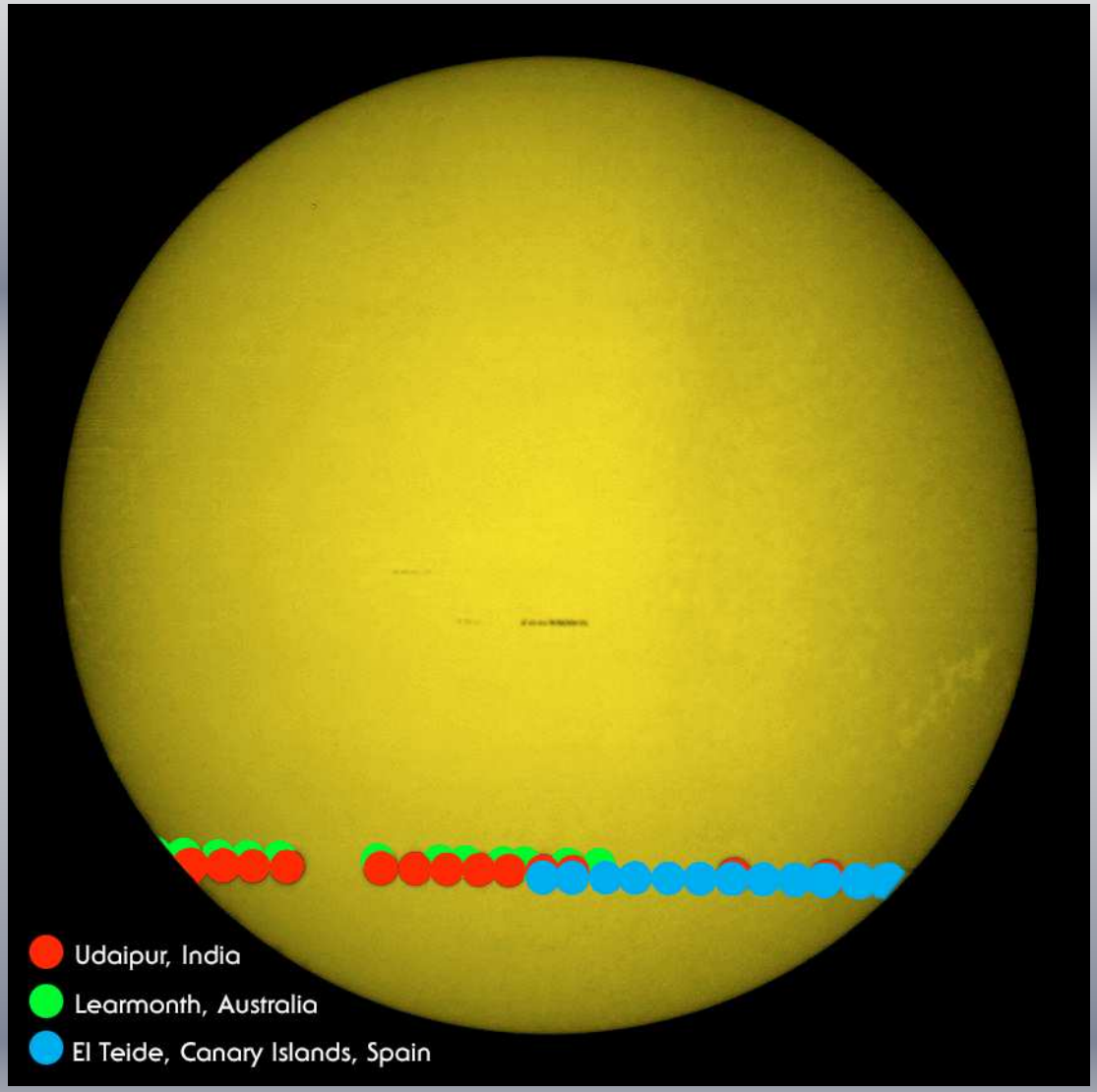
The distance to a nearby star can be measured by observing its ***parallax*** – the ***apparent*** shift of its position on the sky relative to more distant stars. Parallax is caused by Earth's motion around the Sun.

http://sci2.esa.int/interactive/media/flashes/2_1_1.htm

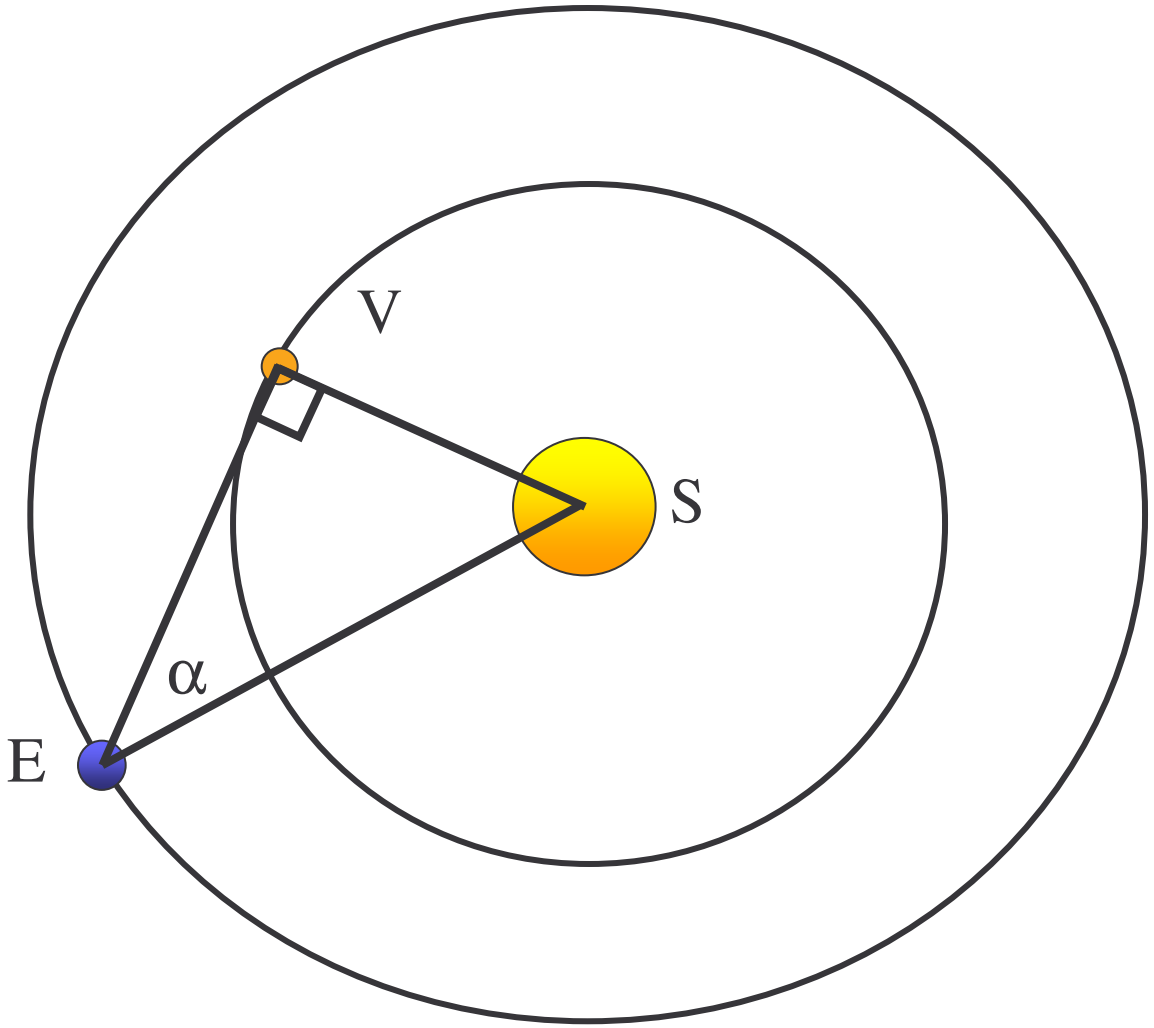

M2
O
Terre
M1
D2
D1
Soleil
C
V
Vénus
V1
V2


Australia


Denmark


Udaipur, India
Learmonth, Australia
El Teide, Canary Islands, Spain

How to calculate the AU
Venus at Greatest Elongation



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

$\alpha \sim 46.054$ deg

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

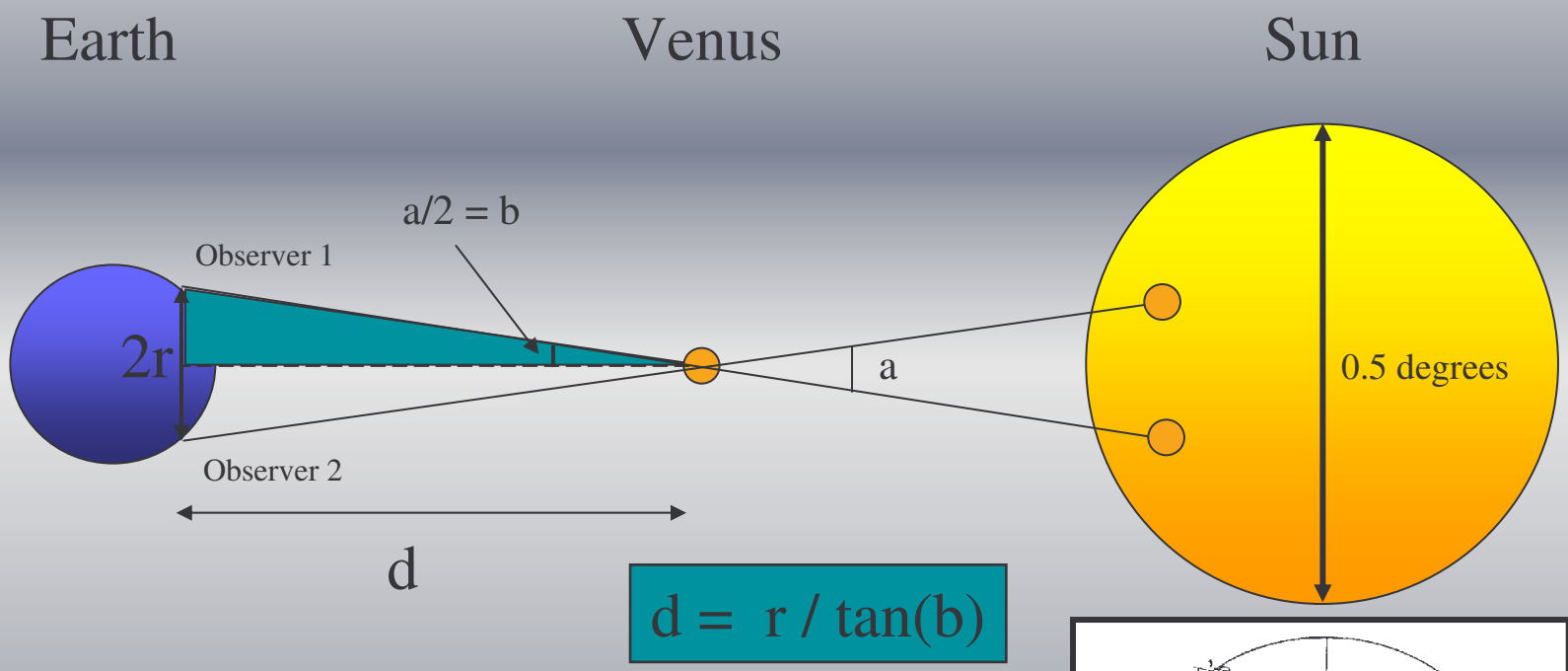
$VS = 0.72$ AU

so…

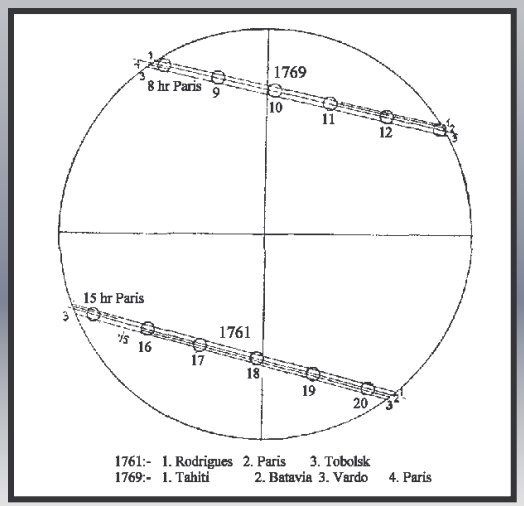
$EV = 1 - 0.72$ AU

$= 0.28$ AU

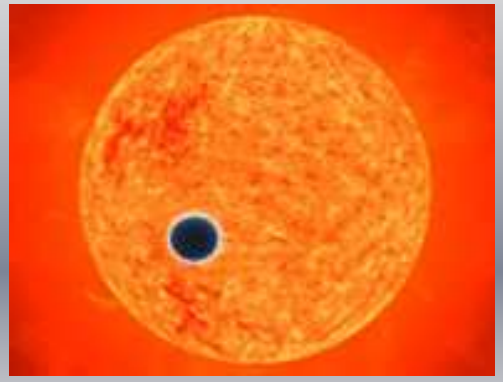
How to calculate the AU Parallax

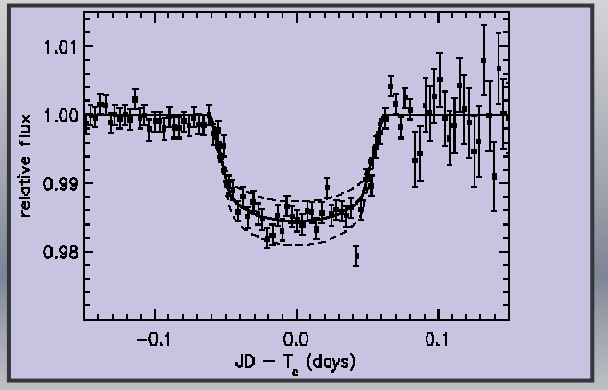


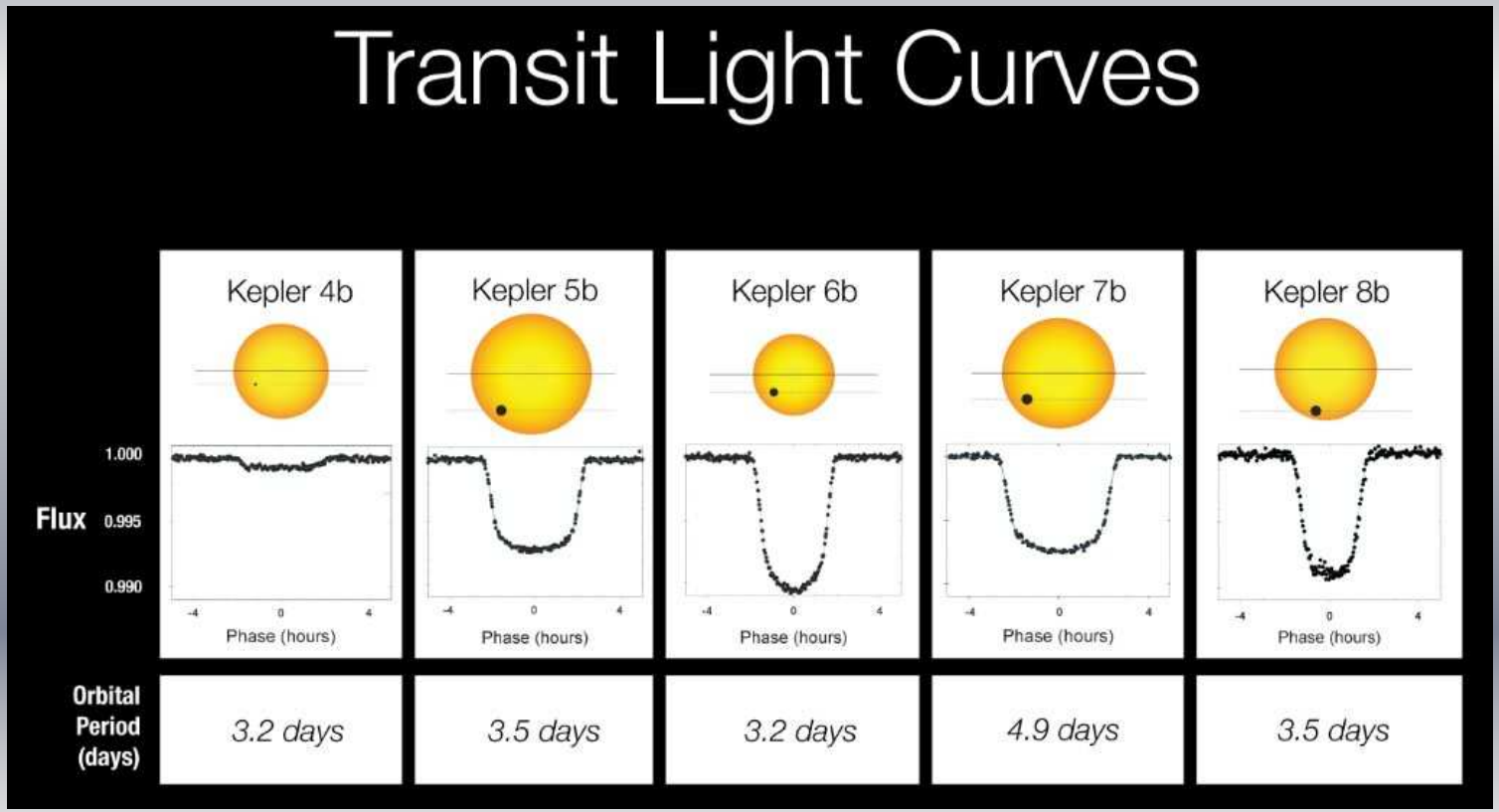
- Venus-Sun equals 0.72 times the distance Earth-Sun from Kepler's third law.
- The distance 2r in km between the two observers is known.



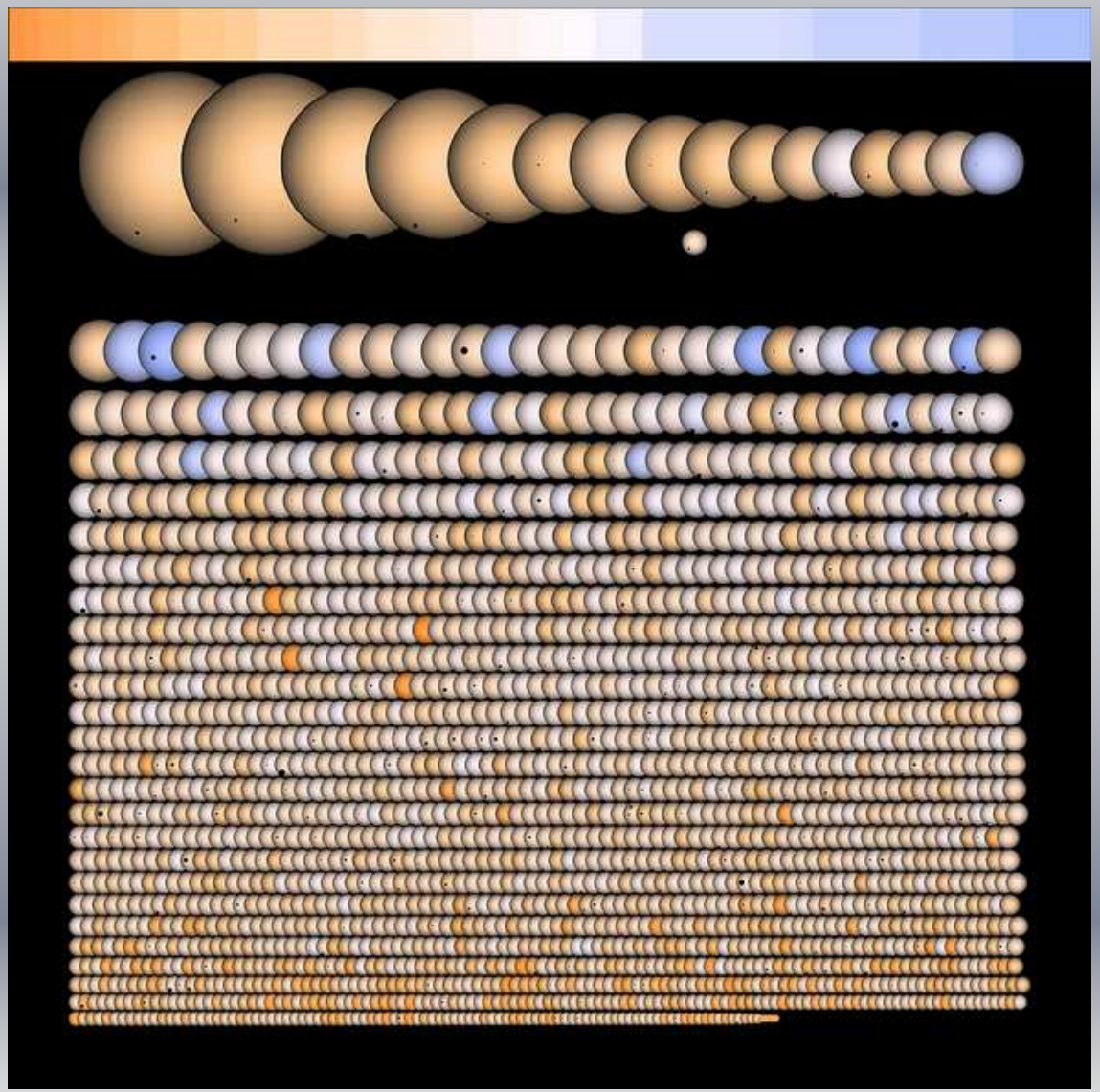
Searching for Extra-Solar Planets





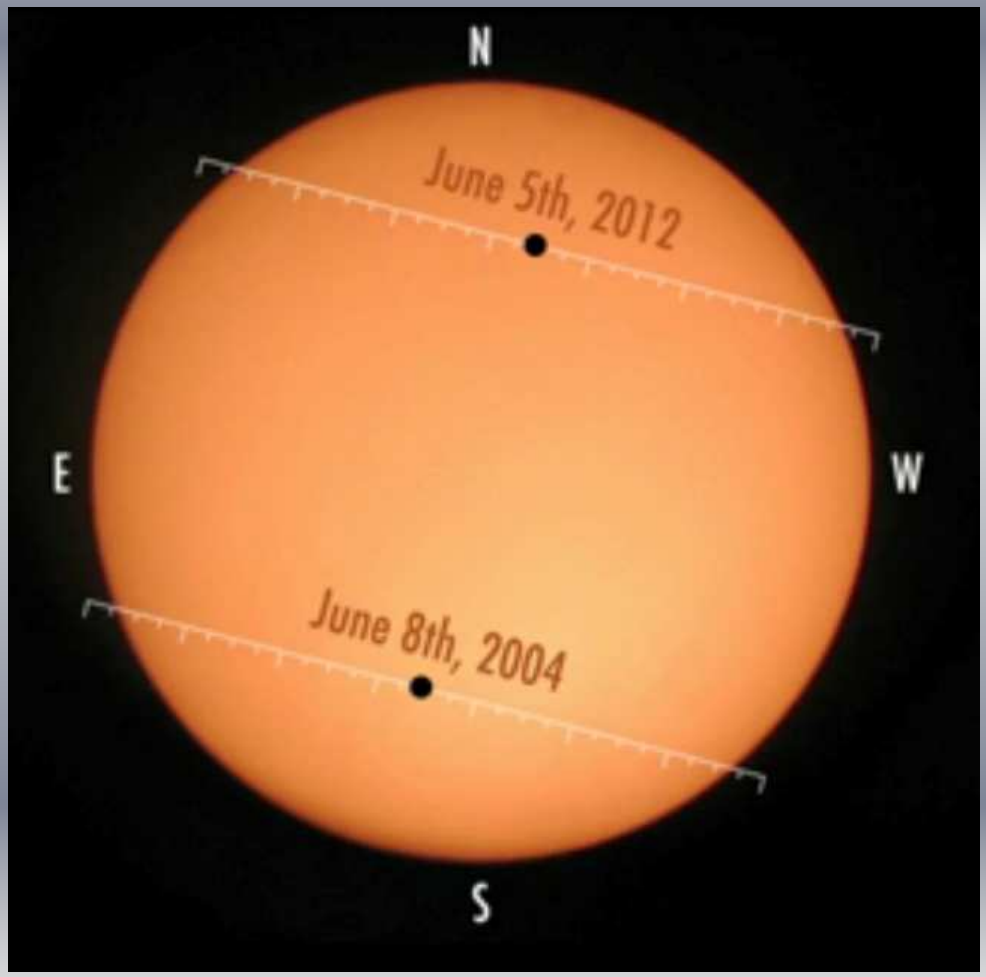


Kepler's Planet Candidates: A Family Portrait



International Space Station:

NASA astronaut Don Pettit, one of six members of the station's Expedition 31 crew, plans to be the first person to photograph the transit of Venus from space.



APP VenusTransit :

•available on iOS (iPhone) and Android platforms

•recreates a centuries-old experiment that was used to help calculate the size of the solar system, the Earth's distance from the sun.

http://www.transitofvenus.org/education/video-new-media

Piece pour deux Cristals écrite par Frederic BOUSQUET créée à l'Observatoire de Paris à l'occasion des TRANSIT OF VENUS 2004/2012

http://www.youtube.com/watch?v=dBbRI1AN7V0

List of observatories and organizations providing live webcasts on June 5 of the Venus transit of 2012:

NASA webcast from Mauna Kea, Hawaii:
http://venustransit.nasa.gov/2012/transit/webcast.php

Exploratorium (in San Francisco, Calif.) webcast from Mauna Loa, Hawaii: http://www.exploratorium.edu/venus/

Slooh Space Camera telescope feed from around the world: http://www.slooh.com/transit-of-venus/

Astronomers Without Borders webcast from the Mount Wilson Observatory in California:
http://www.astronomerswithoutborders.org/projects/transit-of-venus.html