2012 TRANSIT OF VENUS

BY FRED ESPENAK

On the Transit of Venus:

I recommend it therefore again and again to those curious astronomers who (when I am dead) will have an opportunity of observing these things, that they would remember this my admonition, and diligently apply themselves with all their might in making this observation, and I earnestly wish them all imaginable success: in the first place, that they may not by the unseasonable obscurity of a cloudy sky be deprived of this most desirable sight, and then, that having ascertained with more exactness the magnitudes of the planetary orbits, it may redound to their immortal fame and glory.

—Edmund Halley, 1716

The passage of a planet across the face of the Sun, a *transit*, is a relatively rare occurrence. Only transits of Mercury and Venus can be seen from Earth. On average, there are 13 transits of Mercury each century. In contrast, transits of Venus occur in pairs with more than a century separating each pair.

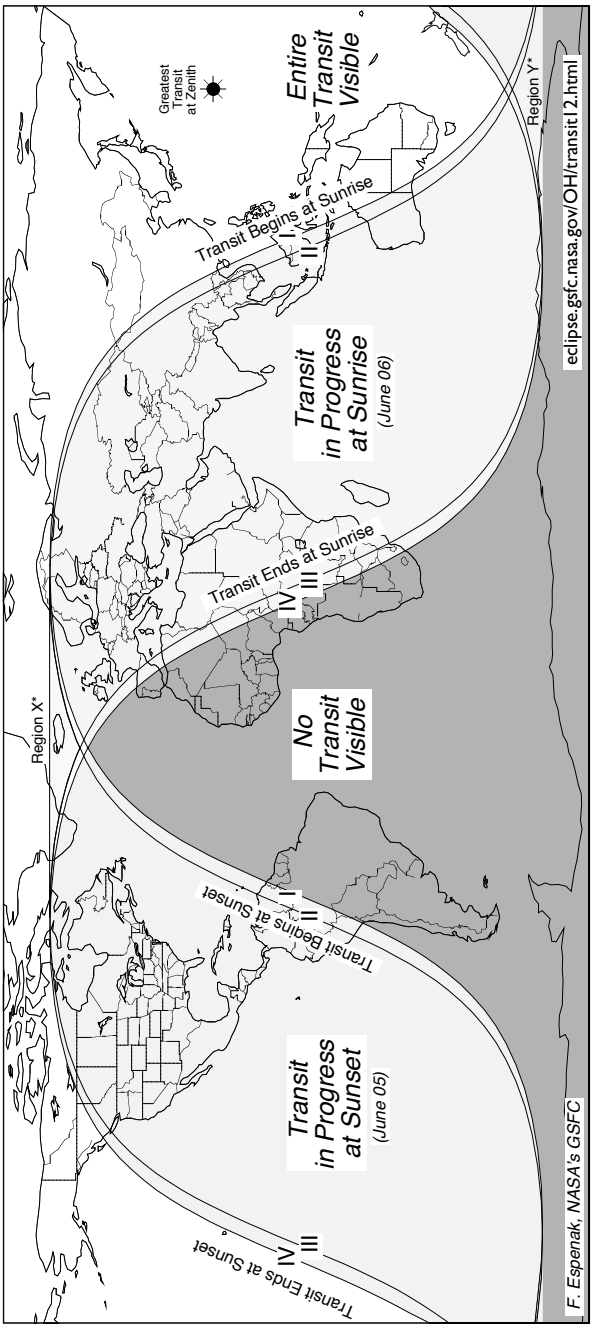
The last transit of Venus was in 2004, and the second event of the pair will occur on Wednesday, 2012 Jun. 6 (Tuesday, Jun. 5, from the Western Hemisphere). The entire event will be widely visible from the western Pacific, eastern Asia, and eastern Australia as shown in Figure 1 (p. 145). Most of North and Central America, and northern South America will witness the beginning of the transit (on Jun. 5), but the Sun will set before the event ends. Similarly, observers in Europe, western and central Asia, eastern Africa, and western Australia will see the end of the event because the transit will already be in progress at sunrise from those locations.

For Northern Hemisphere locations above latitude ~67° north, the entire transit is visible regardless of the longitude. Observers in northern Canada and all of Alaska will also see the entire event. Residents of Iceland are in a unique wedge-shaped part of the path (Region X in Figure 1, p. 145). They will see both the start and end of the transit, but the Sun will set for a short period around greatest transit. A similarly shaped region exists south of Australia (Region Y in Figure 1, p. 145), but here, the Sun rises after the transit begins and sets before the event ends.

The principal events occurring during a transit are conveniently characterized by contacts, analogous to the contacts of an annular solar eclipse. The transit begins with contact I, the instant the planet's disk is externally tangent to the Sun. Shortly after contact I, the planet can be seen as a small notch along the solar limb. The entire disk of the planet is first seen at contact II, when the planet is internally tangent to the Sun. Over the course of several hours, the silhouetted planet slowly traverses the solar disk. At contact III, the planet reaches the opposite limb and once again is internally tangent to the Sun. Finally, the transit ends at contact IV, when the planet's limb is externally tangent to the Sun. Contacts I and II define the phase called "ingress," and contacts III and IV are called "egress."

Table 1 gives the geocentric times of major events during the transit. Greatest transit is the instant when Venus passes closest to the Sun's centre (i.e. minimum separation). During the 2012 transit, Venus's minimum separation from the Sun is 554″. (During the 2004 transit, the minimum separation was 627″.) The position angle is defined as the direction of Venus with respect to the centre of the Sun's disk, measured counterclockwise from the celestial north point on the Sun. Figure 2 (p. 147) shows the path of Venus across the Sun's disk, and the scale gives the Universal Time of Venus's position at any point during the transit. The celestial coordinates of the Sun and Venus are provided at greatest transit as well as the times of the major contacts.

FIGURE 1—WORLD VISIBILITY FOR TRANSIT OF VENUS, 2012 JUNE 5/6



* 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.

TABLE 1—GEOCENTRIC PHASES OF THE TRANSIT OF VENUS, 2012 JUNE 6

Event	Universal Time	Position Angle
Contact I	22:09:38	41°
Contact II	22:27:34	38°
Greatest transit	01:29:36	345°
Contact III	04:31:39	293°
Contact IV	04:49:35	290°

Note that these times are for an observer at Earth's centre. The actual contact times for any given observer may differ by up to ±7 min. This is due to effects of parallax, since Venus's 58″ diameter disk may be shifted up to 30″ from its geocentric coordinates, depending on the observer's exact position on Earth. Tables 2 and 3 (pp. 150–151) list predicted local contact times and corresponding altitudes of the Sun for locations throughout Canada and the United States, respectively. Table 4 (p. 152) provides similar predictions for a number of cities around the world.

Observing the Transit

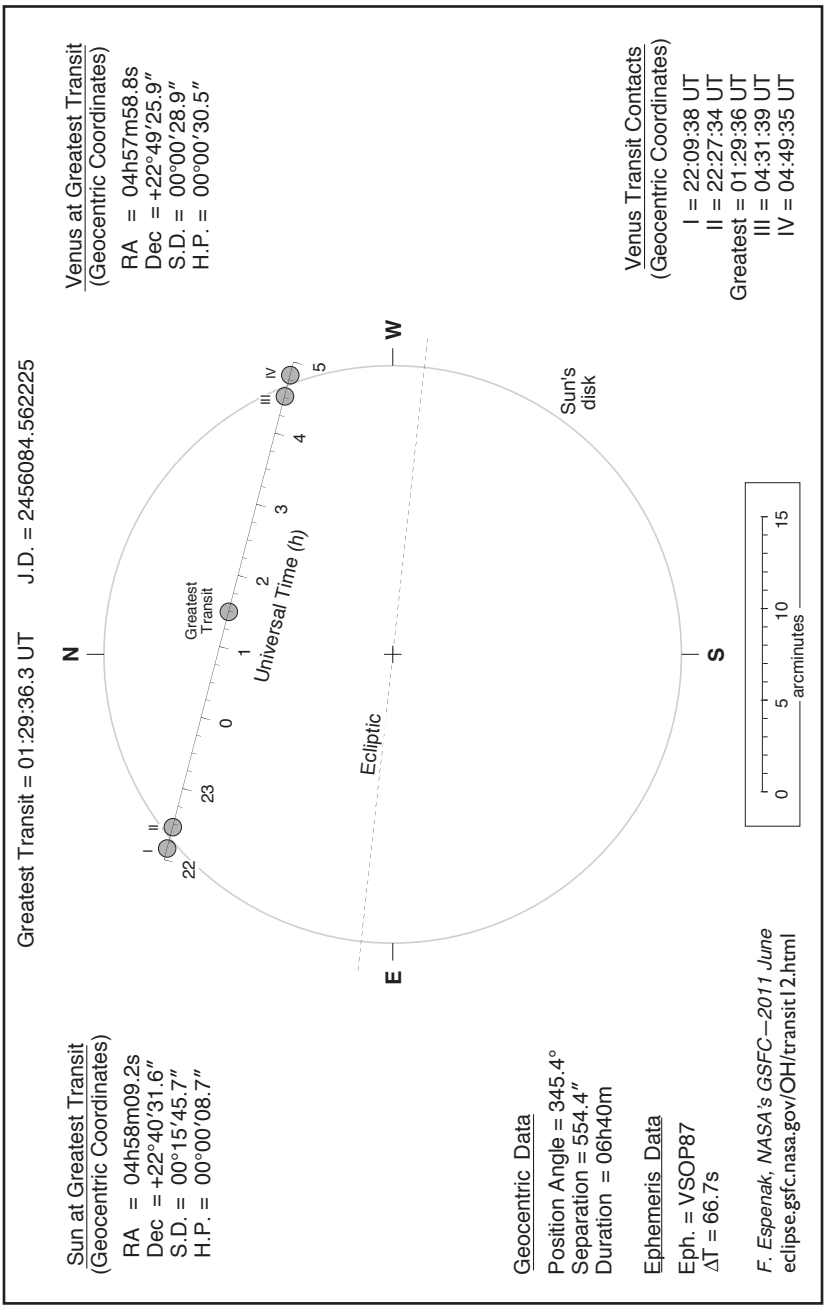
Because the angular diameter of Venus is almost 1′ during the transit, it is just possible to see Venus without optical magnification (but using solar filter protection) as it crosses the Sun. Nevertheless, this angle is only 1/32 of the Sun's angular diameter, so binoculars or a small telescope at modest power will offer a much more satisfying view. All binoculars and telescopes must be suitably equipped with adequate filtration to ensure safe solar viewing. The visual and photographic requirements for observing a transit are identical to those for solar viewing. Amateurs can make a scientific contribution by timing the four contacts at ingress and egress. Observing techniques and equipment are similar to those used for lunar occultations. Poor seeing often increases the uncertainty in contact timings, so an estimate of the possible error associated with each timing should be included. Transit timings and geographic coordinates of the observing site (measured with a topographic map or GPS receiver) should be sent to Association of Lunar & Planetary Observers (ALPO) Transit Section, c/o Dr. John E. Westfall, PO Box 2447, Antioch CA 94531-2447, USA (johnwestfall@comcast.net). Also see the APO Internet page www.alpo-astronomy.org/transitblog.

White-light observations of contacts I and IV are not technically possible because Venus is only visible after contact I and before contact IV. However, with hydrogen-alpha filtration, if available, the planet will be visible against either prominences or the chromosphere before and after contacts I and IV, respectively. Observations of contacts II and III also require amplification. They are defined as the two instants when the planet appears internally tangent to the Sun. However, just before contact II, the so-called "black drop" effect is seen. At that time, the transiting planet seems to be attached to the Sun's limb by a thin column or thread. The instant when the thread breaks and the planet is completely surrounded by sunlight marks the true instant of contact II. Contact III occurs in exactly the reverse order. Atmospheric seeing often makes it difficult to measure contact timings with a precision better than several seconds (see "black drop" effect in **History of Transits** below).

Frequency of Transits

The orbit of Venus is inclined 3.4° with respect to Earth's orbit. It intersects the ecliptic at two points, or nodes, which cross the Sun each year during early June and December. If Venus happens to pass through inferior conjunction at that time, a transit will occur. Although Venus's orbital period is only 224.7 days, its synodic period

FIGURE 2—PATH OF VENUS ACROSS THE SUN'S DISK, 2012 JUNE 5/6



(conjunction to conjunction) is 583.9 days. Due to its inclination, most inferior conjunctions of Venus do not result in a transit because the planet passes too far above or below the ecliptic and does not cross the face of the Sun. Venus transits currently recur at intervals of 8, 105.5, 8 and 121.5 years. Since the invention of the telescope (1609), there have only been seven transits, as listed in Table 5 (below). The 2004 and 2012 transits form a contemporary pair separated by 8 years. More than a century will elapse before the next pair of transits in 2117 and 2125.

TABLE 5—TRANSITS OF VENUS: 1601–2200

Date	Universal Time	Separation
1631 Dec. 7	5:19	939″
1639 Dec. 4	18:26	524″
1761 Jun. 6	5:19	570″
1769 Jun. 3	22:25	609″
1874 Dec. 9	4:07	830″
1882 Dec. 6	17:06	637″
2004 Jun. 8	8:20	627″
2012 Jun. 6	**1:30**	**554″**
2117 Dec. 11	2:48	724″
2125 Dec. 8	16:01	733″

During the 6000-year period from 2000 BC to AD 4000, a total of 81 transits of Venus occur. A catalogue of these events containing additional details is available online at

eclipse.gsfc.nasa.gov/transit/catalog/VenusCatalog.html.

Additional information on transits of both Mercury and Venus can be found at

eclipse.gsfc.nasa.gov/transit/transit.html.

History of Transits

Johannes Kepler's *Rudolphine Tables* of planetary motion, which he published in 1627, permitted him to make detailed and fairly accurate predictions of the future positions and interesting alignments of the planets. Much to his surprise, he discovered that both Mercury and Venus would transit the Sun's disk in late 1631. Kepler died before the transits took place, but French astronomer Pierre Gassendi succeeded in becoming the first to witness a transit of Mercury. The following month, he tried to observe the transit of Venus, but modern calculations show that it was not visible from Europe. Although Kepler's predictions suggested that the next Venus transit would not occur until the following century, a promising young British amateur astronomer named Jeremiah Horrocks believed that another transit would occur in 1639. His calculations were completed just a month before the event, so there was little time to spread the word. Horrocks and his friend William Crabtree were apparently the only ones to witness the transit of Venus on 1639 Dec. 4, which allowed them to accurately measure the apparent diameter of the planet. Unfortunately, Horrocks and Crabtree both died young before reaching their full potential.

Nearly 40 years later, a young Edmund Halley observed the 1677 transit of Mercury while completing a Southern Hemisphere star catalogue from Saint Helena's Island. Halley realized that the careful timing of transits could be used to determine the distance of Earth from the Sun. The technique relied on observations made from the far corners of the globe. The effect of parallax on the remote observers would allow them to derive the absolute distance scale of the entire Solar System. Venus transits were better suited to this goal than Mercury transits because Venus is closer

to Earth and consequently exhibits a larger parallax. Halley challenged future generations to organize major expeditions to the ends of Earth in order to observe the transits of 1761 and 1769.

Many scientific expeditions were mounted, but the results were disappointing. The accurate timings needed were not possible due to a mysterious "black drop" effect in which the edge of Venus's disk appeared to deform and cling to the limb of the Sun. Undeterred by the results, another major observing campaign was mounted by many nations for the Venus transits of 1874 and 1882. Again, the "black drop" limited the precision of the observations and the determination of the Sun's distance. Modern analyses show that the "black drop" is the result of seeing effects due to Earth's turbulent atmosphere.

The distance to the Sun and planets can now be measured extremely accurately using radar, so the 2004 and 2012 transits are of minor scientific importance. Still, transits are remarkably rare events that were of great value during the early history of modern astronomy.

Acknowledgments

The 2012 transit predictions were generated on a Macintosh G4 PowerPC computer using algorithms developed from Meeus (1989) and the *Explanatory Supplement* (1974). Ephemerides for the Sun and Venus were generated from VSOP87.

All calculations, diagrams, tables, and opinions presented in this paper are those of the author, and he assumes full responsibility for their accuracy.

This publication is available electronically, along with additional information and updates, at

eclipse.gsfc.nasa.gov/OH/transit12.html.

References

Aughton, P., *The Transit of Venus*, Weidenfeld & Nicolson, 2004.

Espenak, F., "2004 and 2012 Transits of Venus," *Proceedings for Scientific Frontiers in Research on Extrasolar Planets*, PASP, 2002.

Espenak, F., "2004 Transit of Venus," *Observer's Handbook 2004*, Royal Astronomical Society of Canada, 2003.

Explanatory Supplement to the Astronomical Ephemeris and the American Ephemeris and Nautical Almanac, Her Majesty's Nautical Almanac Office, London, 1974.

Maor, E., *June 8, 2004: Venus in Transit*, Princeton University Press, Princeton, 2000.

Maunder, M. & Moore, P., *Transit: When Planets Cross the Sun*, Springer Verlag, 1999.

Meeus, J., "Transits of Venus, 3000 BC to AD 3000," *JBAA*, 68 (1958), p. 98.

Meeus, J., *Transits*, Willmann-Bell, Inc., Richmond, 1989.

Newcomb, S., "Tables of the Motion of the Earth on its Axis Around the Sun," *Astron. Papers Amer. Eph.,* Vol. 6, Part I, 1895.

Sheehan, W. & Westfall, J., *The Transits of Venus*, Prometheus Books, 2004.

Editor's Note: For another perspective on this historic astronomical event, see Roy Bishop's article on p. 9. For general information on observing Venus, see p. 220. The "black-drop effect" is examined in the article "The Black-Drop Effect during the Transit of Venus on June 8, 2004," by Duval et al., *JRASC 99*, 170–176 (2005), tinyurl.com/5r8fln6. A colour version of that article is available at www.rasc.ca/handbook/supplements.shtml.

TABLE 2—LOCAL CIRCUMSTANCES FROM CANADA FOR TRANSIT OF VENUS, 2012 JUNE 5

Location	External Ingress h : m : s	Sun Alt °	Internal Ingress h : m : s	Sun Alt °	Greatest Transit h : m : s	Sun Alt °	Internal Egress h : m : s	Sun Alt °	External Egress h : m : s	Sun Alt °
Alberta										
Calgary	16:05:23	49	16:22:58	47	19:26:04	19	—	–	—	–
Edmonton	16:05:17	48	16:22:51	46	19:26:11	19	—	–	—	–
British Columbia										
Prince George	15:05:43	52	15:23:17	50	18:26:13	24	21:30:51	0	—	–
Victoria	15:05:59	56	15:23:33	53	18:25:59	24	—	–	—	–
Manitoba										
Brandon	17:04:44	42	17:22:20	39	20:26:07	10	—	–	—	–
Churchill	17:04:24	36	17:21:59	34	20:26:34	11	—	–	—	–
Winnipeg	17:04:36	40	17:22:12	37	20:26:10	8	—	–	—	–
New Brunswick										
Moncton	19:03:26	19	19:21:06	16	—	–	—	–	—	–
Newfoundland and Labrador										
Gander	19:33:14	13	19:50:55	10	—	–	—	–	—	–
St. John's	19:33:11	11	19:50:53	8	—	–	—	–	—	
Northwest Territory										
Inuvik	16:05:35	43	16:23:09	42	19:27:00	29	22:31:52	12	22:49:38	11
Yellowknife	16:05:06	43	16:22:40	41	19:26:36	21	22:31:56	3	22:49:46	1
Nova Scotia										
Halifax	19:03:25	17	19:21:05	14	—	–	—	–	—	–
Sydney	19:03:19	15	19:21:00	13	—	–	—	–	—	–
Nunavut										
Alert	19:04:35	23	19:22:12	22	22:28:03	17	1:34:10	15	1:51:50	15
Iqaluit	18:03:46	23	18:21:23	21	21:27:16	4	—	–	—	–
Resolute	17:04:35	30	17:22:11	29	20:27:23	17	23:33:23	9	23:51:08	8
Ontario										
East York	18:03:56	28	18:21:35	25	—	–	—	–	—	
Gloucester	18:03:47	26	18:21:25	23	—	–	—	–	—	–
Hamilton	18:03:58	29	18:21:36	25	—	–	—	–	—	–
Kingston	18:03:49	26	18:21:28	23	—	–	—	–	—	–
Kitchener	18:03:59	29	18:21:38	26	—	–	—	–	—	–
London	18:04:02	29	18:21:40	26	—	–	—	–	—	–
Mississauga	18:03:57	28	18:21:35	25	—	–	—	–	—	–
Ottawa	18:03:47	26	18:21:25	23	—	–	—	–	—	–
Peterborough	18:03:53	28	18:21:32	24	—	–	—	–	—	–
Saint Catharines	18:03:57	28	18:21:35	25	—	–	—	–	—	
Sault Ste. Marie	18:04:06	32	18:21:43	29	21:26:19	0	—	–		
Sudbury	18:03:58	30	18:21:36	27	—	–	—	–	—	–
Thunder Bay	18:04:17	35	18:21:53	32	21:26:15	3	—	–	—	
Toronto	18:03:56	28	18:21:35	25	—	–	—	–	—	–
Windsor	18:04:07	31	18:21:45	27	—	–	—	–	—	–
York	18:03:57	28	18:21:35	25	—	–	—	–	—	–
Prince Edward Island										
Charlottetown	19:03:24	17	19:21:04	15	—	–	—	–	—	–
Québec										
Chicoutimi	18:03:37	23	18:21:15	20	—	–	—	–	—	–
Drummondville	18:03:40	24	18:21:19	21	—	–	—	–	—	–
Gatineau	18:03:47	26	18:21:25	23	—	–	—	–	—	–
Montréal	18:03:42	24	18:21:21	21	—	–	—	–	—	–
Québec	18:03:37	23	18:21:16	20	—	–	—	–	—	–
Sherbrooke	18:03:39	23	18:21:18	20	—	–	—	–	—	–
Trois Rivières	18:03:40	24	18:21:19	21	—	–	—	–	—	
Saskatchewan										
Regina	16:04:57	44	16:22:32	42	19:26:06	13	—	–	—	–
Saskatoon	16:05:00	45	16:22:35	42	19:26:09	15	—	–	—	–
Yukon										
Whitehorse	15:05:57	50	15:23:31	49	18:26:38	31	21:31:03	9	21:48:51	7

All times are in Local Daylight Saving Time (Saskatchewan times are Central Standard Time).

TABLE 3—LOCAL CIRCUMSTANCES FROM THE USA FOR TRANSIT OF VENUS, 2012 JUNE 5

Location	External Ingress h : m : s	Sun Alt °	Internal Ingress h : m : s	Sun Alt °	Greatest Transit h : m : s	Sun Alt °	Internal Egress h : m : s	Sun Alt °	External Egress h : m : s	Sun Alt °
Albany, NY	18:03:45	24	18:21:24	21	—	–	—	–	—	–
Atlanta, GA	18:04:25	31	18:22:04	27	—	–	—	–	—	–
Anchorage, AK	14:06:30	51	14:24:04	51	17:26:53	38	20:30:46	16	20:48:32	14
Austin, TX	17:05:18	42	17:22:57	38	20:25:39	0	—	–	—	–
Birmingham, AL	18:04:33	33	18:22:12	29	—	–	—	–	—	–
Boise, ID	16:05:48	54	16:23:23	51	19:25:48	19	—	–	—	–
Boston, MA	18:03:39	22	18:21:19	19	—	–	—	–	—	–
Charleston, WV	18:04:09	29	18:21:48	26	—	–	—	–	—	–
Chicago, IL	17:04:20	34	17:21:58	31	20:26:06	0	—	–	—	–
Cincinnati, OH	18:04:15	32	18:21:54	28	—	–	—	–	—	–
Columbia, SC	18:04:15	28	18:21:54	25	—	–	—	–	—	–
Dallas, TX	17:05:08	41	17:22:46	37	20:25:42	0	—	–	—	–
Denver, CO	16:05:19	47	16:22:55	44	19:25:44	9	—	–	—	–
Des Moines, IA	17:04:38	39	17:22:15	35	20:25:58	2	—	–	—	–
Detroit, MI	18:04:07	31	18:21:45	28	—	–	—	–	—	–
El Paso, TX	17:05:47	49	17:23:24	45	20:25:33	8	—	–	—	–
Hartford, CT	18:03:43	23	18:21:22	20	—	–	—	–	—	–
Honolulu, HI	12:10:07	85	12:27:46	89	15:26:20	49	18:26:38	9	18:44:38	5
Houston, TX	17:05:11	39	17:22:50	36	—	–	—	–	—	–
Indianapolis, IN	17:04:19	33	17:21:57	30	—	–	—	–	—	–
Jackson, MS	17:04:46	35	17:22:25	32	—	–	—	–	—	–
Kansas City, MO	17:04:46	39	17:22:23	36	20:25:53	2	—	–	—	–
Kona, HI	12:10:09	86	12:27:48	87	15:26:16	47	18:26:33	7	18:44:33	3
Lincoln, NE	17:04:49	41	17:22:26	37	20:25:53	4	—	–	—	–
Little Rock, AR	17:04:48	37	17:22:26	34	—	–	—	–	—	–
Los Angeles, CA	15:06:26	58	15:24:02	55	18:25:33	18	—	–	—	–
Louisville, KY	18:04:20	32	18:21:59	29	—	–	—	–	—	–
Madison, WI	17:04:23	35	17:22:00	32	20:26:06	0	—	–	—	–
Memphis, TN	18:04:39	36	18:22:18	32	—	–	—	–	—	–
Miami, FL	18:04:31	26	18:22:13	22	—	–	—	–	—	–
Minneapolis, MN	18:04:32	38	18:22:08	35	21:26:04	4	—	–	—	–
New Orleans, LA	17:04:52	35	17:22:31	31	—	–	—	–	—	–
New York, NY	18:03:47	24	18:21:26	21	—	–	—	–	—	–
Omaha, NE	17:04:46	40	17:22:23	37	20:25:54	4	—	–	—	–
Philadelphia, PA	18:03:50	25	18:21:30	21	—	–	—	–	—	–
Phoenix, AZ	15:06:03	54	15:23:40	50	18:25:32	13	—	–	—	–
Pittsburgh, PA	18:04:01	28	18:21:40	25	—	–	—	–	—	–
Portland, OR	15:06:05	57	15:23:40	54	18:25:53	23	—	–	—	–
Providence, RI	18:03:40	22	18:21:20	19	—	–	—	–	—	–
Raleigh, NC	18:04:05	27	18:21:45	23	—	–	—	–	—	–
Richmond, VA	18:03:59	26	18:21:39	23	—	–	—	–	—	–
Rochester, NY	18:03:53	27	18:21:31	24	—	–	—	–	—	–
Sacramento, CA	15:06:23	60	15:23:58	56	18:25:40	21	—	–	—	–
St. Paul, MN	18:04:31	38	18:22:08	35	21:26:04	4	—	–	—	–
St. Louis, MO	17:04:33	36	17:22:11	32	20:25:58	0	—	–	—	–
Salem, OR	15:06:08	58	15:23:43	55	18:25:52	24	—	–	—	–
Salt Lake City, UT	16:05:41	52	16:23:16	49	19:25:43	15	—	–	—	–
San Antonio, TX	17:05:23	42	17:23:02	38	20:25:37	0	—	–	—	–
San Diego, CA	15:06:26	58	15:24:02	54	18:25:31	16	—	–	—	–
San Francisco, CA	15:06:29	61	15:24:04	57	18:25:39	22	—	–	—	–
San Jose, CA	15:06:29	60	15:24:04	57	18:25:38	21	—	–	—	–
Seattle, WA	15:05:58	56	15:23:32	53	18:25:57	23	—	–	—	–
Topeka, KS	17:04:49	40	17:22:26	37	20:25:51	3	—	–	—	–
Tulsa, OK	17:04:57	40	17:22:34	37	20:25:47	1	—	–	—	–
Washington, DC	18:03:56	26	18:21:35	22	—	–	—	–	—	–

All times are in Local Daylight Saving Time (AZ and HI times are Local Standard Time).

TABLE 4—LOCAL CIRCUMSTANCES FOR THE WORLD FOR TRANSIT OF VENUS, 2012 JUNE 6

Location	External Ingress h : m : s	Sun Alt °	Internal Ingress h : m : s	Sun Alt °	Greatest Transit h : m : s	Sun Alt °	Internal Egress h : m : s	Sun Alt °	External Egress h : m : s	Sun Alt °
LATIN AMERICA (June 5)										
Bogota	17:05:29	13	17:23:19	9	—	–	—	–	—	–
Caracas	18:04:45	9	18:22:34	5	—	–	—	–	—	–
Mexico City*	17:06:00	41	17:23:40	37	—	–	—	–	—	–
Panama City	17:05:28	20	17:23:14	16	—	–	—	–	—	–
EUROPE										
Amsterdam*	—	–	—	–	—	–	06:37:20	9	06:54:59	11
Athens*	—	–	—	–	—	–	07:37:58	16	07:55:34	20
Berlin*	—	–	—	–	—	–	06:37:21	14	06:54:58	16
Bern*	—	–	—	–	—	–	06:37:40	8	06:55:19	11
Brussels*	—	–	—	–	—	–	06:37:25	8	06:55:05	10
Bucharest*	—	–	—	–	—	–	07:37:40	20	07:55:14	23
Budapest*	—	–	—	–	—	–	06:37:37	16	06:55:13	19
Copenhagen*	—	–	—	–	—	–	06:37:09	14	06:54:45	17
Dublin*	—	–	—	–	—	–	05:37:07	4	05:54:48	6
Hamburg*	—	–	—	–	—	–	06:37:17	12	06:54:55	15
London*	—	–	—	–	—	–	05:37:20	6	05:55:00	8
Madrid*	—	–	—	–	—	–	—	–	06:55:33	1
Moscow	—	–	—	–	05:30:38	4	08:36:47	28	08:54:19	31
Oslo*	—	–	—	–	—	–	06:36:50	15	06:54:27	17
Paris*	—	–	—	–	—	–	06:37:31	6	06:55:11	9
Rome*	—	–	—	–	—	–	06:37:55	10	06:55:34	13
Stockholm*	—	–	—	–	03:29:59	0	06:36:52	18	06:54:27	20
Vienna*	—	–	—	–	—	–	06:37:36	14	06:55:12	17
Warsaw*	—	–	—	–	—	–	06:37:19	18	06:54:54	21
AFRICA										
Addis Abeba	—	–	—	–	—	–	04:37:35	20	04:55:12	24
Algiers	—	–	—	–	—	–	05:38:05	1	05:55:47	4
Cairo	—	–	—	–	—	–	06:37:59	20	06:55:34	24
Johannesburg	—	–	—	–	—	–	—	–	06:53:56	0
Nairobi	—	–	—	–	—	–	07:37:19	15	07:55:00	19
ASIA MINOR										
‘Amman*	—	–	—	–	—	–	07:37:47	25	07:55:20	28
Istanbul*	—	–	—	–	—	–	08:37:44	21	08:55:18	24
Jerusalem*	—	–	—	–	—	–	07:37:49	24	07:55:22	28
Riyadh	—	–	—	–	—	–	07:37:20	32	07:54:51	36
Tehran*	—	–	—	–	06:02:07	2	09:06:58	38	09:24:27	41
ASIA										
Bangkok	—	–	—	–	08:32:25	36	11:32:23	76	11:49:54	79
Beijing	06:10:01	14	06:27:48	17	09:30:40	52	12:31:59	72	12:49:28	71
Hong Kong	06:11:49	6	06:29:42	10	09:31:29	51	12:31:21	88	12:48:52	84
Jakarta	—	–	—	–	09:32:37	33	12:30:53	61	12:48:30	61
Kolkata (Calcutta)	—	–	—	–	07:02:30	28	10:03:56	69	10:21:24	73
Manila	06:12:47	10	06:30:41	14	09:31:22	55	12:30:18	78	12:47:52	75
Mumbai	—	–	—	–	07:02:58	13	10:05:18	54	10:22:47	58
Shanghai	06:11:05	15	06:28:54	19	09:30:47	57	12:31:07	78	12:48:38	75
Singapore	—	–	—	–	09:32:37	35	12:31:31	67	12:49:05	68
T’aipei	06:11:45	13	06:29:36	17	09:31:00	58	12:30:47	81	12:48:19	77
Tokyo	07:10:49	31	07:28:33	35	10:29:39	70	13:29:55	63	13:47:30	59
OCEANIA										
Adelaide	07:46:09	4	08:04:16	7	11:01:07	30	13:57:08	27	14:15:06	26
Auckland, NZ	10:15:33	24	10:33:35	25	13:29:10	28	16:25:16	7	16:43:25	4
Brisbane	08:15:51	19	08:33:53	22	11:30:10	40	14:26:09	27	14:44:07	24
Christchurch, NZ	10:15:45	17	10:33:50	19	13:29:29	22	16:25:33	4	16:43:43	2
Hobart	08:16:14	5	08:34:22	8	11:30:44	24	14:26:38	17	14:44:41	15
Melbourne	08:16:12	7	08:34:19	10	11:30:48	28	14:26:43	22	14:44:43	20
Papeete, Tahiti	12:12:38	50	12:30:30	49	15:26:46	25	—	–	—	–
Perth	—	–	—	–	09:32:18	23	12:29:04	35	12:46:55	35
Sydney	08:16:04	13	08:34:09	16	11:30:23	33	14:26:17	23	14:44:17	20

All times are in Local Standard Time (Cities marked with * give Daylight Saving Time)