

A MATLAB Script for Predicting Transits of Mercury and Venus

This document describes a MATLAB script named `transit.m` which can be used to predict the local circumstances of transits of Mercury and Venus across the Sun. This software provides the universal times and topocentric coordinates of the Sun at the beginning (ingress - exterior contact) and end (egress - exterior contact) of the solar transit, and the time and coordinates at least distance. The source ephemeris for this routine is a JPL binary ephemeris file. This application uses several functions ported to MATLAB from the Fortran version of the NOVAS (Naval Observatory Vector Astrometry Subroutines) source code developed at the United States Naval Observatory (www.usno.navy.mil/USNO/astronomical-applications/software-products/novas). JPL binary ephemeris files for Windows compatible computers can be downloaded at www.cdeagle.com.

This script uses a combination of one-dimensional minimization and root-finding to solve this problem. The objective function used in these calculations is the topocentric separation angle between the center of the Sun and the planet in transit. This function is given by the following expression:

$$f(t) = \cos^{-1}(\hat{\mathbf{u}}_s \bullet \hat{\mathbf{u}}_p) - (s_s + s_p)$$

where

$\hat{\mathbf{u}}_s$ = topocentric unit position vector of the Sun

$\hat{\mathbf{u}}_p$ = topocentric unit position vector of the planet

s_s = semidiameter of the Sun

s_p = semidiameter of the planet

During the search for minimum separation angles, the software also checks to see if the planet is between the observer and the Sun.

The semidiameter of the Sun is given by

$$s_s = \sin^{-1}\left(\frac{r_s}{d_s}\right)$$

where r_s is the radius of the Sun (696,000 kilometers) and d_s is the topocentric distance of the Sun.

The semidiameter of Mercury and Venus is determined from the expression

$$s_p = \frac{s_{p_0}}{r_p}$$

where s_{p_0} is the semidiameter of the planet at a distance of 1 astronomical unit and r_p is the topocentric distance of the planet. This MATLAB script uses a value of 3.36 arc seconds for Mercury and 8.41 arc seconds for Venus.

Celestial Computing with MATLAB

The following is a typical user interaction with this script. The screen output created by the script illustrates the circumstances of a transit of Venus. The initial calendar date was June 1, 2012, the search duration was 30 days, and the observer was located at the Chamberlin Observatory in Denver, Colorado. The calendar date and time displayed is on the UTC time scale. The ingress and egress conditions correspond to exterior contact.

```
transits of Mercury and Venus
=====

please input an initial UTC calendar date

please input the calendar date
(1 <= month <= 12, 1 <= day <= 31, year = all digits!)
? 6,1,2012

please input the search duration (days)
? 30

target body menu

    <1> Mercury

    <2> Venus

please select the target body
? 2

please input the geographic latitude of the observer
(-90 <= degrees <= +90, 0 <= minutes <= 60, 0 <= seconds <= 60)
(north latitude is positive, south latitude is negative)
? 39,40,36

please input the geographic longitude of the observer
(0 <= degrees <= 360, 0 <= minutes <= 60, 0 <= seconds <= 60)
(east longitude is positive, west longitude is negative)
? -104,57,12

please input the altitude of the observer (meters)
(positive above sea level, negative below sea level)
? 1644

ingress - exterior contact - Venus
-----

calendar date          05-Jun-2012
universal time          22:05:16
UTC Julian date         2456084.4203
azimuth angle of the sun    +260d 55m 21.01s
elevation angle of the sun   +47d 07m 29.61s

least distance of the Sun and Venus
-----

calendar date          06-Jun-2012
universal time          01:25:52
```

Celestial Computing with MATLAB

```

UTC Julian date          2456084.5596

azimuth angle of the sun    +291d 49m 44.18s

elevation angle of the sun  +09d 17m 17.60s

egress - exterior contact - Venus
-----

calendar date            06-Jun-2012

universal time           04:48:53

UTC Julian date          2456084.7006

azimuth angle of the sun    +328d 06m 51.59s

elevation angle of the sun  -20d 41m 47.83s

event duration           +06h 43m 36.9100s
  
```

The following are the results for this same transit using the Multiyear Interactive Computer Almanac (MICA) published by the United States Naval Observatory.

Transit of Venus of 2012 June 06
Delta T: 67.7s

Chamberlin Obs., Denver
Location: W104°57'12.0", N39°40'36.0", 1644m
(Longitude referred to Greenwich meridian)

	UT1	Sun's Altitude	Sun's Azimuth	Position Angle	Angular Separation
	d h m s	°	°	°	'
Transit Begins	5 22:05:21.4	47.1	260.9	41.1	16.2
Ingress Interior Contact	5 22:22:49.2	43.8	264.2	38.6	15.3
Least Angular Distance	6 01:25:42.5	9.3	291.8		9.1
Sunset	6 02:25	----	300.9	-----	----
Duration:	4h 19m 14.9s				
Solar Semidiameter:	15' 45.7"				
Semidiameter of Venus:	0' 28.9"				