

Predicting Transits of Mercury and Venus

This *Numerit* program (`transit`) can be used to predict the local circumstances of transits of Mercury and Venus. The source ephemeris for this program is SLP96. This software provides the the universal times and topocentric coordinates of the Sun at ingress, least separation distance and egress. The ingress and egress conditions correspond to exterior contact.

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

The objective function used during the search for transits of Mercury and Venus is given by the following expression:

$$f(t) = \cos^{-1}(-\mathbf{U}_s \cdot \mathbf{U}_p) - (s_s + s_p) \quad (1)$$

where

- \mathbf{U}_s = geocentric unit position vector of the Sun
- \mathbf{U}_p = geocentric unit position vector of the planet
- s_s = semidiameter of the Sun
- s_p = semidiameter of the planet

The semidiameter of the Sun is given by

$$s_s(t) = \sin^{-1}\left(\frac{r_s}{d_s}\right) \quad (2)$$

where r_s is the radius of the Sun (696,000 kilometers) and d_s is the topocentric distance of the Sun at any search time t .

The semidiameter of Mercury and Venus is determined from the expression

$$s_p = \frac{s_{p_0}}{r_p} \quad (3)$$

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 program uses a value of 3.36 arcseconds for Mercury and 8.41 arcseconds for Venus.

Celestial Computing with Numerit

The following is a typical draft output created with this program. It is Example 6 from the book *Transits* by Jean Meeus.

Transit of Venus

ingress - exterior contact

calendar date	June 5, 2012
universal time	22 h 3 m 44.5196 s
UTC Julian date	2456084.419265273

solar azimuth angle	279 d 5 m 5.26833 s
solar elevation angle	25 d 56 m 12.8208 s

least distance conditions

calendar date	June 6, 2012
universal time	1 h 26 m 9.99654 s
UTC Julian date	2456084.559837923

solar azimuth angle	309 d 47 m 3.49342 s
solar elevation angle	-9 d 39 m 3.1792 s

egress - exterior contact

calendar date	June 6, 2012
universal time	4 h 50 m 59.9329 s
UTC Julian date	2456084.702082557

solar azimuth angle	355 d 49 m 16.1755 s
solar elevation angle	-28 d 16 m 40.7003 s

event duration	6 h 47 m 15.4133 s
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