TRANSIT OF VENUS ACROSS THE DISK OF THE SUN JUNE 5-6, 2012

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http://astroger.com

Input RA and Dec positions of Sun and Venus [1].

$$\mathbf{Data} := \text{READPRN}(\text{"Planets.txt"}) \qquad \text{DegPerRad} := \frac{180}{\pi}$$

Data =

	1	2	3	4	5
1	2456084	4	55	51.4	22
2	2456084.008	4	55	53.4	22
3	2456084.017	4	55	55.5	22
4	2456084.025	4	55	57.6	22
5	2456084.033	4	55	59.6	22
6	2456084.042	4	56	1.7	22
7	2456084.05	4	56	3.7	22
8	2456084.058	4	56	5.8	22
9	2456084.067	4	56	7.9	22
10	2456084.075	4	56	9.9	22
11	2456084.083	4	56	12	22
12	2456084.092	4	56	14	22
13	2456084.1	4	56	16.1	22
14	2456084.108	4	56	18.2	22
15	2456084.117	4	56	20.2	22
16	2456084.125	4	56	22.3	...

$$N := \text{rows}(\mathbf{Data}) \qquad N = 144$$

(Click in worksheet and drag or scroll to see all **Data** values.)

$$\mathbf{X1}(\mathbf{Data}) := \left|\begin{array}{l} \text{for } i \in 1..144 \\ \quad \left|\begin{array}{l} X_i \leftarrow \mathbf{Data}_{i,2} + \dfrac{\mathbf{Data}_{i,3} + \dfrac{\mathbf{Data}_{i,4}}{60}}{60} \\ X_i \leftarrow \text{mod}(X_i, 24) \end{array}\right. \\ X \end{array}\right.$$

Compute Sun's RA values in hours.

$$\mathbf{X2}(\mathbf{Data}) := \left| \begin{array}{l} \text{for } i \in 1..144 \\ \quad \left| \begin{array}{l} X_i \leftarrow \mathbf{Data}_{i,9} + \dfrac{\mathbf{Data}_{i,10} + \dfrac{\mathbf{Data}_{i,11}}{60}}{60} \\ X_i \leftarrow \text{mod}(X_i, 24) \end{array} \right. \\ X \end{array} \right.$$

Compute Venus's RA values in hours.

$$\mathbf{Y1}(\mathbf{Data}) := \left| \begin{array}{l} \text{for } i \in 1..144 \\ \quad \left| \begin{array}{l} Y_i \leftarrow \mathbf{Data}_{i,5} + \dfrac{\mathbf{Data}_{i,6} + \dfrac{\mathbf{Data}_{i,7}}{60}}{60} \\ Y_i \leftarrow \text{mod}(Y_i, 360) \end{array} \right. \\ Y \end{array} \right.$$

Compute Sun's Dec values in degrees.

$$\mathbf{Y2}(\mathbf{Data}) := \left| \begin{array}{l} \text{for } i \in 1..144 \\ \quad \left| \begin{array}{l} Y_i \leftarrow \mathbf{Data}_{i,12} + \dfrac{\mathbf{Data}_{i,13} + \dfrac{\mathbf{Data}_{i,14}}{60}}{60} \\ Y_i \leftarrow \text{mod}(Y_i, 360) \end{array} \right. \\ Y \end{array} \right.$$

Compute Venus's Dec values in degrees.

$Y1c := \mathbf{Y1}(\mathbf{Data})$ $\qquad$ $Y2c := \mathbf{Y2}(\mathbf{Data})$

$X1c := \mathbf{X1}(\mathbf{Data})$ $\qquad$ $X2c := \mathbf{X2}(\mathbf{Data})$

Set up for transit plot.

$i := \text{FRAME} + 1$

$a := 0.2627$ $\qquad$ $b := 0.008$

Values of a and b are semidiameters of Sun and Venus, respectively, on 2012 June 6.

$$\zeta := 0, \frac{\pi}{20} .. 2\cdot\pi \qquad \text{SCALE} := \frac{23.5 - 22}{5.05 - 4.9} \qquad \text{SCALE} = 10$$

Specify x and y coordinates of circle that represents Venus (to be plotted in black) and circle that represents Sun (to be plotted in orange):

(SCALE is used to produce equal scales on x and y axes of plot.)

$$x_1(\zeta, i) := a\cdot\frac{\cos(\zeta)}{\text{SCALE}} + X1c_i \qquad y_1(\zeta, i) := a\cdot\sin(\zeta) + Y1c_i$$

$$x_2(\zeta, i) := b\cdot\frac{\cos(\zeta)}{\text{SCALE}} + X2c_i \qquad y_2(\zeta, i) := b\cdot\sin(\zeta) + Y2c_i$$

The assignments above allow us to plot circles for both Sun and Venus, based upon their apparent semidiameters.

We now want to calculate the ingress and egress times for the transit and see how closely they match the times as given in the U.S. Naval Observatory's *Astronomical Almanac for the Year 2012,* p. A97 [2].

So what we will do is to calculate the angles-only (unit) position vectors and plot the actual separation as a function of time. Then draw a horizontal line corresponding to a separation of 15 min, 45.71 sec of arc, the Sun's semidiameter at 0h TT on June 6, 2012.

$$\mathbf{Sun} := \left|\begin{array}{l} \text{for } i \in 1..144 \\ \quad \left| \begin{array}{l} x \leftarrow \cos\left(\frac{Y1c_i}{\text{DegPerRad}}\right)\cdot\cos\left(\frac{X1c_i\cdot 15}{\text{DegPerRad}}\right) \\ y \leftarrow \cos\left(\frac{Y1c_i}{\text{DegPerRad}}\right)\cdot\sin\left(\frac{X1c_i\cdot 15}{\text{DegPerRad}}\right) \\ z \leftarrow \sin\left(\frac{Y1c_i}{\text{DegPerRad}}\right) \\ \text{Table} \leftarrow (x \;\; y \;\; z)^T \;\text{ if } i = 1 \\ \text{Table} \leftarrow \text{augment}\left[\text{Table}, (x \;\; y \;\; z)^T\right] \;\text{ otherwise} \end{array}\right. \\ \text{Table} \end{array}\right.$$

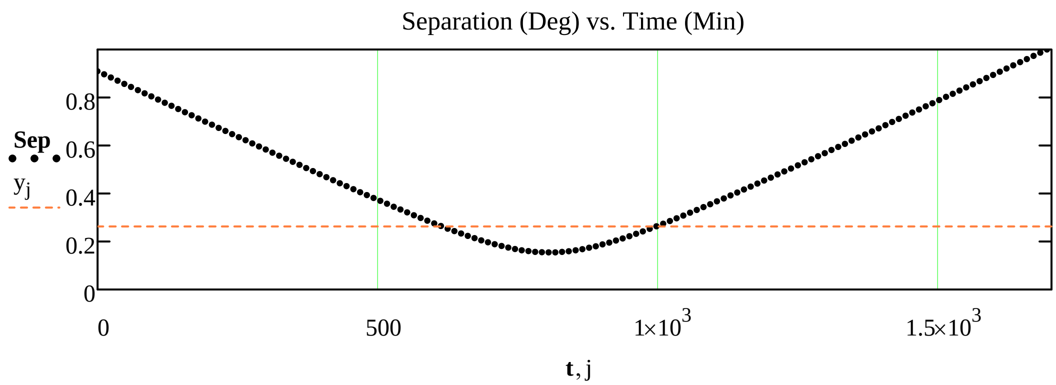
$$\mathbf{Venus} := \left| \begin{array}{l} \text{for } i \in 1..144 \\ \quad \left| \begin{array}{l} x \leftarrow \cos\left(\dfrac{Y2c_i}{DegPerRad}\right)\cdot\cos\left(\dfrac{X2c_i\cdot 15}{DegPerRad}\right) \\ y \leftarrow \cos\left(\dfrac{Y2c_i}{DegPerRad}\right)\cdot\sin\left(\dfrac{X2c_i\cdot 15}{DegPerRad}\right) \\ z \leftarrow \sin\left(\dfrac{Y2c_i}{DegPerRad}\right) \\ \text{Table} \leftarrow (x\ \ y\ \ z)^T \ \text{ if } i = 1 \\ \text{Table} \leftarrow \text{augment}\left[\text{Table}, (x\ \ y\ \ z)^T\right] \ \text{ otherwise} \end{array} \right. \\ \text{Table} \end{array} \right.$$

$$\text{Sun} := \frac{\dfrac{45.71}{60} + 15}{60} \qquad \text{Sun} = 0.26270$$

$$\mathbf{Sep} := \left| \begin{array}{l} \text{for } i \in 1..144 \\ \quad Sep_i \leftarrow \text{acos}\left(\mathbf{Sun}^{\langle i \rangle}\cdot\mathbf{Venus}^{\langle i \rangle}\right)\cdot DegPerRad \\ \text{Sep} \end{array} \right.$$

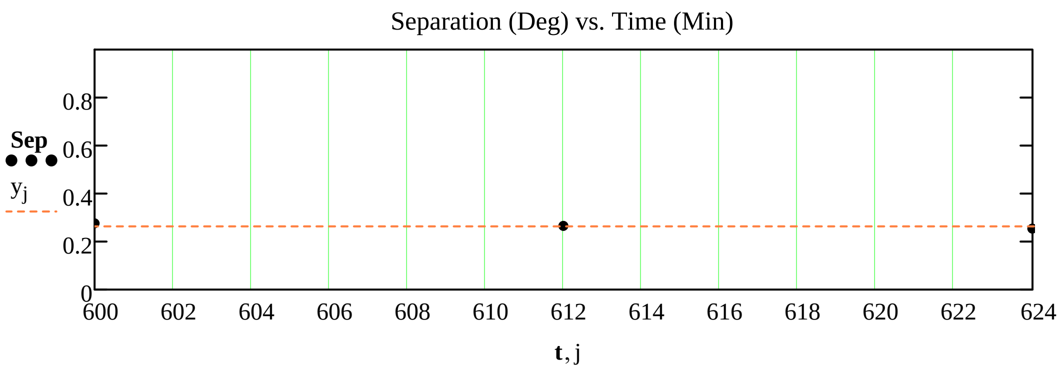
$i := 1..144$ $\qquad$ $\mathbf{t} := \left(\mathbf{Data}^{\langle 1 \rangle} - 2456084.0\right)\cdot 1440$

$j := 1..1700$ $\qquad$ $y_j := \text{Sun}$



We can easily see, by inspection, that ingress is about 600 minutes after epoch and egress is about 1000 minutes after epoch. To refine the estimates, we plot subsets of the graph of separation distance vs. time.

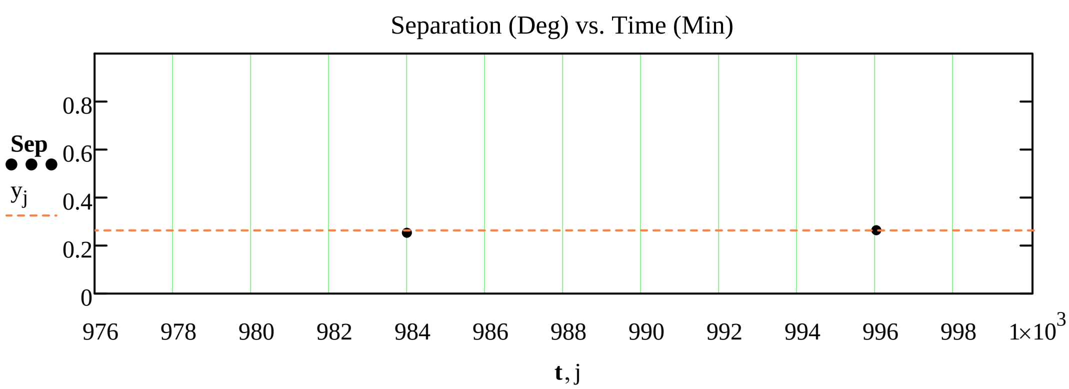
Plot subsets to estimate times of ingress and egress.



Ingress (Center of Venus Enters Disk of Sun)

By inspection, we see ingress at 612 minutes past epoch. Since epoch is at 2012 June 5 at 12:00 TT, we arrive at an ingress time of

2012 June 5 at 22:12 TT.



Egress (Center of Venus Exits Disk of Sun)

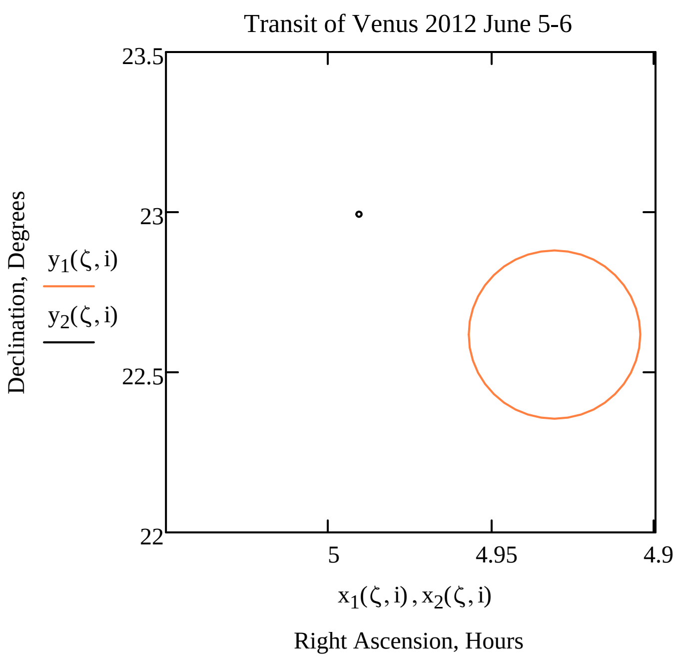
By inspection, we see egress at 996 minutes past epoch. Since epoch is at 2012 June 5 at 12:00 TT, we arrive at an egress time of

2012 June 6 at 04:36 TT.

The *Astronomical Almanac for the Year 2012* reports times of ingress - exterior contact and ingress - interior contact. Our ingress time lies between those two times. Further, the *AsA 2012* reports times of egress - interior contact and egress - exterior contact. Again, our egress time lies between those two times.

$i := FRAME + 1$

Here is the plot that we want to animate. To animate, select Animation>Record from the Tools menu, and for best results, let FRAME go from 0 to 140.



Geocentric Circumstances of the Transit

Ingress Venus (black) enters disk of Sun (orange) on 2012 June 5 at 18:11 EDT.

Egress Venus exits disk of Sun on 2012 June 6 at 00:35 EDT.

CAUTION!

Do not look directly at the Sun. Do wear "eclipse shades" or use pinhole camera projection to view the transit.

REFERENCES

[1] Standish, E. Myles Jr., *et al., JPL Planetary and Lunar Ephemerides on CD-ROM*, available from Willmann-Bell (http://www.willbell.com).

[2] Urban, Sean *et al., The Astronomical Almanac for the Year 2012,* Nautical Almanac Office, U.S. Naval Observatory, Washington, DC USA (also available from Willmann-Bell).