Why Don't Planets Eclipse Each Other? (orig. Feb 2005, rev. 11/2017)

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In grade school, we are always shown a diagram of the solar system where the orbits of the planets are shown snaking around circular orbits flat as a sheet of paper. So why don't they cover each other during passage? The only occultations or eclipses we hear about are those occurring with the sun and the moon, and even those don't happen very often. It seems that very rarely do we hear of one planet covering another in the sky.

The reason is the inclination of the orbits to the ecliptic, which for the planet Mercury is 7 degrees and for Pluto is as large as 17 degrees. The plane of the solar system isn't a plane at all, but a thick slab. As even large and close planets are on the average much less than one arcminute across, there is very little chance of the two planets possessing the same ecliptic offset at the moment of conjunction. The problem is complicated by multiple conjunctions (which increases the number of opportunities) and resonances between planets (which could go either way).

Rather than try to figure the multifarious combination for each planet, let's try to calculate a crude estimate of how often Jupiter occults Saturn, since it would be an impressive event. We need the sidereal periods of the planets (or how often they make a complete turn around the sun) and the synodic period of Jupiter with respect (or how often they line up). The sidereal period of Jupiter is 11.9 years and of Saturn 29.5 years. The synodic period is 19.9 years (the way this is calculated is tedious -- suffice it to say that it involves solving a tortoise-hare problem similar to Zeno's Paradox). Thus, every 20 years or so Jupiter passes Saturn. If the sum of their maximum diameters (46.9 and 19.5 arcseconds) is divided into the maximum inclination to the ecliptic, we see that the fractional probability that any such occultation comes off is 0.0074 or once in 135 passes. If we multiply this by 20 years, we get an average of about 2700 years. That is neglecting any orbital resonance that may occur, which may increase or (more likely) decrease this possibility. Plus, it also neglects multiple conjunctions, i.e., when conjunctions coincide with retrograde loops. In the 251 year span of MICA2 they passed, 19 conjunctions occurred.[1] The separations got nowhere near the 0.01 degree it would take, however, although the one in 2020 will be pretty good. See Table.

Table: Geocentric conjunctions of Saturn and Jupiter 1 Jan 1800 to 31 Dec 2050 (calculated with MICA2)

	Conjunction		Date			Separation			
				(TT)					
				d	h	°			
1	Saturn	1802	Jul	21	3	0.71	North	of	Jupiter
2	Saturn	1821	Jun	25	0	1.26	South	of	Jupiter
3	Saturn	1821	Nov	22	22	1.34	South	of	Jupiter
4	Saturn	1821	Dec	23	10	1.37	South	of	Jupiter
5	Saturn	1842	Jan	25	22	0.54	North	of	Jupiter
6	Saturn	1861	Oct	25	15	0.86	North	of	Jupiter
7	Saturn	1881	Apr	22	11	1.29	South	of	Jupiter
8	Saturn	1901	Nov	28	6	0.44	North	of	Jupiter
9	Saturn	1921	Sep	14	16	1.04	North	of	Jupiter
10	Saturn	1940	Aug	15	13	1.25	South	of	Jupiter
11	Saturn	1940	Oct	11	23	1.29	South	of	Jupiter
12	Saturn	1941	Feb	20	19	1.36	South	of	Jupiter
13	Saturn	1961	Feb	18	14	0.23	North	of	Jupiter
14	Saturn	1981	Jan	14	8	1.14	North	of	Jupiter
15	Saturn	1981	Feb	19	7	1.15	North	of	Jupiter
16	Saturn	1981	Jul	30	21	1.2	North	of	Jupiter
17	Saturn	2000	May	31	10	1.19	South	of	Jupiter
18	Saturn	2020	Dec	21	13	0.1	North	of	Jupiter
19	Saturn	2040	Nov	5	13	1.23	North	of	Jupiter

[1] US Naval Observatory, *Multiyear Interactive Computer Almanac (MICA) Ver 2*, Willmann-Bell, 1998-2005.

It is Venus and Mercury that have the greatest opportunity of coinciding, simply because they have the highest number of conjunctions. The last time they touched was for the evening of May 28 1737, and only from northern latitudes and a very narrow zone of longitude.[2] Figure 1 shows the circumstance plotted in *Stellarium 0.14.2* from Edinburgh, Scotland. At 6 degrees above the horizon in an evening "white night" sky, it would be a very difficult observation. Keep in mind that planetarium simulators like *Stellarium* are being asked to do a lot when reaching way back to 1737, and may be encountering large errors that are much smaller when the separation is only a few years.

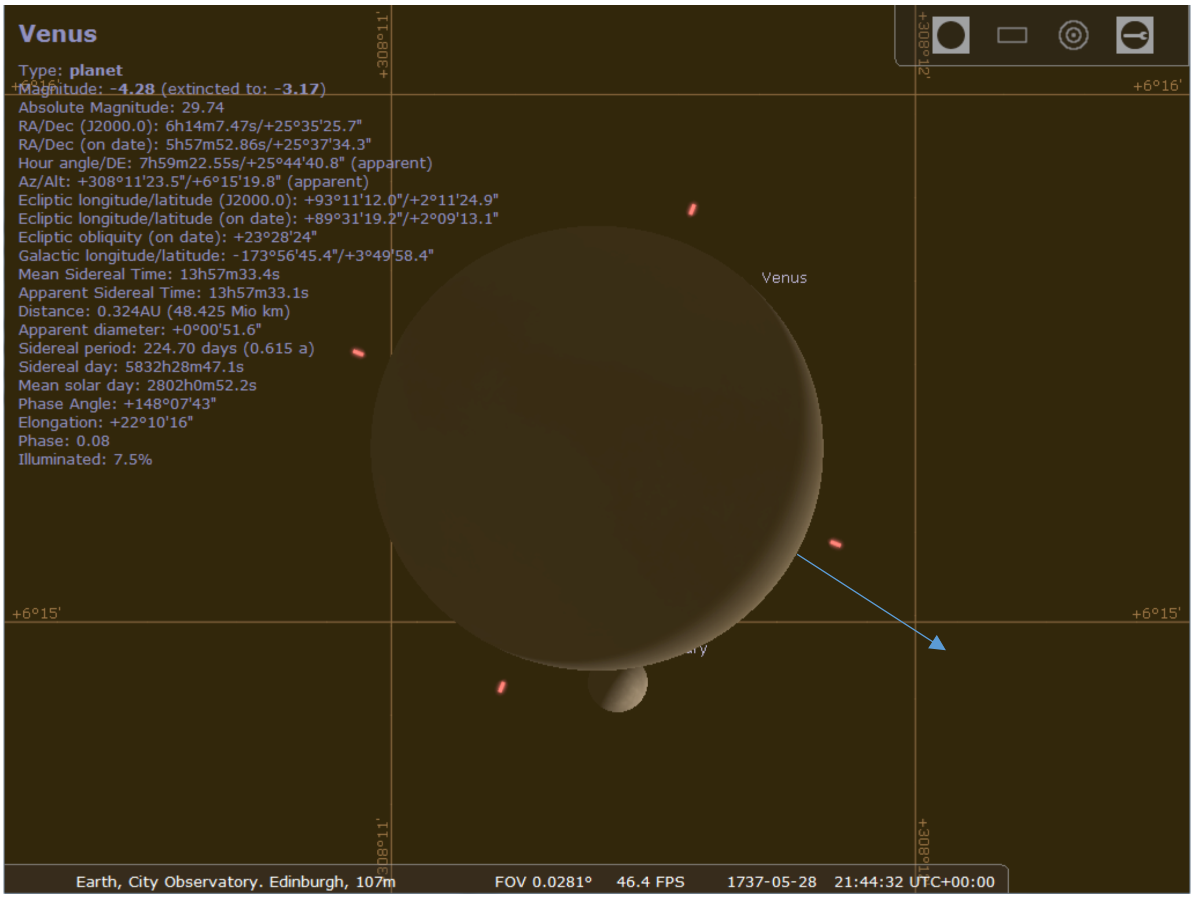

Figure 1. Calculation of circumstances of 1737 occultation of Mercury by Venus. The direction of coverage is indicated by the arrow drawn on top.

If we plot the closest approach angle for 251 years between Jan 1 1800 and Dec 31 2050, we find only one close approach out of 612 conjunctions. In Figure 2, we see that during this period of time it only came within hailing distance (80 arcseconds) once. The calculations have been rounded off to the red lines depicted at the right, so there is some "digitization" involved. The lowest arrow depicts a typical separation and size where we might have a chance of observing such a thing, and it would be good to look at. Plugging the circumstances into Stellarium shows that tight 1859 conjunction was a sad little thing, with both planets being small (see Figure 2 on next page). So, since 1737 there have been no opportunities. Please note that the separation and time of formal conjunction may not be the absolute minimum separation of the two planets, but errors go to zero for the case of very small separation, and that is what we are interested in.

And, of course, we cannot let this topic go without discussing the star of Bethlehem. Figure 3 depicts one of the candidates. The year inserted into *Stellarium* of –1 CE equals 2 BCE, because in the old enumeration they didn't use zero. Such an event is very brief and astrologically not any more significant

[2] Jean Meeus, "Mutual Occultations of Planets," *J Brit. Ast. Assoc.* vol 80, no 4, pp. 282-287, 1970.

than a distant conjunction. However, it is spectacular. The two planets combine in the unaided eye to a single –4 magnitude point in the west. Jupiter is about 10 times farther than Venus. Errors are possible and even likely at this time range.

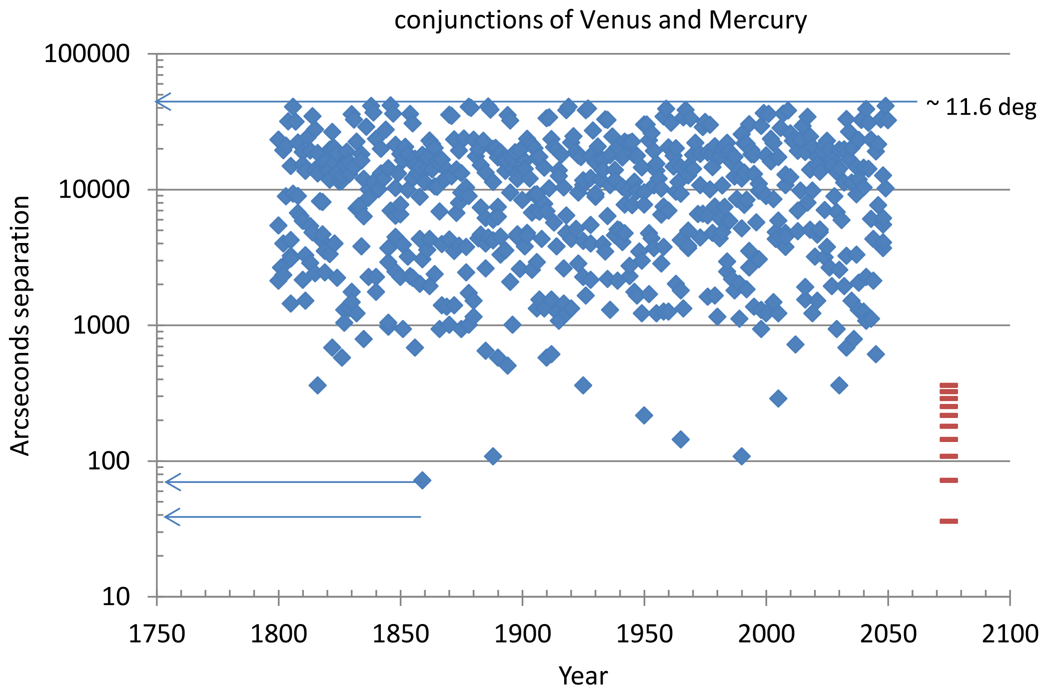

Figure 2. Separations during conjunctions of Venus and Mercury (units: arcseconds).

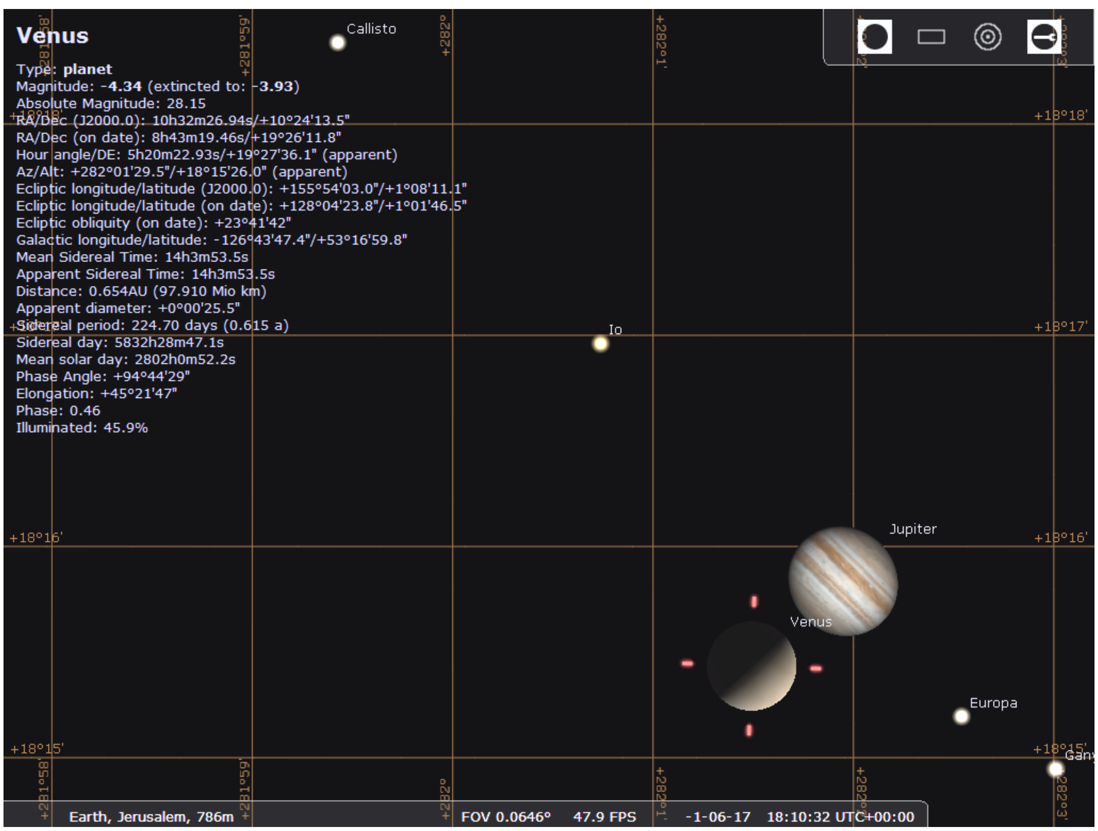

Figure 3. One candidate for the star of Bethlehem. Date is June 17, 2 BCE, in the evening. The divisions in altitude are single arcminutes, about the same as the resolution of the eye.