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Tables of Synodic Events from -800 to 1650 Using Modern and *Almagest* Models

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Abstract: This article describes and makes available computed data for the major synodic events for the inner (Mercury, Venus) and outer (Mars, Jupiter, Saturn) planets for the time period -800 to 1650.

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We have computed the major synodic events for the inner (Mercury, Venus) and outer (Mars, Jupiter, Saturn) planets for the time period -800 to 1650. The events are computed using modern models (Bretagnon 1986) and the models from Ptolemy's *Almagest* (Pedersen 2011). While ordinary ephemerides give planetary positions at a list of times, our tables give the times and positions of the planets for a list of events. Often in discussions of ancient astronomy it is helpful to be able to look up directly the time and positions of such events for both modern models and the *Almagest* models.

The events computed for the inner planets are: 1) superior conjunction of the true planet and the mean Sun, 2) greatest elongation (east), 3) first station, 4) inferior conjunction of the true planet and the mean Sun, 5) second station, and 6) greatest elongation (west).

The events computed for the outer planets are: 1) conjunction of the true planet and the mean Sun, 2) first station, 3) opposition of the true planet and the mean Sun, and 4) second station.

For each event we give the date/time and the corresponding true and mean longitudes of the planet and the Sun. The accuracy of the computed times is about $1/28^{th}$ of a second. This is accomplished in each case by an appropriate set of iterations and/or interpolations, and, no doubt needless to say, is far more precise that any possible observation timing by any ancient astronomer.

We have also computed the date and time of first and last visibilities of the inner and outer planets at Alexandria (longitude 29;55 degrees east, latitude 31;13,12 degrees north) and Babylon (longitude 44;26 degrees east, latitude 33;20 degrees north) for the same time period -800 to 1650 using the same modern and *Almagest* models.

The events computed for the inner planets are: 1) first visibility of the planet in the west after sunset (EF), 2) last visibility of the planet in the west after sunset (EL), 3) first visibility of the planet in the east before sunrise (MF), 4) and last visibility of the planet in the east before sunrise (ML).

The events computed for the outer planets are: 1) first visibility of the planet in the east before sunrise (EF), 4) last visibility of the planet rising after sunset (AR), 3) first visibility of the planet setting before sunrise (CS), and 4) last visibility of the planet in the west after sunset (EL). The AR and CS events are not mentioned in ancient sources, but are included here for completeness.

Computation of these visibility events requires a number of additional assumptions beyond the specification of the models. We use the *arcus visionis* (AV) model of the *Almagest*, which depends upon

the specification of an AV distance of the Sun below the horizon at the moment the planet is on the horizon. For both the modern and *Almagest* models we give results for two sets of parameters. The first set uses the default convention of the program PLSV (Swerdlow 2004) that the apparent planet, i.e. corrected for refraction (Meeus 1998, 101), is on the horizon and the Sun is depressed below the horizon at a set of AV values specific to each planet and event type that generally follow Schoch (Schoch 1924). The second set assumes the true planet is on the horizon and uses the values from the *Almagest* XIII 7 (Toomer 1984) except that for the AR and CS events we use half the AV value since the Sun is on the opposite horizon as the planet.

In all cases the date given for the visibility events cannot be considered as more than indicative, since such events are in reality sensitive not only to the AV values but also to local weather, obscurations of the horizon, azimuth differences of the planet and the Sun, etc. It is the case, however, that our results for the modern model do match fairly closely with the results from PLSV.

There are ten files for each planet. Here is the key to the otherwise cryptic file names:

1. planet1650 (where 'planet' is one of planet names): YMDH calendar dates for Alexandria, then the corresponding JD's for Greenwich, then for the outer planets the mean and true longitudes of the planet and the Sun for the synodic events conjunction, first station, opposition, second station. For the inner planets, as above but the events are superior conjunction, greatest elongation (east), first station, inferior conjunction, second station, greatest elongation (west).
2. planet1650pt, as above but using the *Almagest* models for the longitudes. The YMDH calendar dates and the corresponding JD's are both for Alexandria.
3. planet1650v: modern models, YMDH and JD's for Alexandria, then for the outer planets the longitude and latitude, the longitude of the Sun, the azimuth and altitude of the planet, and the altitude and azimuth of the Sun. The altitude of the planet is always -0.5667 degrees, which corresponds approximately to an apparent, i.e. refraction corrected, altitude of 0 degrees. The observer is assumed to be in Alexandria. For the outer planets the event sequence is MF,AR,CS,EL. For the inner planets the sequence is EF,EL,ML,MF.
4. planet1650v1: the same as planet1650v except that the true altitude of the planet is 0 degrees, which is the convention used in the *Almagest*.
5. planet1650vb: the same as planet1650v except the observer is assumed to be in Babylon.
6. planet1650v1b: the same as planet1650v1 except the observer is assumed to be in Babylon.
7. planet1650ptv: the same as planet1650v except the *Almagest* models are used.
8. planet1650ptv1: the same as planet1650v1 except the *Almagest* models are used.
9. planet1650ptvb: the same as planet1650vb except the *Almagest* models are used.
10. planet1650ptv1b: the same as planet1650v1b except the *Almagest* models are used.

References

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Appendix 1: Links to data as Microsoft Excel Spreadsheets

Mercury	Venus	Mars	Jupiter	Saturn

mercury1650.xlsx	venus1650.xlsx	mars1650.xlsx	jupiter1650.xlsx	saturn1650.xlsx
mercury1650pt.xlsx	venus1650pt.xlsx	mars1650pt.xlsx	jupiter1650pt.xlsx	saturn1650pt.xlsx
mercury1650v.xlsx	venus1650v.xlsx	mars1650v.xlsx	jupiter1650v.xlsx	saturn1650v.xlsx
mercury1650v1.xlsx	venus1650v1.xlsx	mars1650v1.xlsx	jupiter1650v1.xlsx	saturn1650v1.xlsx
mercury1650vb.xlsx	venus1650vb.xlsx	mars1650vb.xlsx	jupiter1650vb.xlsx	saturn1650vb.xlsx
mercury1650v1b.xlsx	venus1650v1b.xlsx	mars1650v1b.xlsx	jupiter1650v1b.xlsx	saturn1650v1b.xlsx
mercury1650ptv.xlsx	venus1650ptv.xlsx	mars1650ptv.xlsx	jupiter1650ptv.xlsx	saturn1650ptv.xlsx
mercury1650ptv1.xlsx	venus1650ptv1.xlsx	mars1650ptv1.xlsx	jupiter1650ptv1.xlsx	saturn1650ptv1.xlsx
mercury1650ptvb.xlsx	venus1650ptvb.xlsx	mars1650ptvb.xlsx	jupiter1650ptvb.xlsx	saturn1650ptvb.xlsx
mercury1650ptv1b.xlsx	venus1650ptv1b.xlsx	mars1650ptv1b.xlsx	jupiter1650ptv1b.xlsx	saturn1650ptv1b.xlsx

Appendix 2: Links to Data as CSV Files

Mercury	Venus	Mars	Jupiter	Saturn
mercury1650.csv	venus1650.csv	mars1650.csv	jupiter1650.csv	saturn1650.csv
mercury1650pt.csv	venus1650pt.csv	mars1650pt.csv	jupiter1650pt.csv	saturn1650pt.csv
mercury1650v.csv	venus1650v.csv	mars1650v.csv	jupiter1650v.csv	saturn1650v.csv
mercury1650v1.csv	venus1650v1.csv	mars1650v1.csv	jupiter1650v1.csv	saturn1650v1.csv
mercury1650vb.csv	venus1650vb.csv	mars1650vb.csv	jupiter1650vb.csv	saturn1650vb.csv
mercury1650v1b.csv	venus1650v1b.csv	mars1650v1b.csv	jupiter1650v1b.csv	saturn1650v1b.csv
mercury1650ptv.csv	venus1650ptv.csv	mars1650ptv.csv	jupiter1650ptv.csv	saturn1650ptv.csv
mercury1650ptv1.csv	venus1650ptv1.csv	mars1650ptv1.csv	jupiter1650ptv1.csv	saturn1650ptv1.csv
mercury1650ptvb.csv	venus1650ptvb.csv	mars1650ptvb.csv	jupiter1650ptvb.csv	saturn1650ptvb.csv
mercury1650ptv1b.csv	venus1650ptv1b.csv	mars1650ptv1b.csv	jupiter1650ptv1b.csv	saturn1650ptv1b.csv

Appendix 3: Links to Data as HTML Tables

mercury1650.html	venus1650.html	mars1650.html	jupiter1650.html	saturn1650.html
mercury1650pt.html	venus1650pt.html	mars1650pt.html	jupiter1650pt.html	saturn1650pt.html
mercury1650v.html	venus1650v.html	mars1650v.html	jupiter1650v.html	saturn1650v.html
mercury1650v1.html	venus1650v1.html	mars1650v1.html	jupiter1650v1.html	saturn1650v1.html
mercury1650vb.html	venus1650vb.html	mars1650vb.html	jupiter1650vb.html	saturn1650vb.html
mercury1650v1b.html	venus1650v1b.html	mars1650v1b.html	jupiter1650v1b.html	saturn1650v1b.html
mercury1650ptv.html	venus1650ptv.html	mars1650ptv.html	jupiter1650ptv.html	saturn1650ptv.html
mercury1650ptv1.html	venus1650ptv1.html	mars1650ptv1.html	jupiter1650ptv1.html	saturn1650ptv1.html
mercury1650ptvb.html	venus1650ptvb.html	mars1650ptvb.html	jupiter1650ptvb.html	saturn1650ptvb.html
mercury1650ptv1b.html	venus1650ptv1b.html	mars1650ptv1b.html	jupiter1650ptv1b.html	saturn1650ptv1b.html

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