Jupiter-Saturn Conjunction Series from 0 CE to 3000 CE

(You read correctly: 3000 Years!)

Overview

This page analyzes conjunctions of Jupiter and Saturn over the 3000 year interval 0 CE to 3000 CE (occultation data from 10000 BCE to 10000 CE), and describes the reasons behind the various patterns that are associated with these events. The long time intervals are needed because these conjunctions occur rather infrequently, and you need to track a lot of them to learn what is going on. There is also a page specific to the conjunction of Dec 21, 2020, if you are looking for something more focused on that event.

Saturn and Jupiter are two of the five planets visible to the unaided eye in the night sky. Jupiter is particularly bright, appearing as a brilliant point of white light in the sky, while Saturn is a fainter dull white object, yet still about as bright as a typical bright star. Every 20 years or so Jupiter and Saturn align (i.e. are in conjunction), and during those years these planets can make a beautiful pair in the sky. Their relative motion during a conjunction year is fun to watch, and provides an excellent way to learn about planetary motions. This article covers the basics of the Jupiter-Saturn conjunctions, and then goes into detail as to how the different conjunctions relate to one another. The more you dive in and ask more questions about the motions, the more complex the answers become. Yet ultimately all of the behavior described here comes from orbital motions of the Earth, Jupiter, and Saturn.

Visibility

In terms of pure spectacle, conjunctions between Venus and Jupiter are generally flashier than ones between Jupiter and Saturn. While Jupiter is typically impressive in the night sky and easily visible even in fairly bright twilight and in urban areas, the same is not always true for Saturn. Both Jupiter and Saturn are fainter when they appear close to the Sun than they are when they are closest to us (and on the opposite side of the sky from the Sun). Compared with their maximum brightnesses, Jupiter drops by about a half when it appears close to the Sun and Saturn by about a third. This brightness drop is more of a problem for Saturn as it is always much fainter than Jupiter, and can get lost in twilight glare. If the sky is too bright to see Jupiter, you're not going to see Saturn. As we shall see, many of the closest approaches of Jupiter and Saturn occur either in the eastern skies at dawn or in the west at sunset. Binoculars can help out a lot for viewing conjunctions in bright twilight.

Nonetheless, conjunctions between Jupiter and Saturn have a lot going for them. Unlike conjunctions between any of the other bright planets, Jupiter and Saturn typically remain within ten degrees of one another in the sky for a period of a year or more around the actual date of the conjunction, making for a long event that one can easily monitor on a casual basis. Even if the conjunction itself happens to be difficult to see because it occurs close to the Sun, the planets will make an impressive pair in the night sky for months beforehand and afterwards, meaning they can be observed together when they are closest to us and appear their brightest, and are located in a fully dark sky well above the horizon. There are also rare years that feature three distinct conjunctions, all visible in the middle of the night. We discuss how all this plays out below.

What is a Conjunction?

Simply put, a conjunction is when two objects line up in the sky. But that alignment is never perfect, as the orbits for planets like Jupiter and Saturn are tilted slightly relative to one another, so what we really want to say is that a conjunction occurs when planets come close together and then move apart. But how close together should count for a conjunction? We need a quantitative definition.

Because the orbits of the planets all lie nearly in one plane, a natural thing to do is to measure the angle (known as longitude) to the position of the planet measured in the plane of the Earth's orbit counterclockwise from some reference direction. In the diagrams below, that reference direction is to the right, and is where the Sun appears when viewed from the Earth on the first day of spring. With this choice, the rightmost part of the orbit has longitude zero degrees, the top is 90 degrees, leftmost is 180 degrees, and bottom is 270 degrees. *If Jupiter and Saturn have the same longitude as viewed from the Earth, we will call that a conjunction.* Notice by this definition the planets may approach one another, but until the longitudes overlap we don't count it as a conjunction. For orbits in a plane, conjunction defined this way means that the planets exactly align during conjunction, which is what we want. As a technical point, the closest approach is called an appulse. But whenever two planets like Jupiter and Saturn pass one another they are moving along the plane, so the closest approach (appulse) coincides with the longitudes being the same (conjunction) to a high degree of accuracy.

Because the orbits of Jupiter and Saturn around the Sun are both significantly larger than the size of the Earth's orbit, the view of the planets from the Earth is similar to what you'd see from from Sun. Hence, the time of conjunction as seen from the Earth is quite similar to the moment where they have the same longitude as viewed from the Sun, and we can use this fact to help think about the problem. Where the Earth is located in its orbit has crucial consequences as to whether a conjunction can be observed, as the Earth's position determines the time of year of the conjunction and also its elongation from the Sun, but we can worry about those aspects once we get the general cycles of the conjunctions figured out.

The Basics

Both Jupiter and Saturn are outer planets (outside the Earth's orbit). Like all the planets including Earth, they orbit in a counter-clockwise direction as viewed from a point far above the Earth's north pole. The inner planets move fastest. Jupiter has an orbital period of **11.86 years** and Saturn's period is **29.46 years**.

Suppose Jupiter and Saturn line up when viewed from the Sun (as in the figure below). How long would it take for them to line up again? Jupiter takes 11.86 years = 4332.59 days to orbit, and so on average moves 0.083092 degrees per day. Saturn moves around slower, at 0.033463 degrees per day. Thus, Jupiter is constantly picking up 0.0496284 degrees on Saturn every day. After a time (360/0.0496284) days = 7253.91 days = **19.86 years**, Jupiter will have gained 360 degrees on Saturn and once again the planets will align as viewed from the Sun. For this reason, Jupiter and Saturn conjunctions happen about once every 20 years. You can break up your life into a few of these segments if you like, marking time with this cosmic watch. A typical lifespan includes four conjunctions of Jupiter and Saturn.

The 5:2 Jovian/Saturnian Orbital Resonance and the Six Different Conjunction Series

Let's look at this a bit more closely. If we start by aligning Jupiter and Saturn to the right of the Sun (call it Conjunction 0 and define that as zero degrees), then the next conjunction (call it Conjunction 1) as viewed from the Sun will occur after 19.86 years and Saturn will have moved (19.860/29.457)*360 = 242.7 degrees, while Jupiter has moved (19.860/11.862)*360 = 602.7 = 242.7 + 360 degrees. Similarly, Conjunction number 2 now occurs at 242.7 + 242.7 = 485.4 degrees = 125.4 degrees on the circles. Finally, Conjunction 3 puts us at 125.4 + 242.7 = 368.1 = 8.15 degrees. Conjunction 6 is therefore at 16.3

degrees. This situation is shown in the following figure:

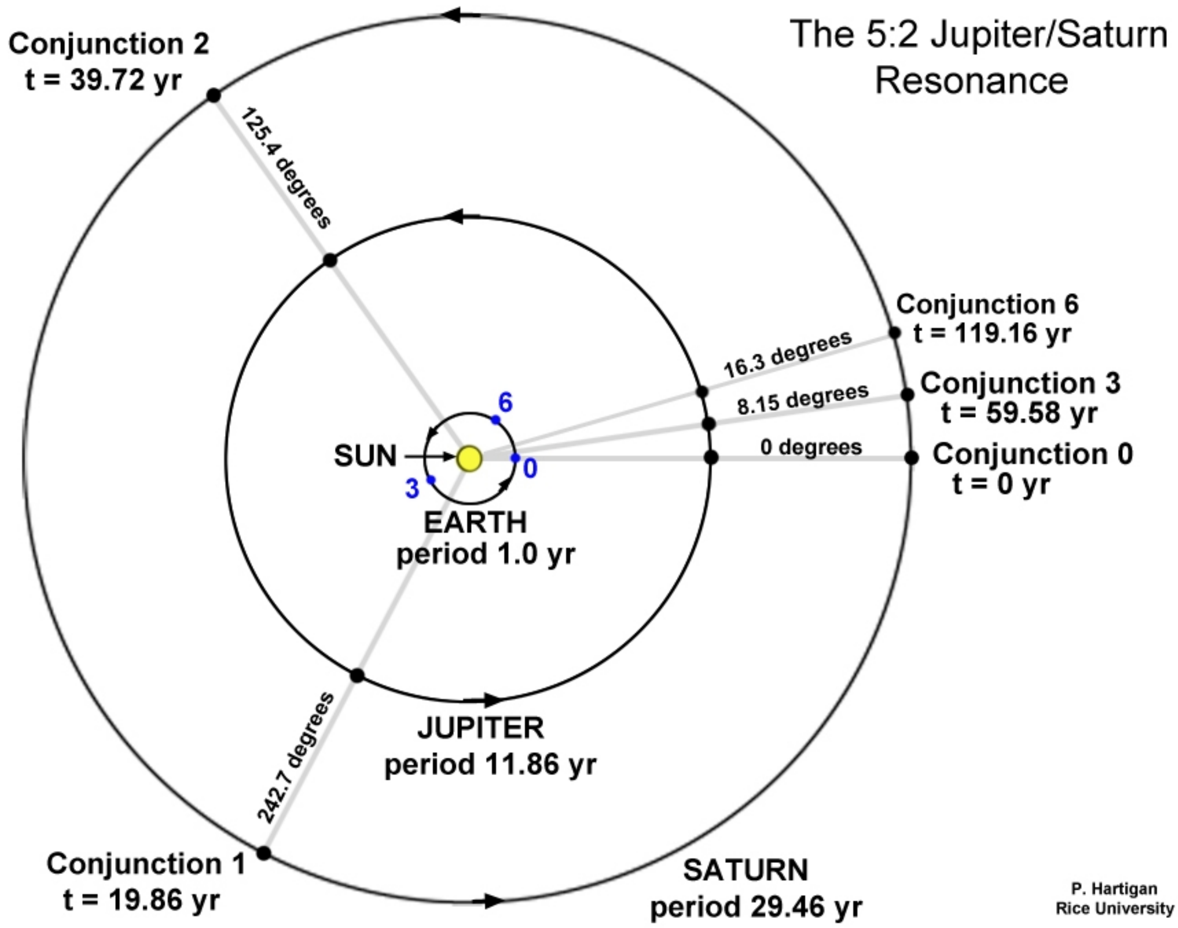
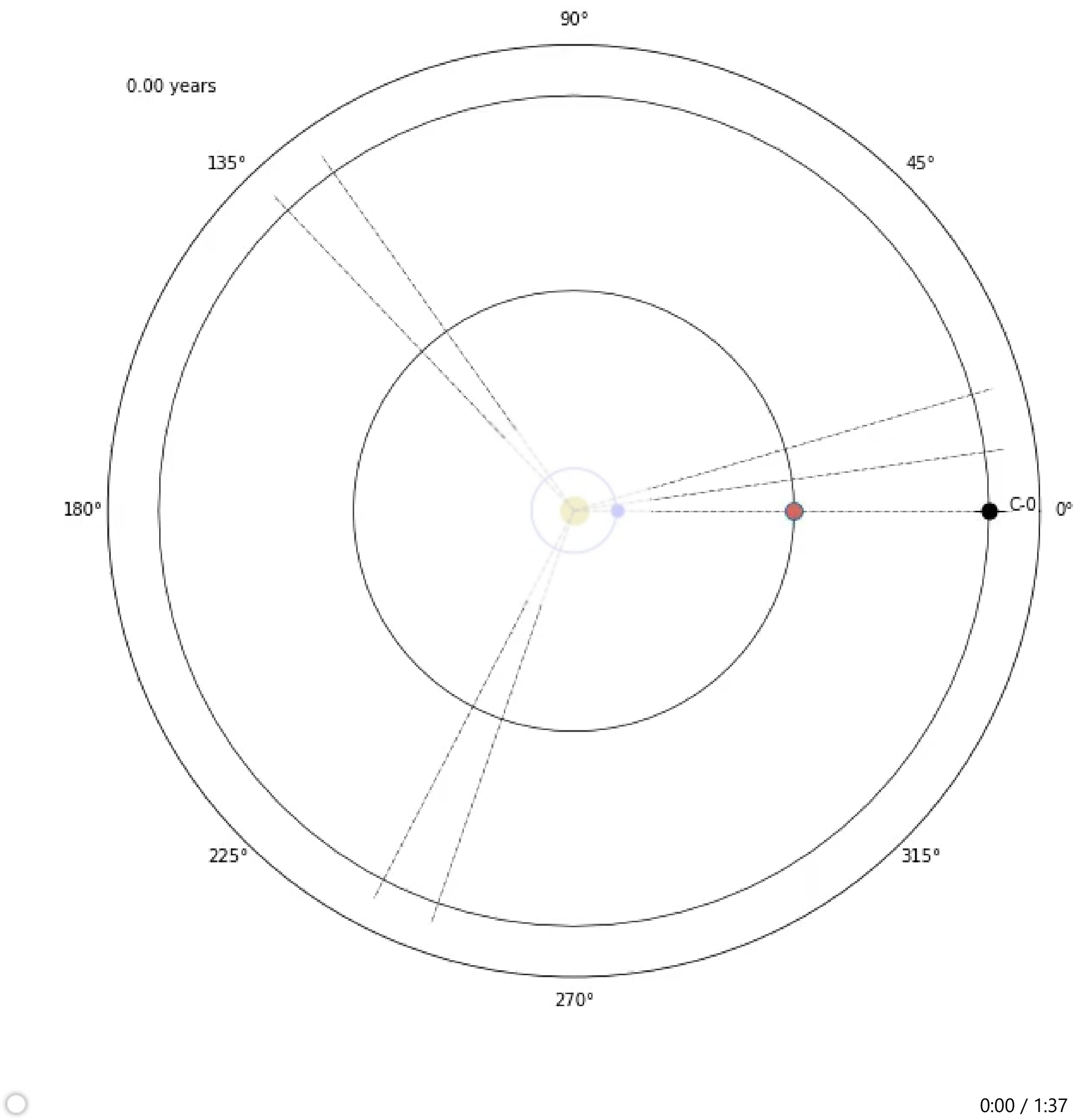


Diagram to scale of the orbits of the Earth, Jupiter and Saturn. Initially, we align Jupiter and Saturn relative to the Sun at longitude = 0 in an event denoted as 'Conjunction 0'. Subsequent conjunctions are labeled. Conjunctions 3 and 6 nearly line up with Conjunction 0. The Earth moves slowly clockwise in its orbit for successive conjunctions. For example, if the Earth (blue dot) is at position 0 for Conjunction 0, it will be at position 3 for Conjunction 3 and position 6 for Conjunction 6.

Notice after three conjunctions we are nearly back to the same position in the orbits! At that point Jupiter has gone around just over 5 times and Saturn just over 2 times. We could have noticed this by dividing their mean motions (0.083092/0.033463) = 2.483 ~ 2.5 = 5/2. So it isn't a perfect resonance, but it is pretty close. Hence, we might expect conjunctions of Jupiter and Saturn to occur in distinct groups of three, and after three conjunctions we'd return to about the same place in the figure. Hence, grouping conjunctions into three series ensures that each conjunction in that series occurs in the same general location in the sky. Resonances of this sort are common occurrences in celestial mechanics, and cause gaps and concentrations in many orbiting systems, such as Saturn's rings (resonances with its moons) and the asteroid belt (resonances with Jupiter).

Although the above series of three is real, we forgot one detail - we are observing from the Earth and not from the Sun. If you are on the bottom side of the Earth's orbit and Jupiter and Saturn are off to the right (e.g., Conjunction 3), then Jupiter and Saturn will be visible in the morning sky before dawn, while if you are on the other side of the Earth's orbit (e.g. Conjunction 6) the planets will be visible in the evening sky after sunset. That is, after three conjunctions = 59.58 years, the Earth completes a bit more than 59-1/2 of its own orbits, and so is nearly on the other side of its orbit from wherever it was three conjunctions ago. So this isn't good - if we said that Conjunction 3 was in the same series as Conjunction 6 then one event would evening, the next one morning, then evening, and so on for adjacent events in the series. Instead, if we break up the conjunctions into groups of six, then after six conjunctions = 119.1608 years, Jupiter and Saturn will now have moved 2*8.15 = 16.3 degrees ahead (counterclockwise) as viewed from the Sun, while the Earth has moved 0.1608*360 = 57.9 degrees, or about 2 months, also in the same direction.



Animation of 120 years of the motions of the Earth (inner orbit), Jupiter (middle orbit), and Saturn (outer orbit). The orbits are to scale. Conjunctions of Jupiter and Saturn as viewed from the Sun are marked as C-0 through C-6.

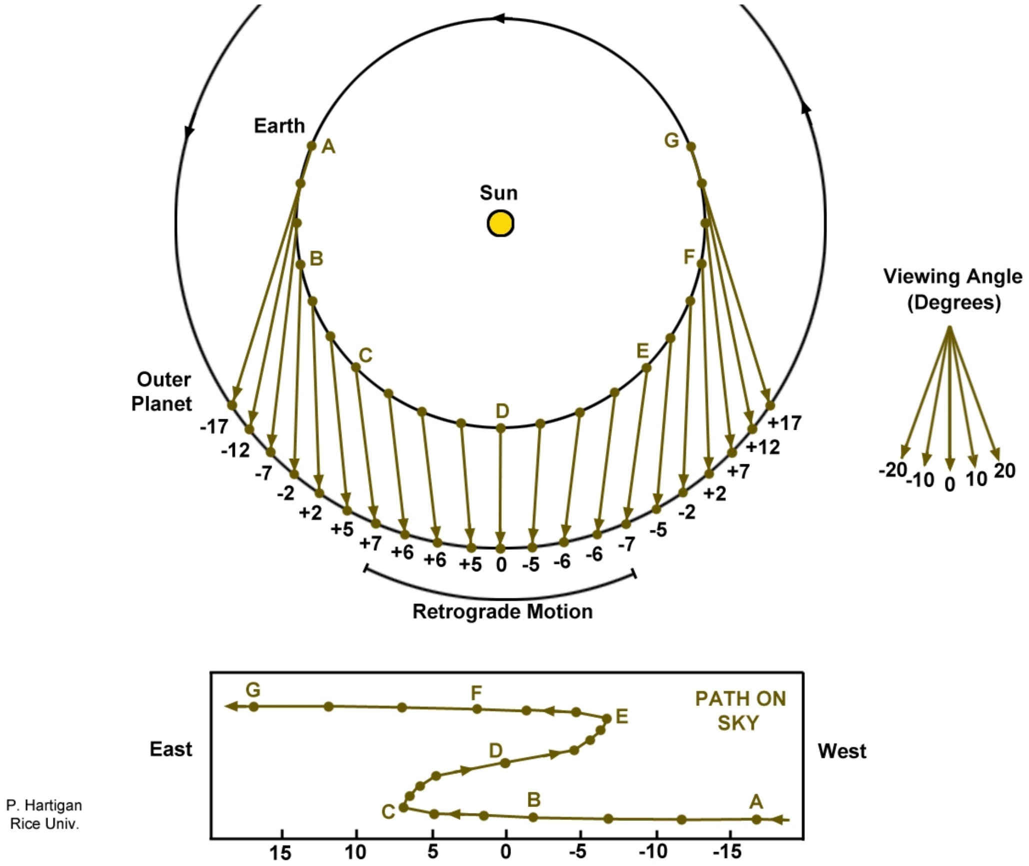
You'll notice that there will be slight differences between when Jupiter and Saturn line up with the Sun and when they line up with the Earth. For example, in the diagram, Conjunction 3 as viewed from the Sun occurs a bit earlier for the Earth because the Earth is on the bottom half of its orbit, and from that vantage point Jupiter has already passed Saturn when Jupiter and Saturn line up with the Sun. Similarly, Conjunction 6 occurs a bit later for the Earth than it does for the Sun because the Earth is on the top half of its orbit, where it does not appear that Jupiter has passed Saturn quite yet. These small positional offsets will introduce some scatter, but on average we expect the dates between successive conjunctions in a series (like Conjunction 0 and Conjunction 6) to increase by about two months or so. Within a series, a conjunction in May should be preceded by one 119 years ago in March and followed in 119 years by one in July. The longitudes should increase, but slowly, in a series.

This is good: adjacent conjunctions within any one of the six series will generally occur at about the same time of the year, and because the series were constructed to keep adjacent conjunctions in the same part of the sky, it means the planets will have roughly the same elongation from the Sun between adjacent conjunctions within a given series. So it makes sense to group the conjunctions into six separate series.

Opposition and Triplet Conjunctions

It is getting complicated so it is time to look at some data soon. But first we need to recognize what can happen with outer planet conjunctions when they are observed near opposition, when the Earth is situated on a line between the planets and the Sun. These conjunctions should be the best ones as they will visible in the middle of the night, and the planets are also brighter because they are closer to us.

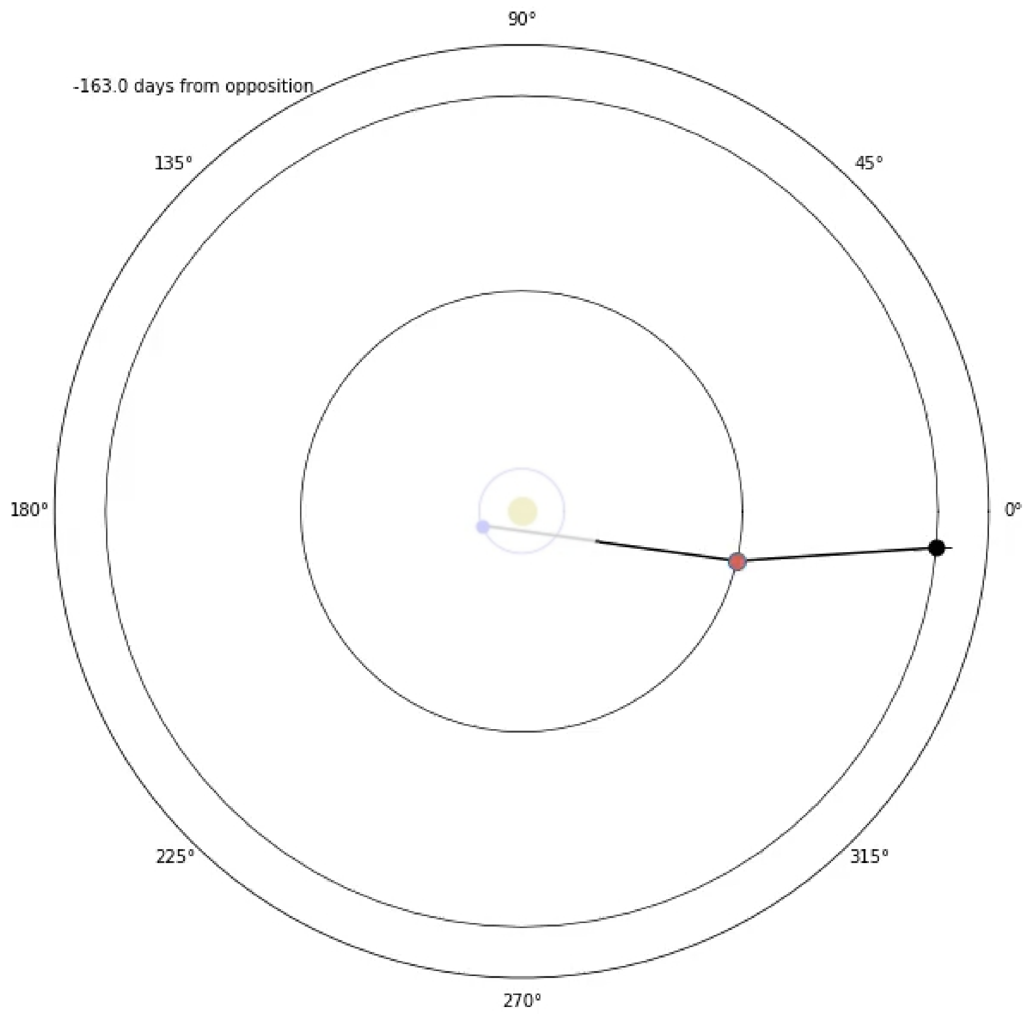
Take a look at the following diagram. Here we have an outer planet like Mars, Jupiter or Saturn being observed from the Earth. What matters as far as an observer on Earth is concerned is the angle the planet appears relative to the stars, indicated by the brown arrows. In the diagram, we are taking the down direction to be zero degrees. At point A, the planet appears at about -17 degrees. As the Earth moves from A to C, that angle steadily increases to about +7 degrees. Increasing angles are to the east in the sky. But between points C and E the angle *decreases*, and so the planet now moves westward in the sky, moving fastest at opposition (point D) when it appears opposite to the Sun in the sky. This westward movement is called *retrograde motion*. It happens when the Earth is passing the planet and is similar to what you see on the highway when you drive past a slower vehicle and that vehicle appears to move backward relative to the surrounding scenery. As far as north/south is concerned, whether the planet moves in either direction or even goes north and then south and makes a loop depends on how the orbits are tilted. Here, I have the planet continuing to go north in the bottom diagram. If the Earth and the planet were exactly in the same plane the planet would simply shift east and west, and overwrite its path in the sky. The Earth and the outer planets are fairly close to being in the same plane, and so the motion is primarily left and right (east and west) on the sky.



Retrograde motion occurs between points C and E in this diagram. Opposition occurs at point D.

Notice retrograde motion occurs only over a segment of the orbital paths of the Earth and planet. This segment gets larger as the planet gets further away, and approaches 180 degrees, i.e., the entire bottom half of the Earth's orbit instead of just from C to E as in the diagram, for a very distant planet. However, the amplitude of retrograde motion, i.e., the distance between C and E on the sky, decreases for more distant planets. For example, Saturn's retrograde motion typically covers about 6.6 degrees on the sky and occurs over 141 days centered on opposition, while Jupiter retrogrades more, 9.9 degrees over a shorter interval, 123 days. From one year to the next (opposition to opposition), Saturn moves eastward about 12 degrees on the sky, while Jupiter moves 30 degrees eastward.

When the planets are aligned closely enough with opposition to get triplet conjunctions, the first one of these will occur before retrograde motion begins, and the third one will occur after retrograde motion ends, with the middle one happening during retrograde. This is all made clear (hopefully!) in the following animation and diagram.



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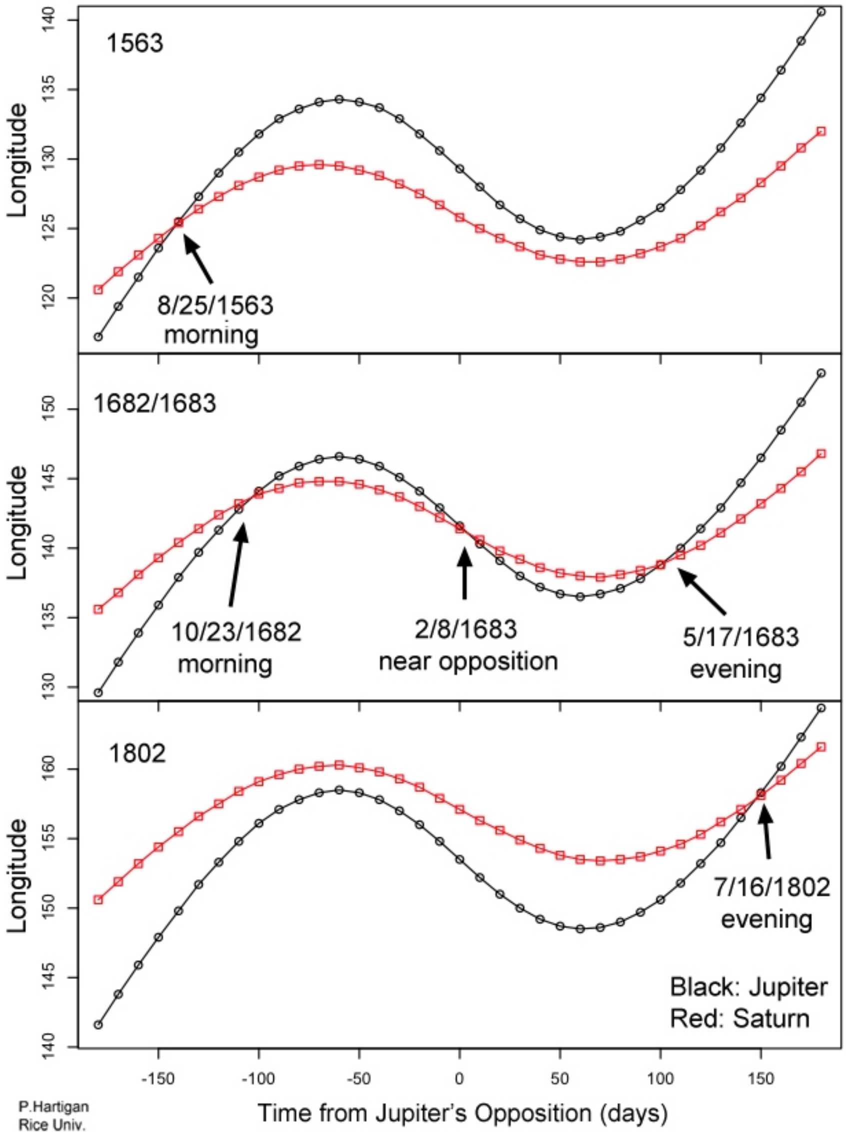
Animation of a triplet opposition conjunction of Jupiter and Saturn. The conjunctions occur when the line between the Earth, Jupiter, and Saturn is exactly straight, at about -100, 0, and +100 days from opposition. The animation runs long enough to show no conjunction occurs the following year.



Longitudes of Jupiter and Saturn for a morning, triplet, and evening conjunction from consecutive members of the conjunction years in Series 2. Longitude increases to the east and decreases to the west. The planets move westward (retrograde; down in the plot) around the time of opposition. The vertical separation between the curves is the distance between the planets in longitude, essentially equal to their separation in degrees on the sky. If the red curve is above the black one, Saturn is to the east of Jupiter, while if the black curve is above the red, then Saturn lies to the west of Jupiter.

Let's think about what happens as Jupiter passes Saturn by. Three scenarios from consecutive members of series 2 are shown in the above figure. The Aug 25, 1563 event was a morning-only conjunction. Jupiter caught up with Saturn and moved well past it before the planets began to retrograde. By then Jupiter had gone too far ahead, and its retrograde motion was not enough to catch up with Saturn again, so there was only one conjunction, at longitude 125.3 degrees. After 119 years in 1682-1683, the next conjunction in the series occurs in roughly the same part of the sky at longitude 143.5 degrees, about two months later in the year in the morning of Oct 23, 1682. But this time the curve for Jupiter was shifted just a bit to the west (lower longitudes) relative to Saturn than it was in 1563. So this time Jupiter caught up with Saturn as they both moved westward during their retrograde motions and there was a conjunction on Feb 8, 1683, only a few days from opposition for both planets. After a month or two the planets again turned to the east, and Jupiter passed Saturn for a third time, visible in the evening skies on May 17, 1683. The next event in this series, 119 years later, was on July 16, 1802. The steady progression of Jupiter's curve to lower longitudes relative to Saturn's produced an evening-only event, as Jupiter did not catch up to Saturn before retrograde. In this way, conjunctions within a series move from the morning sky, to a triplet near opposition, to the evening sky.

Conjunctions within a series typically move forward about 1 - 2 months between successive events, and we see that here, as the morning conjunctions shifted from Aug 25 to Oct 23 between 1563 and 1682, and the evening one moved from May 17 to July 16 between 1683 and 1802. Triplet conjunctions are a bridge that connect the morning events with the evening ones. Triplet conjunctions are rather rare, as the oppositions need to line up fairly well to get all three conjunctions, but they do happen regularly and we should be on the lookout for them as we go forward.

As the above animation shows, the opposition that follows a conjunction year does not produce another conjunction (also no conjunctions occur in the preceding year) For example, after the 1802 conjunction there was no conjunction 1803: Jupiter needed to loop completely around the sky relative to Saturn before they lined up again about 20 years later in the morning of June 18, 1821. However, that conjunction was part of a different series and occurred in a different part of the sky from the one in 1802.

Initial Predictions

With this setup of six conjunction series and considering triplet conjunctions, we predict the following:

- Individual conjunction events within a series will be separated by 119 years and will move forward on average about two months each conjunction until the triplet conjunctions occur.

- All series will have progressions where conjunctions aligned with the Sun gradually move into the morning sky, then around midnight when a group of three conjunctions (triplet) may occur together, and then finally the series moves to the evening sky before aligning once again with the Sun. The time for a series to make this full progression should be about (360/(57.9-16.3))*119.16 ~ 1360 years.
- The location in the sky of each conjunction in a series should increase in longitude by 16.3 degrees, making one full cycle relative to the stars every 2634 years. If instead we use the convention of measuring longitude eastward from the vernal equinox for that year, we have to keep in mind that the vernal equinox itself moves around once every 25772 years, so longitude measured that way increases a little faster, 17.95 degrees each time and the time to return to fixed longitude is then a bit shorter, 2390 years.
- Conjunction series 1 and 4, offset from one another by about 60 years, should occur in roughly the same part of the sky, but they will mirror one another in the sense that when one is in the morning, the other is evening and vice-versa. Similarly when one has a conjunction aligned with the Sun, the other will have a conjunction near opposition. Series 2 and 5 will have a similar relationship relative to one another, as will series 3 and 6.

How do these predictions stack up against real data?

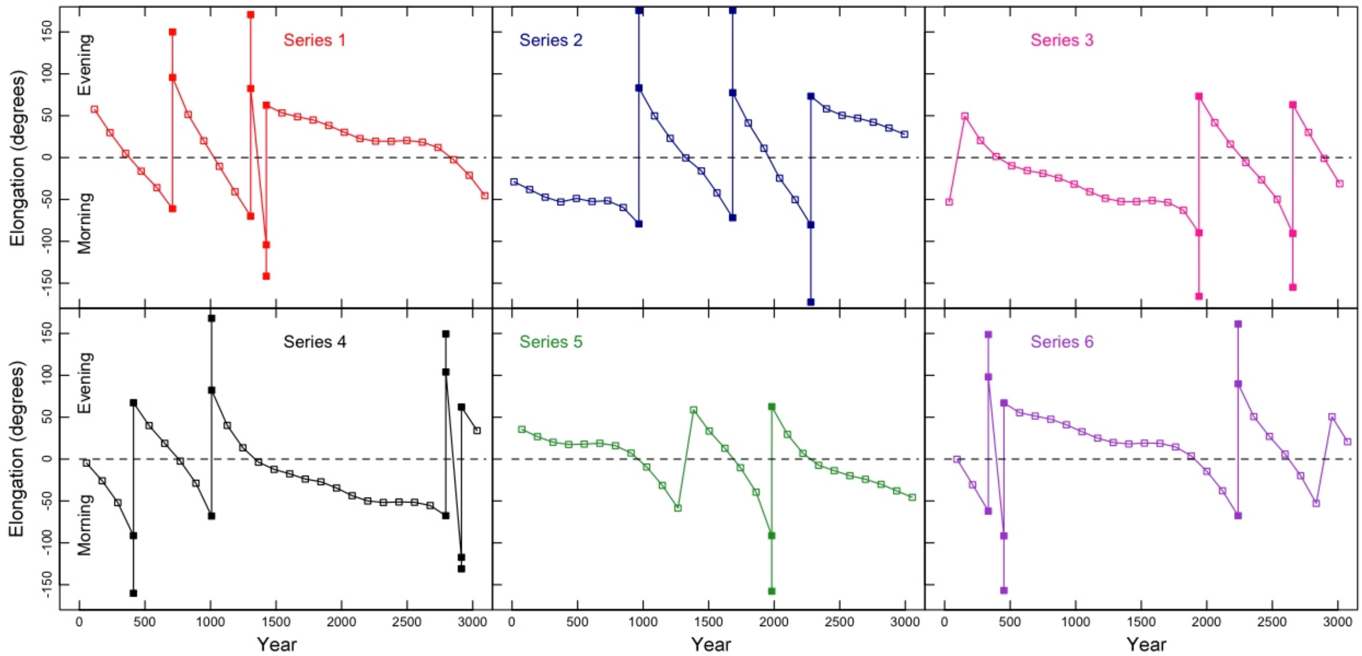
The following table compiles data for the conjunctions between 1200 CE and 2400 CE. The longitude (fixed, 2000 coordinates) shows where the conjunction occurs on the sky. Note the longitudes are similar every 60 years, with a slight forward drift, as expected. The separation between the planets is next, and then comes the elongation in degrees from the Sun, with negative being morning and positive being evening. The minus sign changes every 60 years, as subsequent conjunctions switch from morning to evening and back again, with exceptions when the series goes past the Sun or switches from morning to evening as it passes through opposition. These behavior we also expected. Then comes the series number, and you'll notice it simply progresses 1-2-3-4-5-6 through the different series except where there are triplets. Series 2 and 5 have similar longitudes, as expected, as do series 1 and 4 and series 3 and 6. The last columns show whether or not a conjunction is particularly close, if it is easy to see, and if there is a group of three associated with an opposition. A '?' means the conjunction will be relatively easy to see at some latitudes, but not others. All triplet conjunctions are easy to see because they are visible in the middle of the night. After a triplet conjunction the series moves to the evening (positive elongations), moves to align with the Sun (decreasing values) and then to the morning sky (negative elongations), until once again getting close enough to opposition to have a triplet conjunction. We anticipated all of this behavior. The closest conjunctions occur in specific longitude ranges, and all conjunctions are within 1.3 degrees. The section below on separations explains these aspects of the conjunctions.

CONJUNCTIONS FROM 1200 CE to 2400 CE

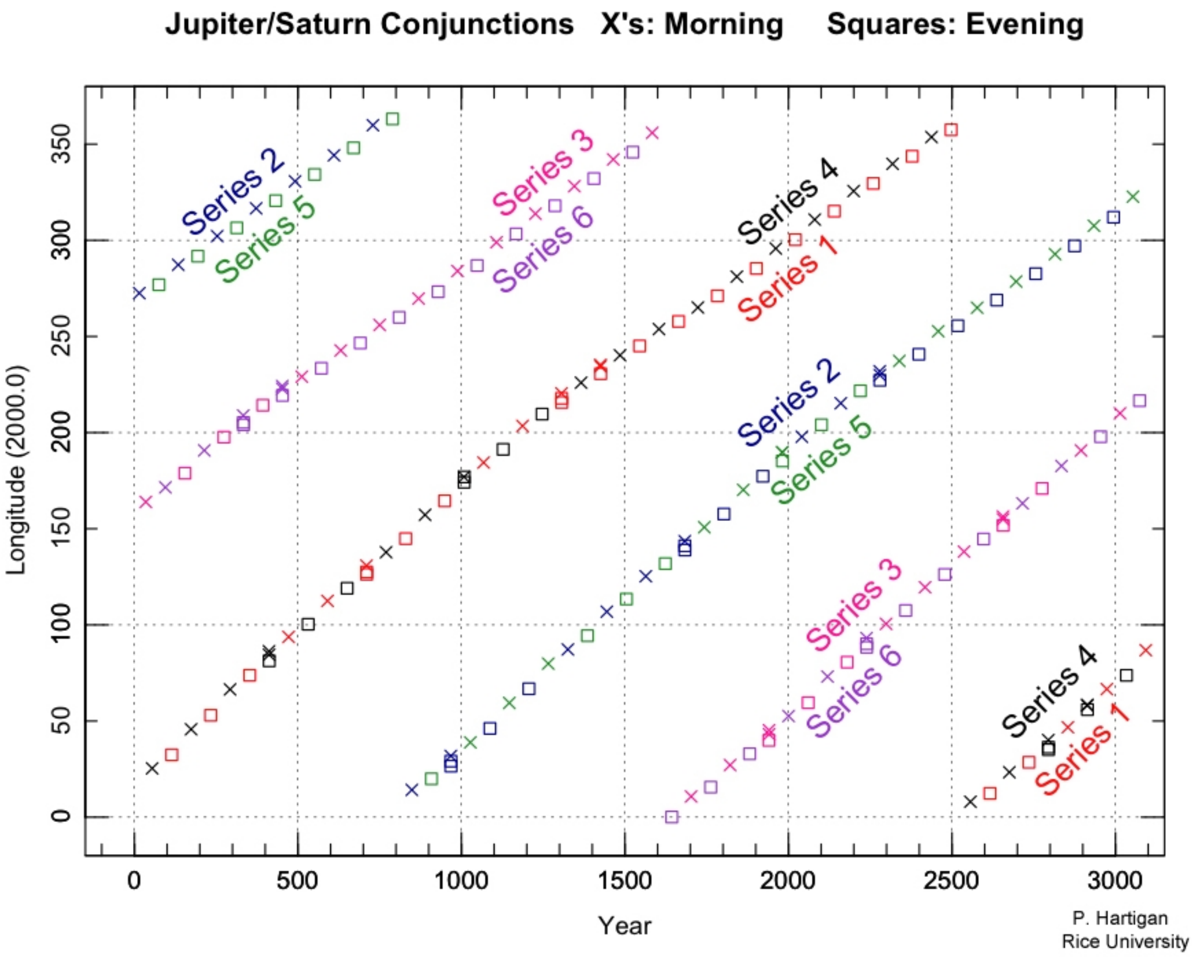
DATE	Longitude (2000)	Separation (arcmin)	Degrees From Sun	Series	Close? (< 20')	Visible Easily?	Triplet?
4/16/1206	66.8	65.3	23.0	2		?	
3/4/1226	313.8	2.1	-48.6	3	Y	Y	
9/21/1246	209.6	62.3	13.5	4		N	
7/23/1265	79.9	57.3	-58.5	5		Y	
12/31/1285	318.0	10.6	19.8	6		?	
12/24/1305	220.4	71.5	-70.0	1		Y	Y
4/20/1306	217.8	75.5	170.7	1		Y	Y
7/19/1306	215.7	78.6	82.5	1		Y	Y
6/1/1325	87.2	49.2	-0.4	2		N	
3/24/1345	328.2	21.2	-52.5	3		Y	
10/25/1365	226.0	72.6	-3.7	4		N	
4/8/1385	94.4	43.2	58.8	5		Y	
1/16/1405	332.1	29.3	18.1	6		N	
2/10/1425	235.2	70.7	-104.1	1		Y	Y
3/19/1425	234.4	72.4	-141.6	1		Y	Y
8/24/1425	230.6	76.3	62.6	1		Y	Y
7/13/1444	106.9	28.5	-15.9	2		N	
4/7/1464	342.1	38.2	-52.6	3		Y	
11/17/1484	240.2	68.3	-12.3	4		N	
5/25/1504	113.4	18.7	33.5	5	Y	?	
1/30/1524	345.8	46.1	19.1	6		N	
9/17/1544	245.1	69.2	53.4	1		Y	
8/25/1563	125.3	6.8	-42.1	2	Y	Y	
5/2/1583	355.9	52.9	-51.2	3		Y	
12/17/1603	253.8	59.0	-17.6	4		N	
7/16/1623	131.9	5.2	12.9	5	Y	N	
2/24/1643	0.1	59.3	18.8	6		N	
10/17/1663	254.8	59.2	48.7	1		Y	
10/23/1682	143.5	15.4	-71.8	2	Y	Y	Y
2/8/1683	141.1	11.6	175.8	2	Y	Y	Y
5/17/1683	138.9	15.8	77.5	2	Y	Y	Y
5/21/1702	10.8	63.4	-53.5	3		Y	
1/5/1723	265.1	47.7	-23.8	4		?	
8/30/1742	150.8	27.8	-10.3	5		N	
3/18/1762	15.6	69.4	14.5	6		N	
11/5/1782	271.1	44.6	44.9	1		Y	
7/16/1802	157.7	39.5	41.3	2		Y	
6/18/1821	27.1	72.9	-62.9	3		Y	
1/26/1842	281.1	32.3	-27.1	4		?	
10/20/1861	170.2	47.4	-39.5	5		Y	
4/17/1881	33.0	74.5	3.8	6		N	
11/28/1901	285.4	26.5	38.3	1		Y	
9/8/1921	177.3	58.3	11.1	2		N	
8/6/1940	45.2	71.4	-89.8	3		Y	Y
10/21/1940	41.1	74.1	-165.7	3		Y	Y
2/14/1940	39.9	77.4	73.3	3		Y	Y
2/18/1961	295.7	13.8	-34.5	4	Y	?	
1/1/1981	189.8	63.7	-91.4	5		Y	Y
3/6/1981	188.3	63.3	-155.9	5		Y	Y
7/25/1981	185.3	67.6	62.7	5		Y	Y
5/28/2000	52.6	68.9	-14.6	6		N	
12/21/2020	300.3	6.1	30.2	1	Y	?	
11/4/2040	197.8	72.8	-24.6	2		?	
4/8/2060	59.6	67.5	41.7	3		Y	
3/15/2080	310.8	6.0	-43.7	4	Y	Y	
9/18/2100	204.1	62.5	29.5	5		?	
7/15/2119	73.2	57.5	-37.8	6		Y	
1/14/2140	315.1	14.5	22.7	1	Y	?	
2/20/2159	215.3	71.2	-50.3	2		Y	
5/28/2179	80.6	49.5	16.1	3		N	
4/8/2199	325.6	25.2	-50.0	4		Y	
11/1/2219	221.7	63.1	6.8	5		N	

9/6/2238	93.2	39.3	-67.6	6		Y	Y
1/12/2239	90.2	47.5	161.3	6		Y	Y
3/22/2239	88.4	45.3	89.9	6		Y	Y
2/2/2259	329.6	33.3	19.6	1		?	
2/5/2279	231.9	69.9	-80.3	2		Y	Y
5/7/2279	229.9	73.8	-172.6	2		Y	Y
8/31/2279	227.2	74.9	73.3	2		Y	Y
7/12/2298	100.6	28.3	-6.0	3		N	
4/26/2318	339.8	41.8	-51.8	4		Y	
12/1/2338	237.3	66.3	-7.4	5		N	
5/22/2358	107.5	18.5	50.7	6	Y	Y	
2/18/2378	343.7	50.5	19.4	1		N	
10/2/2398	240.7	65.9	58.2	2		Y	

As we noted above, triplets aren't too common. Within the 1200-year interval tabulated above, there were 54 single conjunctions and 7 triplets. Some of the single conjunction events such as the ones in 1265, 1385, 1821, and 2398 nearly had triplets. Some plots of the six series may help clarify further:



Elongations (positive=evening, negative=morning) for all Jupiter-Saturn conjunctions from 0 CE to 3000 CE. The spikes are triplet conjunctions (filled symbols) that group around the opposition date for that year.



Locations in the sky (longitude for coordinate system 2000.0) for all Jupiter-Saturn conjunctions from 0 CE to 3000 CE. X's are morning conjunctions and open squares are evening ones. Three symbols on top of one-another indicate a triplet. Series 1 and 4 trace nearly exactly the same longitudes, but alternate from morning to evening between them, as do Series 2 and 5, and Series 3 and 6. All series progress steadily to the east (higher longitudes) with time.

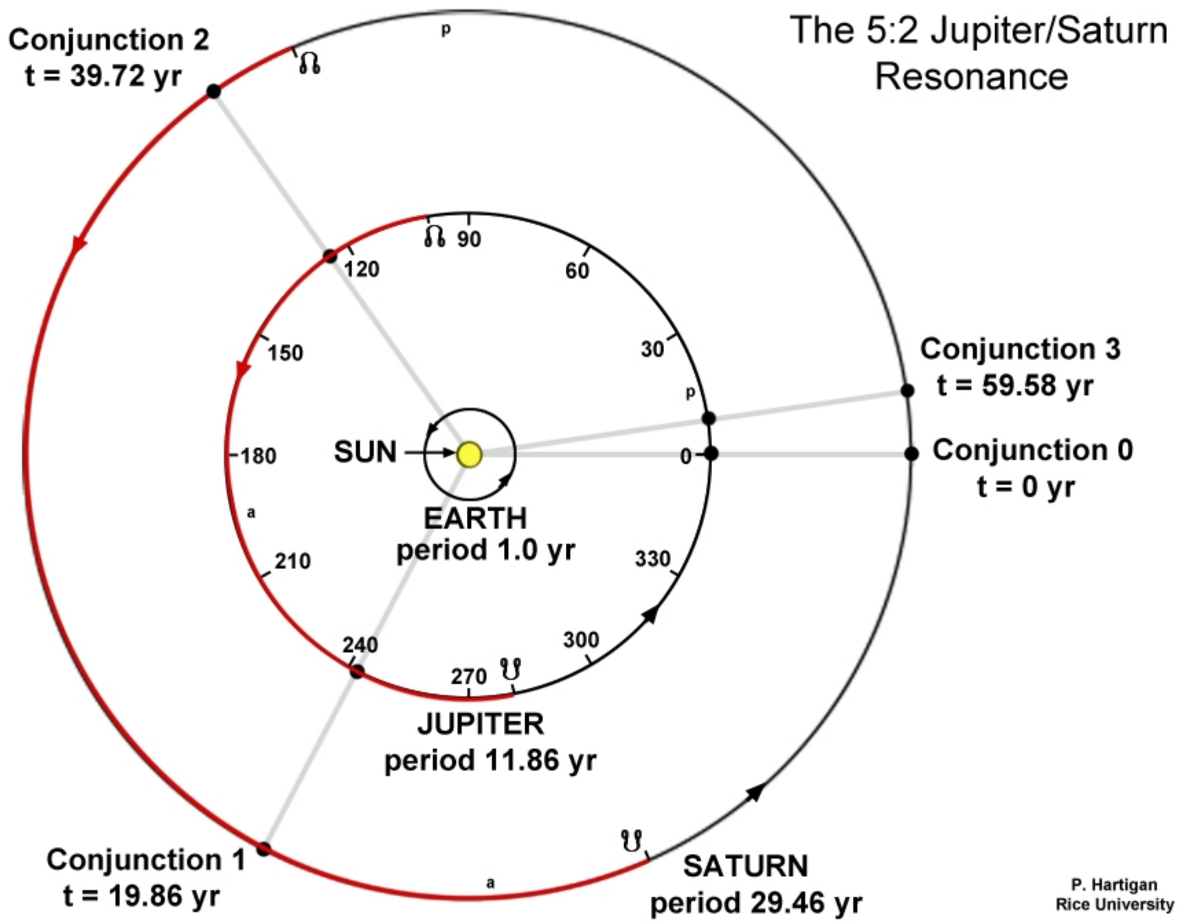
So the predictions all held true, generally. All the series have a progression from evening skies (positive elongation), to aligned with the Sun (zero elongation), to morning events (negative elongations) and then usually one or two triplet conjunctions visible in the middle of the night. Series 1 and 4 (and similarly 2 and 5, and 3 and 6) are related in that they have similar longitudes, and when one is in the morning the other is in the evening, and when one is near the Sun the other has a triplet opposition conjunction. The graphs show that the time required for a cycle to move once around the sky is about 2600 years, exactly as predicted.

However, some features emerged here we did not expect. We don't always get a triplet conjunction in a series; for example, in Series 5 the single morning conjunction on July 23, 1265 was followed by a single evening conjunction on April 8, 1385. Both of these were close to being triplet conjunctions but the retrograde motion just missed causing them. For example, after the July 23, 1265 event, the planets approached to within about 68 arcminutes of one another on January 13, 1266 before separating again, but this approach did not qualify as a conjunction because Jupiter never quite caught up to Saturn in longitude. On the other hand, sometimes we get more than one triplet conjunction back to back, as happened in Series 1 in 1305/1306 and again in 1425. The plots show that while the average time between triplet conjunctions in a series may be around 1360 years, the period seems to vary, and the shape isn't very periodic - it is almost like it is dragged out in some places and compressed in others, which explains why we might sometimes get no triplet conjunctions and sometimes get two of them. What might cause these variations?

The Orbits Aren't Circular

It's time to look at the orbital shapes in more detail. First of all, they are not all in the same plane, something that affects mainly the separation distance, as described in [the next section]. But the orbits are also ellipses and not circles. This detail matters a lot because planets move faster when they are closer to the Sun. Astronomers use eccentricity (e) to define how oblate an orbit appears, with e=0 being a perfect circle and e=1 opening so much it never closes, making a parabola. For Jupiter, e=0.0484 and Saturn has e=0.0539. These are actually relatively large. The Earth's eccentricity is lower by a factor of three, e=0.0167 (though it does vary over very long timescales and can get up to 0.068 or so, in the so-called Milankovitch cycles).

If the average radius of a circular orbit is R, then its diameter would be 2R. For an ellipse, we define 2R to be long axis of the ellipse, so R is half that, called the semimajor axis. The Sun is located off the center of the ellipse, such that the closest approach of the planet to the Sun, known as perihelion, is R*(1-e) and the farthest distance, known as aphelion, R*(1+e). If the average orbital speed is v, then when e is small like it is here, the planet moves at v(1+e) when closest, and v(1-e) when furthest away. Let's redraw the orbit diagram we used above, indicating the locations of perihelion with a 'p' and aphelion with an 'a', and add a longitude scale while we are at it. The red arcs and the curly symbols have to do with the tilt of the orbital plane, and we'll go over that in the next section.



Orbits of the Earth, Jupiter, and Saturn to scale. The Earth's orbit is in the plane. In the red halves of their orbits, Jupiter and Saturn are above the plane, and the black halves they are below the plane. The Omega-shaped symbol is the ascending node, where an orbit moves from below the plane to above it, and the U-shaped symbol is its counterpart, the descending node where planets move below the plane. The location where a planet is closest to the Sun on its elliptical orbit is marked with a `p', and the location where it is furthest from the Sun is marked `a'.

Jupiter and Saturn move most rapidly when they are close to perihelion, at longitudes 14.8 degrees and 92.5 degrees, respectively. After 10 Jupiter periods = 118.6 years, Jupiter returns to the same place in its orbit. The eccentricity doesn't matter one way or another for that to hold true. Now Saturn already returned to its starting point after 4*29.46 yrs = 117.84 yrs and so has had 0.76 years to move ahead in its orbit. If Jupiter's orbit were circular, it would move ahead 9.8146 degrees, and catch up to Saturn at a rate of 0.0496284 degrees/day if Saturn's orbit were circular, overtaking it in 197 days = 0.54144 yrs. This is how we got 118.62 + 0.54 = 119.16 years between cycles.

But now suppose Saturn is near aphelion, around longitude l = 270. Jupiter is about halfway between aphelion and perihelion, so should be moving near to its average speed. But Saturn's orbital motion is now slower than average by a factor of (1-e) so it moves ahead only (1-0.0539)*9.8146 = 9.28559 degrees, meaning that Jupiter has less far to go to catch Saturn. Moreover, the rate Jupiter gains on Saturn is faster because Saturn is going slower than average: 0.083092-(1-0.0539)*0.033463 = 0.05143 degrees/day, assuming Jupiter is going its normal speed. So it now takes 9.28559/0.05143 = 181 days, or 16 days less time than usual for Jupiter to catch up with Saturn. Hence, the Earth is about 16 degrees back of where it would be if the planets were moving at their average speeds. If the Earth would normally be, say, at l = 240 degrees it is now at 225 degrees or so. But this offset also shifts the conjunction a bit earlier because now Jupiter appears just ahead of Saturn as seen from the Earth. Combining these effects it is possible for the dates between adjacent conjunctions in a series to advance as slowly as two weeks in this part of the Jupiter/Saturn orbital diagram. The effect is largest when Saturn is at aphelion and Jupiter at perihelion, around l = 330 degrees. Conversely, a conjunction series will move quickly when Saturn is at perihelion and Jupiter at aphelion, around l = 150 degrees.

The position of the Jupiter/Saturn conjunction doesn't change a whole lot from the eccentricity effects, but the delays and speed-ups make a difference as to where the Earth is in its orbit, and therefore how the series appears from Earth. The eccentricity effect is evident in the plots, where the series seem drawn out for longitudes between 270 degrees and 360 degrees, and compressed when the longitude is between 90 degrees and 180 degrees. For example, Series 1 moves very rapidly from a conjunction located close to the Sun in 351 CE through the morning sky to a triplet conjunction at opposition in 710 CE, back through the evening sky to a conjunction near the Sun again by 1068 CE and onward to triplet conjunctions at opposition in 1306 CE and 1425 CE. So the Cycle has moved Sun->opposition->Sun->opposition in only nine conjunctions (1074 years). The average longitude in this period is 116 degrees. But after 1425 CE, Series 1 gets stalled in the evening sky and takes twelve conjunctions (1429 years) to finish just one leg, opposition->Sun, in 2854 CE. The average longitude during this period is 322 degrees, exactly where we expect eccentricity to make the series progress slowly.

Triplet conjunctions occur when the oppositions of Jupiter and Saturn are within about 1.7 days of one another. If a Series moves quickly then the conjunctions may be sparse enough to miss that window so that no conjunctions occur, as noted above for Series 5 that went directly from a single morning conjunction in 1265 to a single evening one in 1385. Likewise, if the elongation and timing are right, it is possible to have a Series contain back to back triplets. Although it did not occur in the interval from 0 CE to 3000 CE, in principle it should be possible to get three triplets in a row in a series. It almost happened during the late Roman Empire in Series 6, where there were triplets in 333 CE and 452 CE, and very nearly a third one in 571 CE, missing a triplet on March 2, 571 by less than a half degree in longitude.

What About Separation Distances?

If the elliptical orbits of Jupiter and Saturn were in the same plane, then every time Jupiter moved in front of Saturn, their disks would line up perfectly and Jupiter would occult (move in front of) Saturn. However, orbits are never exactly in the same plane. Astronomers describe the tilt of an orbit relative to the plane of the Earth's orbit by two angles: (1) the 'inclination', i.e., the amount of the tilt, and (2) by 'longitude of the ascending node' where on the sky the orbit of the planet intersects the plane of the Earth's orbit such that the planet moves from below the Earth's orbital plane to above it. In the above orbital diagram, the parts of the orbits above the plane are shown in red, and below the plane in black. The curly symbols represent the nodes, when the planet moves above Earth's plane or below it. As you might guess, you get a descending node at a longitude 180 degrees away from the ascending node.

Saturn's orbital inclination relative to the Earth is 2.485 degrees, and Jupiter's is 1.303 degrees. It is interesting that the ascending nodes of both planets are similar, 100.6 degrees for Jupiter and 113.7 degrees for Saturn, so that if Saturn is above or below the Earth's orbital plane, Jupiter usually is as well (this is partly caused by the Earth's orbit being tilted relative to all the large planets). Hence, in the diagram you can imagine both orbits tilting a bit above the plane on the left side (longitudes 100.6-280.6 for Jupiter and 113.7-293.7 for Saturn) and below the plane on the right side.

Because the orbits of Jupiter and Saturn align reasonably well, we expect that no closest approach will ever be worse than about 2.485 - 1.303 ~ 1.2 degrees, the difference in the inclinations of the two planets. Indeed, between 0 CE and 3000 CE the maximum conjunction distance, i.e., the 'worst' ones, were 1.3 degrees in 1306 and again in 1940. Both years featured triplet conjunctions at opposition, so the proximity of the Earth to Jupiter and Saturn accentuated the inclination differences. Conjunctions in both years occurred when the planets were tilted most out of the plane: longitude 206 degrees (therefore above the plane) in 1306, and longitude 39 degrees (therefore below the plane) in 1940. Jupiter/Saturn conjunctions are good that way, always within 1.3 degrees of one another in the sky.

What about closest approaches? As seen from the Sun, the orbits of Jupiter and Saturn intersect at longitudes 127.4 degrees and 307.4 degrees. These locations will have the closest conjunctions. The observed longitude for closest approaches may vary by +/- 10 degrees or so from these two values depending on where Earth is in its orbit, and as the conjunctions get wider, we will begin stray from the optimal range.

Let's look at more data. The next table shows the closest conjunctions during the 3000 year interval:

The Closest 25 Conjunctions from 0 CE to 3000 CE

DATE	Longitude (2000 coords)	Separation (arcmin)	Degrees From Sun	Series	Visible Easily?	Triplet?	
3/6/372	316.6	1.9	-53.0	2	Y	N	
3/4/1226	313.8	2.1	-48.6	3	Y	N	
12/25/2874	297.1	2.3	35.3	2	Y	N	
7/22/769	137.8	4.3	-2.4	4	N	N	<-- Close to Sun
7/16/1623	131.9	5.2	12.9	5	N	N	<-- Close to Sun
8/24/2417	119.6	5.4	-26.5	3	?	N	
3/15/2080	310.8	6.0	-43.7	4	Y	N	<---------- 2080 conjunction
12/21/2020	300.3	6.1	30.2	1	?	N	<---------- 2020 conjunction
12/31/431	320.6	6.2	17.4	5	N	N	
7/6/2477	126.2	6.3	27.1	6	?	N	
8/25/1563	125.3	6.8	-42.1	2	Y	N	
9/13/709	130.8	8.3	-61.1	1	Y	Y	
3/19/2934	307.6	9.7	-37.9	5	Y	N	
12/11/1166	303.3	9.8	25.0	6	N	N	
2/23/2815	292.8	10.0	-30.1	5	?	N	
12/31/1285	318.0	10.5	19.8	6	?	N	
2/8/1683	141.1	11.6	175.8	2	Y	Y	
3/30/710	126.3	12.1	95.7	1	Y	Y	
12/13/312	306.5	13.4	20.1	5	?	N	
2/18/1961	295.7	13.8	-34.5	4	?	N	
1/14/2140	315.1	14.5	22.7	1	?	N	
10/23/1682	143.5	15.4	-71.8	2	Y	Y	
2/4/710	127.5	15.5	150.0	1	Y	Y	
5/17/1683	138.9	15.8	77.5	2	Y	Y	
6/4/829	144.9	15.9	51.4	1	Y	N	

Look at those longitudes! The pattern for closest approaches is clear: they all have longitudes in two narrow ranges - between 119.6-144.9 degrees and 292.8-320.6 degrees - close to the predicted optimal orbital intersections of 127.4 +/- 10 degrees and 307.4 +/- 10 degrees. Hence, there are specific locations in their orbits where Jupiter and Saturn appear to overlap in the sky. The 2020 and 2080 conjunctions are close because they line up with these special points in the orbits. For the 2020 conjunction, Jupiter and Saturn are around longitude 300 degrees, just below the Earth's orbital plane, while the Earth is up at the top of its orbit at 90 degrees. The Earth spins counterclockwise, so this case of the planets appearing to the left of the Sun as viewed from the Earth means the conjunction is an evening event. After three more conjunctions we get to 2080, where after two Saturn orbits and five from Jupiter, the planets have moved about 8 degrees ahead to around 308 degrees. The Earth is now over at a longitude 175 degrees or so, and this vantage point pushes the longitude of conjunction ahead a bit to 310 degrees. Now the planets are visible to the right of the Sun, and so the 2080 event occurs in the morning sky.

The standouts in the table are the conjunctions of March 6, 372, and March 4, 1226. Both easily visible in the morning sky, Jupiter and Saturn would have merged into a single point of light for most people. The image below (again adapted from Stellarium) shows what the 372 CE conjunction would have looked like in a telescope. Though undoubtedly the conjunction was observed, no one ever saw it like this because telescopes had not yet been invented in this time of the Roman emperor Valentin I. Another favorite has to be the triplet sequence that occurred in 1682 and 1683, where the three conjunctions were not only visible in the middle of the night when skies were dark and the planets at their brightest, but these conjunctions were also very close. These conjunctions happened only 73 years after the invention of the telescope, and not long after Huygens first identified Saturn as having rings in 1655.

Occultations and the 854-Year Cycle

The disk of Jupiter never occults Saturn during the 3000 year interval of this study. Even the 372 CE conjunction with its separation of 1.9 arcminutes does not achieve the 0.4 arcminute separation required for an occultation. The apparent sizes of the disks of Jupiter and Saturn are just really small, so it is very difficult to line them up perfectly. In addition to the 372 CE event, there was a nice triplet conjunction in 1793 BCE and the one on May 1 of that year had a separation of only 1.3 arcminutes. But to try to find a case for occultation, where Jupiter runs in front of Saturn, we need to expand the time interval of the study. This actually begins to get a bit tricky to do. While there are excellent predictions for the positions of all the planets going forward or backward in time for several thousand years, once we start looking at times before about 4000 BCE or ahead of about 6000 CE the predictions begin to get more uncertain. There is a recent compilation available from JPL, published in 2014, which gives planetary ephemerides outside of this date range. I use these predictions in this section, though it is good to recognize that there are uncertainties in the best of predictions, and the effect these have on the results grows with distance into the future or past.

Concentrating on the group of closest approaches (less than about 10 arcminutes) an interesting aspect appears: the closest approaches concentrate into distinct groups, where the members of each group are separated by nearly exactly 854 years. This grouping scheme removes the 80% or so of wide conjuctions and leaves only the close ones, as shown in the following table.

854 Year Cycles of Closest Approach
10000 BCE to 10000 CE

DATE	Longitude (2000 coords)	Separation (arcmin)	Degrees From Sun	Series	Visible Easily?	Triplet?
2/6/-9696	38.4	12.6	-9.2	5	N	N
1/19/-8842	31.8	13.1	6.2	6	N	N
1/1/-7988	24.9	13.2	23.1	1	?	N
12/8/-7135	17.5	11.6	44.6	2	Y	N
4/22/-6281	14.7	5.6	-81.8	3	Y	Y
7/27/-6281	12.2	5.4	-176.8	3	Y	Y
11/3/-6281	9.5	6.6	78.3	3	Y	Y
3/15/-5427	6.8	7.7	-48.5	4	Y	N
2/17/-4573	359.0	8.1	-25.8	5	?	N
1/28/-3719	352.1	8.6	-8.3	6	N	N
1/17/-2865	346.6	9.7	4.1	1	N	N
4/14/-9756	31.7	5.5	-81.1	2	Y	Y
7/16/-9756	29.3	18.7	-175.4	2	Y	Y
10/28/-9756	26.6	3.0	76.0	2	Y	Y
3/17/-8902	25.2	1.8	-55.2	3	Y	N
2/21/-8048	17.8	0.5	-33.1	4	Y	N
1/27/-7194	10.0	0.8	-12.2	5	N	N
1/1/-6340	1.4	2.7	10.7	6	N	N
12/6/-5487	353.2	5.4	34.1	1	?	N
11/12/-4633	346.0	8.1	57.9	2	Y	N
4/5/-3779	345.5	5.2	-79.7	3	Y	Y
7/21/-3779	342.6	18.1	175.0	3	Y	Y
10/17/-3779	340.2	10.8	84.4	3	Y	Y
3/23/-2925	341.1	1.5	-64.7	4	Y	N
3/16/-2071	337.7	2.3	-57.7	5	Y	N
3/19/-1217	335.0	6.8	-54.9	6	Y	N
3/19/-363	332.7	11.6	-54.1	1	Y	N
12/23/-2985	330.4	12.0	12.0	1	N	N
12/22/-2131	327.4	8.0	15.3	2	N	N
12/25/-1277	325.1	3.3	16.1	3	N	N
12/28/-423	322.8	1.5	16.7	4	N	N
12/31/431	320.6	6.2	17.4	5	N	N
12/31/1285	318.0	10.5	19.8	6	N	N
3/3/-1336	321.4	11.0	-56.5	6	Y	N
3/5/-482	319.1	6.4	-55.1	1	Y	N
3/6/372	316.6	1.9	-53.0	2	Y	N
3/4/1226	313.8	2.1	-48.6	3	Y	N
3/15/2080	310.8	6.0	-43.7	4	Y	N
3/19/2934	307.6	9.7	-37.9	5	Y	N
12/13/312	306.5	13.4	20.1	5	?	N
12/11/1166	303.3	9.8	25.0	6	?	N
12/21/2020	300.3	6.1	30.1	1	?	N
12/25/2874	297.1	2.3	35.3	2	Y	N
12/30/3728	294.3	2.0	39.4	3	Y	Y
1/6/4583	291.8	6.7	42.1	4	Y	N
2/22/2815	292.8	9.9	-30.0	5	?	N
2/28/3669	290.1	5.6	-26.7	6	?	N
3/8/4523	287.8	1.0	-24.7	1	?	N
3/16/5377	285.6	4.0	-23.4	2	?	N
3/25/6231	283.3	8.9	-21.9	3	?	N
12/17/4463	278.0	12.3	46.2	4	Y	N
12/25/5317	275.8	7.0	47.7	5	Y	N
1/1/6172	273.4	1.8	50.1	6	Y	N
1/5/7026	270.6	2.9	55.1	1	Y	N
6/22/7879	272.0	8.4	-101.1	2	Y	Y
8/8/7879	270.9	8.0	-148.0	2	Y	Y
1/4/7880	267.5	7.1	63.9	2	Y	Y
3/1/6112	269.0	10.0	-14.8	3	N	N
3/3/6966	265.6	6.1	-8.4	4	N	N
3/2/7820	261.7	2.8	0.4	5	N	N
2/25/8674	256.9	0.2*	12.4	6	N	N
2/18/9528	251.7	2.0	26.7	1	?	N
8/25/-9359	205.6	1.9	-37.1	4	Y	N
8/20/-8505	202.1	1.8	-28.4	5	?	N
8/18/-7651	199.3	6.1	-23.3	6	?	N
8/19/-6797	196.7	10.7	-19.8	1	?	N
6/5/-9418	195.7	12.5	34.9	1	Y	N
5/31/-8564	192.5	9.3	41.8	2	Y	N
6/1/-7710	190.1	4.7	45.2	3	Y	N
6/1/-6856	187.7	0.1*	48.4	4	Y	N
6/1/-6002	185.4	4.8	51.5	5	Y	N
5/27/-5148	182.3	8.5	58.5	6	Y	N
10/25/-4295	183.6	10.6	-84.0	1	Y	Y
1/14/-4294	181.6	1.7	-168.2	1	Y	Y
5/17/-4294	178.7	11.1	70.8	1	Y	Y
10/1/-3441	178.6	14.3	-58.2	2	Y	Y
3/9/-3440	174.8	5.9	137.8	2	Y	Y
4/9/-3440	174.1	9.4	106.8	2	Y	Y
4/9/-3440	174.1	9.4	106.8	2	Y	Y
9/8/-2587	172.7	16.3	-35.9	3	Y	N
8/3/-7770	186.6	10.4	-21.2	6	?	N
8/3/-6916	184.2	5.9	-18.0	1	N	N
8/2/-6062	181.4	1.7	-13.8	2	N	N

7/27/-5208	177.6	1.5	-5.6	3	N	N
7/17/-4354	173.1	3.9	6.1	4	N	N
6/28/-3500	167.0	4.5	23.2	5	?	N
6/5/-2646	160.5	3.9	44.6	6	Y	N
5/1/-1792	153.4	1.3	76.1	1	Y	Y
1/19/-1792	155.8	5.3	178.3	1	Y	Y
10/8/-1793	158.2	2.6	-74.1	1	Y	Y
9/3/-939	151.0	3.5	-41.7	2	Y	N
8/11/-85	144.2	3.8	-19.7	3	N	N
7/22/769	137.8	4.3	-2.4	4	N	N
7/16/1623	131.9	5.2	12.9	5	N	N
7/6/2477	126.2	6.3	27.1	6	?	N
6/27/3331	120.6	7.4	42.6	1	Y	N
9/6/-4414	167.0	7.7	-52.0	1	N	N
8/12/-3560	160.3	6.8	-27.8	2	?	N
7/19/-2706	153.1	7.1	-5.5	3	N	N
6/23/-1852	145.6	8.2	16.8	4	N	N
5/30/-998	138.5	9.3	38.6	5	Y	N
10/18/-145	136.5	10.7	-94.9	6	Y	Y
12/10/-145	135.3	14.9	-150.2	6	Y	Y
5/4/-144	132.0	10.5	61.9	6	Y	Y
9/13/709	130.8	8.3	-61.1	1	Y	Y
2/4/710	127.6	15.3	150.4	1	Y	Y
3/30/710	126.3	12.3	95.7	1	Y	Y
8/25/1563	125.3	6.8	-42.1	2	Y	N
8/24/2417	119.6	5.4	-26.5	3	?	N
8/15/3271	113.4	4.2	-12.1	4	N	N
8/4/4125	107.7	3.4	2.8	5	N	N
7/24/4979	101.4	2.8	18.5	6	N	N
7/12/5833	95.2	2.2	35.1	1	Y	N
6/29/6687	89.2	1.4	52.7	2	Y	N
12/6/7540	89.1	1.8	-90.2	3	Y	Y
2/16/7541	87.3	0.5*	-163.0	3	Y	Y
6/17/7541	83.9	0.0*	71.4	3	Y	Y
11/24/8394	84.8	4.3	-71.7	4	Y	Y
3/28/8395	81.4	2.5	161.7	4	Y	Y
6/3/8395	79.5	2.5	92.4	4	Y	Y
11/21/9248	81.2	7.7	-62.7	5	Y	N

(*) Occultation

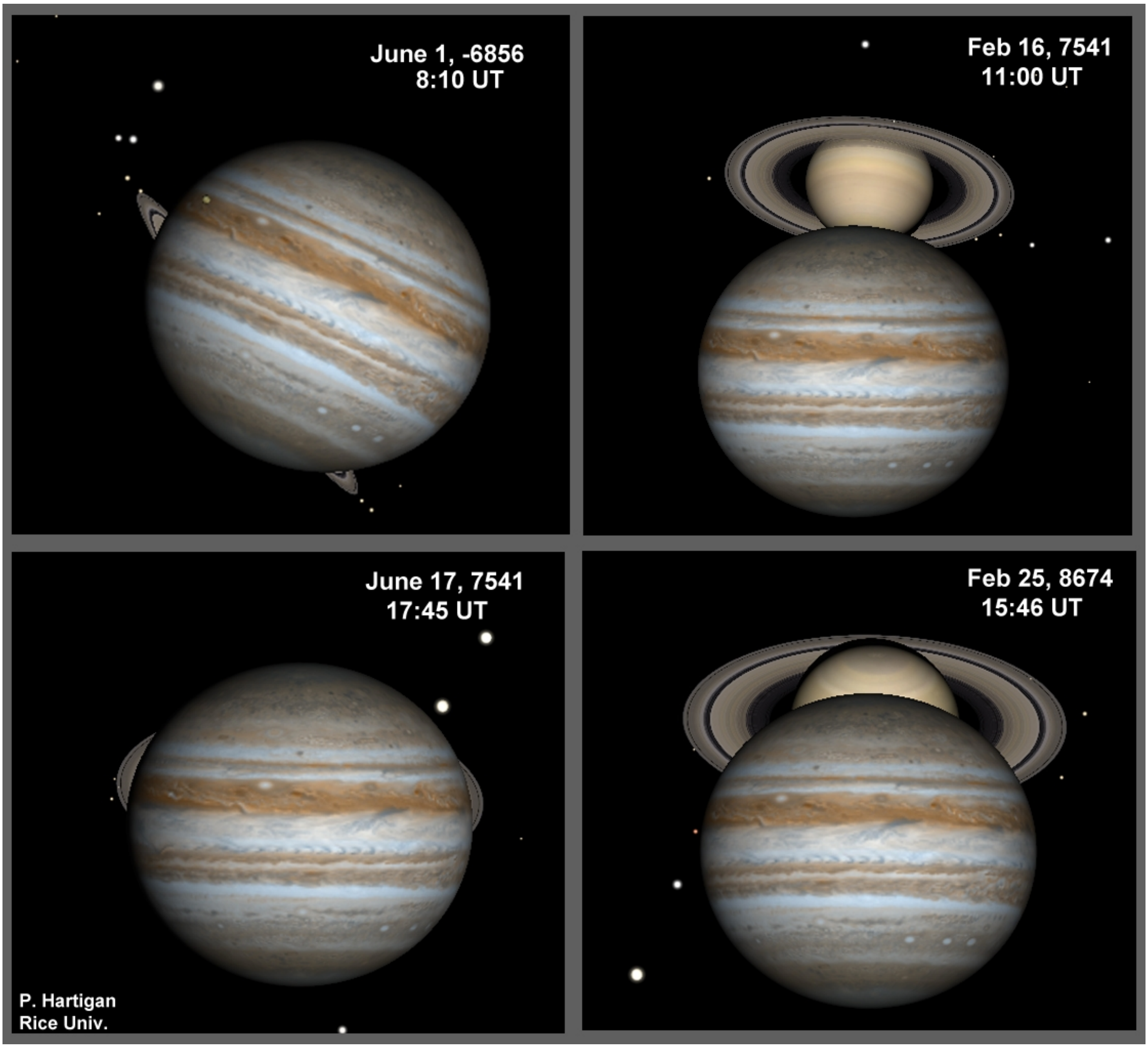
Look at the entries in the last grouping. We start on September 6 of -4414 (4415 BCE). Nearly exactly 854 years later, on August 12, -3560, we have a conjunction with nearly the same longitude, separation, and in the morning sky. The series gradually shifts earlier in the year to May, in 854 year intervals. The May 4, -144 conjunction is a triplet that includes Dec. 10, -145, and Oct. 18, -145, and another triplet follows 854 years later with Sept. 13, 709 in the morning, Feb. 4, 710 in the middle of the night and March 30, 710 the last of the evening ones. Starting from the morning triplet of Sept. 13, 709, we now move ahead 854 years later on Aug. 25, 1563 with a single morning conjunction, and continue every 854 years as the series moves towards the Sun and the evening sky, and get triplets again in 7540/7541 CE and 8394/8395 CE. All the groups behave in a similar manner. Notice how similar the longitudes are, and the regular pattern for the series that goes ...1-2-3-4-5-6-1-2-3...

So what causes the 854-year cycle/series for close approaches? Go back and look at the first diagram up at the top of the page (the 5:2 resonance figure). Suppose conjunction 0 was a nearly perfect alignment (remember the orbits of Jupiter and Saturn are tilted out of the plane). Conjunction 3 almost gets us back to Conjunction 0, but is off by 8.15 degrees. In the meantime, Conjunction 4 will occur a little to the right of Conjunction 1, Conjunction 7 a little more to the right and so on. Now, each synodic period of 19.86055 years moves us 242.7359 degrees around the circle, so after n synodic periods the conjunction location is at n*242.7359 degrees. We only care where it ends up on the circle, not how many times it goes around, so we want the remainder of n*242.7359 to be as close to zero as possible. Likewise we need the Earth to be in the same spot, so we want n synodic periods to be equal to an integer number of years.

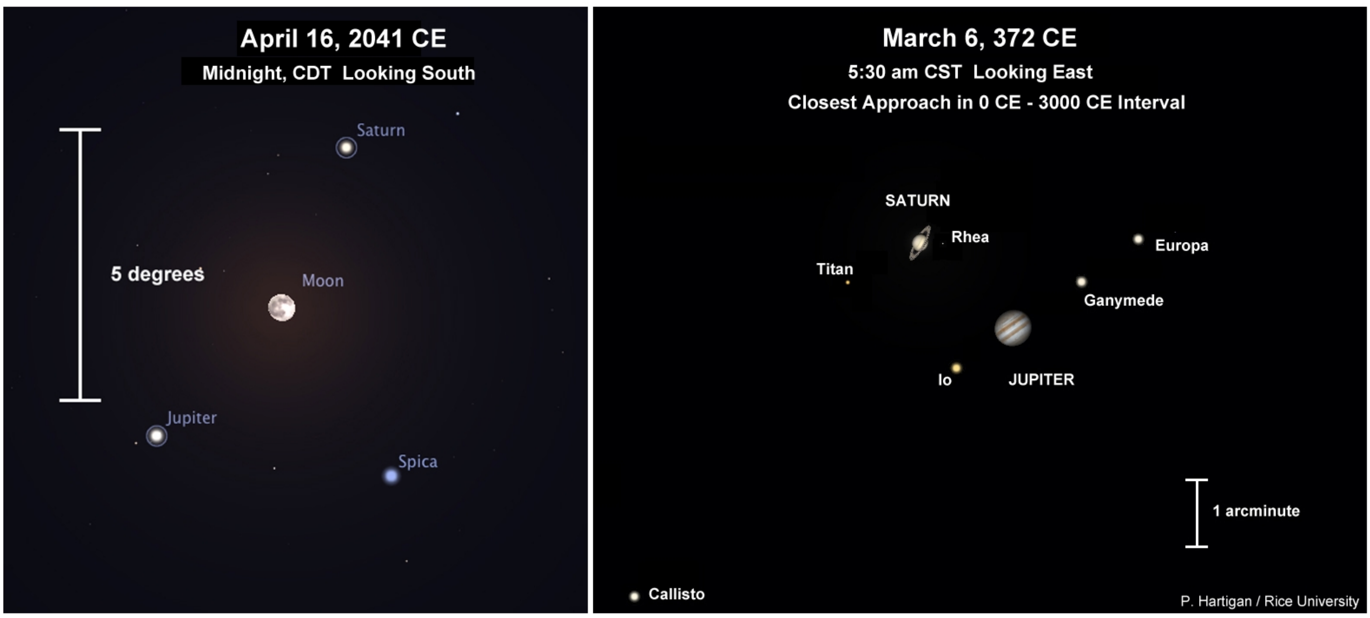
It is easy enough to loop through values of n and see what might work. For example, n=3 leaves you 8.15 degrees too far, or a fraction 0.023 = 8.15/360 of the circle ahead of where you'd like to be. That isn't too bad, but n=3 corresponds to 59.582 years, so you are 0.582 around the Earth's orbit from where you want to be, and that's pretty bad. So we want n to bring both of these as close to 0 (or equivalently, 1, which puts you in the same place because once around a circle is the same as never moving).

Drumroll.... n=43 equals 19.86055*43 = 854.0036 Earth years, and corresponds with 43*242.7359/360 = 28.993, or almost exactly 29 revolutions. So after 43 synodic periods we return to a nearly identical setup as Conjunction 0. Notice that 43 = 6*7 + 1, so we go through series 1 through 6 seven times, with one left over. This is why the series number always increases by 1 after 854 years in the table.

To the extent that the planetary positions are reliable, the above table gives some interesting results. There are now **four** occultations, one in the distant, prehistoric past on 6/1/-6856, and three in the far future (two in the same year!) on 2/16/7541, 6/17/7541, and 2/25/8674. The ones on 6/1/-6856 and 6/17/7541 are so well-aligned that the entire ball of Saturn disappears behind Jupiter, leaving only the rings to poke out. It looks like Jupiter has little handles or ears. Unless you have a scheme for living 5500 years, you'll have to be content with the pictures on this one.



Rogue's gallery of Jupiter/Saturn occultations predicted to occur in the time interval between 10000 BCE and 10000 CE using planetary ephemerides from the JPL DE-431 compendium of Folkner et al. (2014). These predictions depend entirely upon the accuracy of the ephemerides. The images are adapted from Stellarium. Upper left: "Wheee! Skateboard!" Upper right: "A tip of the hat to you." Lower left: "Nothing to see here." Lower right: "Leave my friend alone!"



Left: A pretty alignment between a bright star, the full Moon, and Jupiter and Saturn. Conjunction years often produce striking combinations such as this one. Right: The closest Jovian-Saturnian conjunction in the 3000 year interval studied.

Though Occultations are Extremely Rare, There are Plenty of Pretty Alignments

Although there are no occultations between Jupiter and Saturn in the 0 CE and 3000 CE interval, there are no shortages of beautiful alignments of the Jupiter/Saturn pair with other celestial objects. Above is one I noticed from the next conjunction in 2040/2041: a lovely alignment between Jupiter, Saturn, and the star Spica in a near perfect isosceles triangle with the full Moon right in the middle.

Other Planets Can Join the Fun

In a conjunction year for Jupiter and Saturn, the two planets are always within about 10 degrees of one-another in the sky. Over the course of the year they move once around the sky relative to the Sun, and during that time they will always go past Mercury and Venus, and usually Mars as well. So every conjunction year between Jupiter and Saturn features groupings that involve other planets, and, of course, the Moon, which moves around the sky once each month. Sometimes the conjunctions with other planets are impressive in their own right, though many are lost in the glare of the Sun. One good one ocurred on December 5, 749, where only a few hours before the closest approach of Jupiter and Saturn somehow Mercury managed to slip between them! That event would have been hard, but perhaps not impossible to observe as it was only 19 degrees from the Sun. In 2020, Mars passed within a degree of Jupiter on March 20 and then Saturn on March 31, with the waning crescent Moon in the vicinity on March 18. During this time Jupiter was about 7 degrees from Saturn. After the Jupiter/Saturn conjunction as the planets emerged into the morning sky, there was a fairly close conjunction of Jupiter with Mercury on March 5, 2021 at an elongation of about 27 degrees from the Sun, though by then, Jupiter and Saturn were/will be about 8.5 degrees apart, and starting to look less associated. Every conjunction year has things like this happening, so if you have a Jupiter/Saturn conjunction year it is worthwhile looking to see what the other planets are doing as well. There is always something going on!