Five thousand years of Jupiter–Saturn conjunctions

Mark Kidger

The recent so-called 'Great Conjunction' of Jupiter and Saturn, in 2020 December, was the latest in a series of conjunctions of the two planets that occur, on average, every 19.67 years. Although events between Jupiter and Saturn are visually not the most spectacular of conjunctions, they are of great historical interest due to the triple conjunction that occurred around the time of the Nativity, which authors such as Hughes (1976) have associated with the Star of Bethlehem. A total of 309 Jupiter–Saturn conjunctions are found between 1000 BC and AD 4000, which include 84 grouped in 28 triple conjunctions. The 2020 conjunction is found to be in the top five percent of closest approaches of the two planets over five millennia. The closest conjunctions show a strong preference for occurring in Cancer in July/August, or Capricornus in December.

Introduction

Not all close approaches of two planets are conjunctions. A classical conjunction occurs when a planet has the same right ascension as another celestial object, which may be a star, another planet, a satellite, *etc*. In other words, the two objects pass each other crossing the north–south line. As the ecliptic is inclined with respect to the celestial equator, it is possible for two objects to have the same ecliptic longitude without ever crossing the north–south line: such approximations in ecliptic longitude are not classed as conjunctions. Here, we only treat the former case.



Figure 1. The 2020 Dec 21 conjunction, observed from the seafront in Puerto de la Cruz (Tenerife). 1/17s exposure at *f*/1.7; equivalent ISO 320 and 4mm focal length with a hand-held Samsung SM-A705FN smartphone. *Mark Kidger*

The 2020 conjunction of Jupiter and Saturn (Figure 1) attracted a great deal of interest. Part of this interest was down to the minimum separation between the two planets being rather small (six arcminutes). Part was due to the fact that the conjunction occurred only a few days before Christmas. Another part was explained by the excellent placement of the two planets, low in the evening sky, which made observation easy (albeit less so from northern latitudes). However, the biggest single factor was possibly the parallel with the 7 BC triple conjunction that occurred around the time of the Nativity. This event is often linked with the Star of Bethlehem and the Nativity story, by authors such as Hughes (1976).[1]

Much has been written about Jupiter–Saturn conjunctions and, in particular, those of 7 BC and AD 2020, but the author is unaware of any studies of Jupiter–Saturn conjunctions as a whole that would put these two events in context. This has been the motivation for this study.

To give context, it should be stated that, although planetary conjunctions are common, Jupiter–Saturn events are much rarer. Sinnott (1968) pointed out that there were almost 200 conjunctions of the five brightest planets in the 18 years from 12 BC to AD 7 and 20 massings of three or more planets,[2] with them all located within a circle of diameter three degrees. However, most of these events took place close to solar conjunction and would not have been observable, or would have been difficult to observe, being very close to the Sun in the sky. Others were relatively unspectacular, with a wide separation between the planets – these Sinnott rejected as 'too commonplace' (on this criterion, the 7 BC Jupiter–Saturn triple conjunction was rejected by him as a candidate for the Star of Bethlehem).

In the end, Sinnott found six two-planet conjunctions that took place at least 20 degrees from the Sun in the sky and with a minimum separation of 12 arcminutes or less. Of these, by far

the most spectacular were the conjunctions of Venus and Jupiter in 3 BC and 2 BC. Unfortunately, these two events are strongly in conflict with the dating of the death of King Herod, which Josephus (*c.* 75 AD) appears to state happened in the month after the 4 BC March partial lunar eclipse.[3] Josephus also gives a second line of dating, stating that the Battle of Actium occurred in the seventh year of Herod's reign and that he died 37 years after the Roman Senate voted to make him king of Judea. The vote by the Senate happened in 41 BC, also giving a 4 BC date for his death.

Interestingly, the 7 BC triple conjunction is one of the few astronomical events for which we have surviving Babylonian records. Tablet BM 35429, in the British Museum, is an astronomical almanac for Seleucid Era 305 and describes the three conjunctions.[4]

Five millennia of Jupiter–Saturn conjunctions

The calculation

A search for conjunctions of Jupiter and Saturn was made for the interval 1000 BC to AD 4000, using *Dance of the Planets* (hereinafter '*Dance*') software (v. 2.71, QED edition, ARC Software), using the *DOSBox* emulator. Despite its relative age, the software has excellent accuracy over several millennia. The calculation took approximately seven and a half hours with a Dell Ultrabook laptop.

The *Dance* software distinguishes in its results between genuine, classical conjunctions and approaches in which the ecliptic longitude is equal, but no physical conjunction occurs. No approaches of the latter class were found in this study.

Similarly, the output of the *Dance* software does not present dates in the classical BC/AD format. It is a peculiarity of the calendar introduced by Dionysius Exiguus that the date jumps directly from 1 BC Dec 31 to AD 1 Jan 1 (a brief background to the rather complex history of the Dionysian calendar can be found in ref. 6). *Dance* avoids the arithmetic issue by outputting dates in 1 BC as the (non-existent) year 0 and numbering previous years as –1 (2 BC), –2 (3 BC), … These dates have been translated to the traditional BC/AD format here. [*NB: Dance* accepts dates only in the range 4681 BC to AD 9999.] A further peculiarity of *Dance* is that it uses the Gregorian calendar throughout and thus gives the equivalent Gregorian date for events prior to 1582.

Finally, *Dance* outputs dates and times in Universal Time (UT). Since the 1976 resolution of the XVIth IAU General Assembly, astronomical dates are generally given in Terrestrial Time (TT), originally Terrestrial Dynamic Time (TDT). The current difference between TT and UT is less than a minute. Over the period 1600–2100 (high-accuracy range), *Dance* claims a maximum error in the correction of TT to UT of two minutes. Over ±2,000 years the error may amount to several minutes and, at the extremes of the range of permitted dates, 'several hours';[7] the times given here should thus be taken as orientative when more than 2,000 years from the current date.

Normal conjunctions

The historical sequence consists of 309 conjunctions, of which 225 are single events ('normal' conjunctions) and the remaining 84 are grouped into 28 triple conjunctions, where a series of three conjunctions take place in an interval of approximately six months. The first conjunction of the sequence took place on 999 BC May 30 and the last will take place on AD 3987 Jan 13. Hence, the average time between conjunctions is 19.671 years.

The median separation of Jupiter and Saturn at conjunction for all events is 55 arcminutes, with a maximum separation of 78 arcminutes, which occurred in AD 1306 (the final event of the AD 1305/06 triple) and will again in AD 2795 (the final event of the AD 2794/95 triple). Although very close conjunctions of Jupiter and Saturn are infrequent, there are 11 events with a separation

Table 1. Close Jupiter–Saturn conjunctions between 1000 BC & AD 4000

Date	*Time (UT)*	*J mag.*	*S mag.*	*α (h m)*	*δ*	*Const.*	*Dist. (′)*
424 BC Dec 28	10:59	–2.0	0.4	19 24	–22	Cap	87″
372 Mar 6	13:31	–2.1	0.5	19 44	–22	Cap	2
1226 Mar 5	04:14	–2.0	0.6	20 22	–20	Cap	2
2874 Dec 25	15:07	–2.0	0.7	20 48	–18	Sgr	2
3728 Dec 30	16:49	–2.0	0.8	21 24	–15	Sgr	2
940 BC Sep 4	02:24	–1.8	0.2	07 28	+23	Leo*	3
86 BC Aug 11	18:36	–1.8	0.2	07 49	+22	Leo	4
769 Jul 23	01:55	–1.7	0.2	08 12	+21	Cnc†	4
3271 Aug 15	08:14	–1.8	0.3	08 57	+17	Gem	4
1623 Jul 16	22:34	–1.8	0.2	08 37	+19	Cnc	5
2417 Aug 24	16:01	–1.8	0.2	08 32	+19	Cnc‡	5
483 BC Mar 6	01:11	–2.1	0.5	19 04	–23	Cap	6
431 Dec 31	17:16	–2.0	0.5	20 04	–21	Cap	6
2020 Dec 21	18:21	–2.0	0.6	20 11	–21	Cap§	6
2080 Mar 15	01:36	–2.0	0.7	20 58	–18	Cap	6
2477 Jul 6	19:50	–1.8	0.3	09 02	+17	Cnc‖	6
3669 Feb 28	07:22	–1.9	0.7	21 04	–17	Sgr	6

* Very close to Regulus. † On the border with Leo. ‡ Close to border with Gem. § Close to border with Sgr. ‖ Takes place in the outer fringes of Praesepe (M44).

Notes: This table gives the 17 Jupiter–Saturn conjunctions with a separation of six arcminutes or less between 1000 BC and AD 4000. Most of these occur close to solar conjunction. Columns are, from left to right: the date (Gregorian calendar, with the equivalent Gregorian date prior to 1582; AD unless indicated otherwise), time (Universal Time), magnitude of Jupiter, magnitude of Saturn, right ascension and declination (J2000), constellation and separation (in arcminutes, unless stated otherwise).

of five arcminutes or less (Table 1) – closer than the six arcminutes of the AD 2020 December 'Great Conjunction'. One thing that we note immediately from Table 1 is that the distribution of the conjunctions with very small separations shows that they are not random, either in date or in position in the sky. Events concentrate very strongly towards Cancer (in July/August) and Capricornus (in March and December).

The only conjunction in the series with a separation under one and a half arcminutes was that of 424 BC December, in Capricornus. However, two other events stand out. The 940 BC conjunction took place just two degrees from Regulus, while the AD 2477 conjunction will take place in the outer fringes of the Praesepe cluster (M44).

Triple conjunctions

The mean interval between the central events of triple conjunctions is 169.77 years but is highly variable. On eight occasions over five millennia, two triple conjunctions are separated by just a single, normal conjunction (this was the case for the triple conjunctions of AD 967 and 1008 as well as AD 1940 and 1981; it will be again for those of AD 2239 and 2279, for example). In contrast, there are no fewer than 18 normal conjunctions between the triples in 522 and 146 BC (374 years), or those in AD 2279 and 2656 (377 years).

On two occasions, three triple conjunctions occur in just 119 years. This was the case between AD 333 and 452, when three normal conjunctions separated the triples in the years AD 333 and 411, while a single normal conjunction occurred between the AD 411 and 452 triples. The same pattern will be seen between the years AD 3133 and 3252, with a triple conjunction in AD 3133, followed by three normal conjunctions, a triple in AD 3211/12, a normal conjunction and then another triple in AD 3252.

At the other extreme, after the AD 3252 triple, a sequence of 25 normal conjunctions split by just a single triple (in AD 3509/10) will occur up to the year AD 3748.

The median separation of the planets in triple conjunctions is slightly larger than for normal conjunctions (63 arcminutes, as against 50 arcminutes for the normal events). The circumstances of triple conjunctions make it rare to have extremely close approaches: just one of the 84 found has a minimum separation of under 10 arcminutes. Arguably, the most spectacular triple conjunction over the five millennia examined was that of 146/145 BC, in which all three approaches were to between 10 and 15 arcminutes: a fifth of the distance in 7 BC. The other extreme is represented by the AD 1940/41 triple conjunction, in which the separations were in the range 71–77 arcminutes, and AD 1305/06, when they were 72–78 arcminutes.

The five closest triple conjunctions all occur towards Cancer. Particularly interesting to observe would have been the AD 710 triple, in which the central event occurred within Praesepe and the third conjunction in its outer fringes. Even more exceptional is the AD 3212 triple, in which Uranus will be just one degree away for the third conjunction.

Johannes Kepler, the 1603 conjunction & the link with 7 BC

The association of the 7 BC triple conjunction with the Nativity appears to have been first made by Johannes Kepler, but it is a misconception that Kepler proposed that it *was* the Star of Bethlehem.

Kepler calculated that a conjunction of Jupiter and Saturn would happen in 1603 December and set out in an attempt to confirm his calculations observationally. This, though, was easier said than done. The 1603 Jupiter–Saturn conjunction was not a spectacular one. The minimum distance, on Dec 18, was 60 arcminutes and occurred so low in the sky that, although Kepler was able to observe Jupiter (magnitude –1.8), it was several days before the much fainter Saturn (magnitude +0.5) could be spotted by him as it started to climb out of the horizon glow. Only then

Table 2. The five closest triple conjunctions between 1000 BC & AD 4000

Date	*Time (UT)*	*J mag.*	*S mag.*	*α (h m)*	*δ*	*Const.*	*Dist. (')*
146 BC Oct 18	07:59	–2.2	0.0			Cnc	11
146 BC Dec 10	08:03	–2.5	–0.3	07 08	+23		15
145 BC May 4	16:11	–1.9	0.2				10
709 Sep 13	19:28	–2.0	0.2			Cnc*	8
710 Feb 5	02:11	–2.5	–0.3	07 25	+23		16
710 Mar 30	22:02	–2.2	0.1				12
1682 Oct 24	08:11	–2.0	0.4			Leo	15
1683 Feb 9	01:22	–2.6	–0.1	09 18	+17		12
1683 May 18	04:17	–2.0	0.4				16
3211 Oct 16	12:18	–2.2	0.2			Gem†	17
3212 Jan 16	15:24	–2.7	0.3	08 14	+20		22
3212 May 3	23:36	–2.1	0.2				19
821 BC Nov 16	19:49	–2.1	0.4			Leo	25
820 BC Jan 7	23:36	–2.4	0.1	08 53	+19		22
820 BC Jun 5	01:55	–1.9	0.5				28

* The central conjunction takes place within Praesepe, while the third event takes place in its outer fringes. † The third event takes place one degree from Uranus.

Notes: The columns are, from left to right: the date (Gregorian calendar; equivalent Gregorian date prior to 1582; AD unless indicated otherwise), magnitude of Jupiter, magnitude of Saturn, right ascension and declination (J2000), constellation (coordinates and constellation are given for the central event) and separation (in arcminutes).

could he ascertain that there had, indeed, been a conjunction at the time he had calculated.[8]

Kepler's conjunction was similar in some respects to that of 2020 December, with the major difference being that the 1603 event happened low in the dawn sky, while the 2020 conjunction occurred low in the evening sky. Kepler's conjunction took place in Sagittarius – although it was in what is now Ophiuchus – and, although Jupiter and Saturn had crossed into Capricornus three days before the 2020 conjunction, they had been in Sagittarius for the previous year and a half.

Kepler's interest in the 1603 event was strictly astrological. For him, as the last of the great astrologer-astronomers, the 1603 conjunction was the third in a series of Jupiter–Saturn conjunctions in fire signs (Aries, Leo and Sagittarius), marking what was, astrologically, a 'fiery trigon'. Interest increased still further when Mars joined the two planets in Sagittarius, in a planetary massing that formed a 'fiery trigon within a fiery trigon' and led to widespread predictions of impending calamity.

Investigating further, Kepler calculated that a Jupiter–Saturn conjunction had occurred in Pisces in 7 BC, around the time of the Nativity, although he appears not to have noticed that it too was followed by a planetary massing of Jupiter, Saturn and Mars. Then, in 1604 October, a galactic supernova now commonly referred to as Kepler's Supernova appeared between Jupiter and Saturn (Figure 2), further enhancing the astrological significance of the planetary configuration. It was this event – the supernova – following closely on the conjunction, that Kepler associated with the Star of Bethlehem. He suggested that a similar nova might have followed the 7 BC conjunction, to guide the Magi.[9]

The proximity of the supernova to Mars and Jupiter was fortuitous, as it ensured that this region of the sky was being intensely observed at the time. Baade compiled statements from multiple observers,[10] such as Johann Fabricius, indicating that the supernova was not visible on Oct 8. The first known observation of the supernova from Europe was by Lodovico delle Colombe, from Italy, on 1604 Oct 9,[11] while Kepler himself did not observe it until Oct 17. Clark & Stephenson note that the supernova was detected from China on Oct 10 and then from Korea on Oct 13;[12] they estimate that it was magnitude +0.9 on Oct 9 and as bright as magnitude –1.1 when detected in Korea. This supernova is now known to be of Type I, associated with the remnant G004.5+06.8 and, thanks to the European and oriental observations, we know that it was discovered nearly three weeks before maximum.

The 7 BC triple conjunction

The 7 BC triple conjunction in Pisces has been discussed extensively. It was the third triple conjunction of the millennium to take place in Pisces after those of 980 and 861/860 BC and, in terms of the average separation of the two planets (60 arcminutes over the three conjunctions; see Table 3), the least impressive of the three. A further triple conjunction in Pisces, with Jupiter at its maximum possible magnitude but with separations of the two planets at 69, 71 & 75 arcminutes, occurred in AD 967/68. There will be no further triple conjunctions in Pisces before AD 4000.

It should be noted that the difference in brightness between the two planets during the 7 BC triple conjunction was 3.3 magnitudes (a factor of 21 in flux). The flux difference between the brightness of the two planets was thus double that of AD 2020 (2.6 magnitudes, or a factor of 11 in flux), as the rings were almost edge-on in 7 BC. This is almost the maximum possible difference in magnitude between the two planets at conjunction (3.4 magnitudes, when the rings of Saturn are completely edge-on). In contrast, the minimum possible difference is 1.8 magnitudes, with the rings fully open.

In strict terms of visual impression, the 146/145 BC triple conjunction in Cancer would have been far more spectacular, both due to the lesser separation between the planets and the much smaller difference in magnitude. Similarly, the normal conjunctions of 86 BC August, in Leo (to four arcminutes, with a difference of 2.0

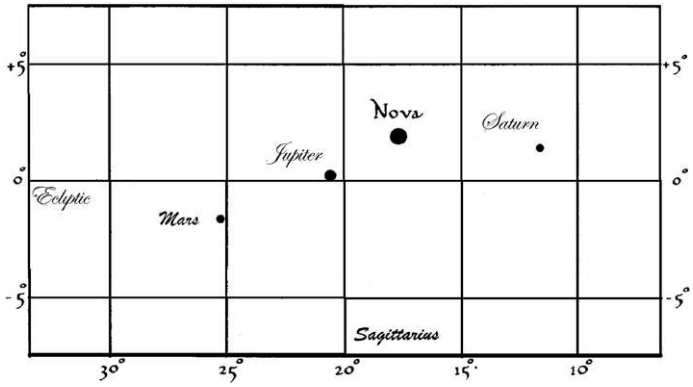


Figure 2. The position of Kepler's 'nova' (SN 1604a) in relation to Mars, Jupiter and Saturn. The four objects were within a nine-degree diameter along the ecliptic, in Ophiuchus, although astrologically, Kepler assigned their position to Sagittarius. *(Adapted from ref. 11.)*

Table 3. Circumstances of the 7 BC triple conjunction

Date	*Time (UT)*	*J mag.*	*S mag.*	*Dist. (')*
7 BC May 29	08:22	–2.3	1.0	59
7 BC Sep 30	20:58	–2.9	0.5	58
7 BC Dec 5	05:27	–2.5	0.8	63

Notes: The columns are, from left to right: the date and time of conjunction, the magnitude of Jupiter and Saturn respectively, and the minimum separation in arcminutes.

Table 4: Summary of the next three Jupiter–Saturn conjunctions

Date	*Time (UT)*	*J mag.*	*S mag.*	*α (h m)*	*δ*	*Const.*	*Sep. (')*	*Diff. (mag)*
2040 Oct 31	09:56	–1.7	0.8	13 08	–06	Vir	68	2.5
2060 Apr 7	23:29	–2.1	0.1	03 55	+20	Tau	67	2.2
2080 Mar 15	01:36	–2	0.7	20 57	–18	Cap	6	2.7

Notes: The columns are, from left to right: date and time, magnitude of Jupiter and Saturn respectively, right ascension and declination (J2000), constellation in which the conjunction occurs, minimum separation in arcminutes and magnitude difference of the two planets.

magnitudes), and of 26 BC June (to 16 arcminutes, with a difference of 2.1 magnitudes), just three degrees from Regulus, would have been far more spectacular visually.

Upcoming Jupiter–Saturn conjunctions

The next three Jupiter–Saturn conjunctions will occur in 2040, 2060 and 2080, continuing the recent 'morning sky – evening sky' sequence. The 2040 conjunction will be difficult to observe, being low in the dawn sky and at a wide separation. 2060 will be an evening event, with the planets both higher in the sky and brighter, although again with a separation greater than a degree.

In contrast, the 2080 conjunction will be a morning event in Capricornus and, following the pattern of conjunctions in the constellation, the separation of the planets will be as small as in 2020. In all respects, save taking place in the morning sky, it will be almost a copy of the 2020 conjunction. There will not be a closer approach of the two planets until the year 2417.

Conclusions

Statistically, a conjunction as close or closer than the 2020 event occurs approximately every 300 years over the five millennia studied. Very close conjunctions tend to occur preferentially in Cancer and Capricornus. Younger observers are likely to have the opportunity to observe a similarly close Jupiter–Saturn conjunction in 2080, albeit in the morning sky. No closer conjunction has been observed since 1623 or will be observed until the year 2417.

Address: European Space Agency, European Space Astronomy Centre, C/Bajo el Castillo, s/n, Villanueva de la Cañada, 28692 Madrid, Spain *[mrkidger@hotmail.com]*

References

1 Hughes D. W., 'The Star of Bethlehem', *Nature*, **264**, 513–517 (1976)
2 Sinnott R. W., 'Thoughts on the Star of Bethlehem', *Sky & Telescope*, 384–386 (1968 December)
3 Josephus F., *The Jewish War*, 1.14.4 (*c*. 75 AD)
4 Tablet BM 35429 (examined *in situ* by the author): **http://www.jstor.org/stable/4200210** (URL accessed 2021 January)
5 Dionysius E., *Liber de Paschate*, Preface (text in Latin: **http://henk-reints.nl/cal/audette/denys.html**). A partial translation can be found in: **http://hbar.phys.msu.ru/gorm/chrono/paschata.htm**. (Accessed 2021 January)
6 Kidger M., 'Star of Bethlehem III: The calendar (or when should we celebrate Christmas, really?': **https://openspacescience.blog/2017/12/16/star-of-bethlehem-ii-the-calendar-question-or-when-should-we-celebrate-christmas-really/** (2017; accessed 2021 January)
7 Ligon T. R., *Dance of the Planets User Manual*, ARC Science Simulations, 1995, p. A-29
8 Burke-Gaffney W., *J. R. Astron. Soc. Can.*, **31**, 417 (1937)
9 Kepler J., *De Stella Nova*, Paul Sessius: Prague, Kingdom of Bohemia, 1606
10 Baade W., *Astrophys. J*, **97**, 119 (1943)
11 delle Colombe L., *Discorso di Lodovico delle Colombe nel quale si dimostra che la nuova Stella apparita l'Ottobre passato 1604 nel Sagittario non è Cometa, ne stella generata, ò creata di nuovo, ne apparente: ma una di quelle che furono da principio nel cielo; e ciò esser conforme alla vera Filosofia, Teologia, e Astronomiche dimostrazioni*, Firenze, Giunti, 1606
12 Clark D. H. & Stephenson F. R., *The Historical Supernovae*, Pergamon Press, Oxford, 1977, p. 191

Received 2021 January 2; accepted 2021 January 23

