Appulses of Jupiter and Saturn

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Abstract. The latest conjunction of Jupiter and Saturn occurred at an optical distance of 6 arc minutes on 21 December 2020. We re-analysed all encounters of these two planets between -1000 and +3000 CE, as the extraordinary ones (< 10′) take place near the line of nodes every 400 years. An occultation of their discs did not and will not happen within the historical time span of ±5,000 years around now. When viewed from Neptune though, there will be an occultation in 2046.

Keywords: Jupiter-Saturn conjunction, Appulse, Trigon, Occultation.

Introduction

The slowest naked-eye planets Jupiter and Saturn made an impressive encounter in December 2020. Their approaches have been termed “Great Conjunctions” in former times and they happen regularly every ≈20 years. Before the discovery of the outer ice giants these classical planets rendered the longest known cycle. The separation at the instant of conjunction varies up to 1 degree of arc, but the latest meeting was particularly tight since the planets stood closer than at any other occasion for as long as 400 years.

Periodic Overtaking

The precise average of the conjunction interval is 19.88 years and represents the synodic period, \( T_{\text{syn}} \), when two moving bodies apparently meet as seen from a third body (Earth):

\[
\frac{1}{T_{\text{syn}}} = \frac{1}{T_{\text{Jup}}} - \frac{1}{T_{\text{Sat}}},
\]

with \( T_{\text{Jup}} \) and \( T_{\text{Sat}} \) being the heliocentric orbital periods of Jupiter and Saturn, respectively. Because of the ellipticity of the orbits, \( T_{\text{syn}} \) fluctuates between 18.85 and 21.07 years.

A threefold encounter within one year, called “triple conjunction”, can occur during the retrograde motion of the planets. It happens at irregular times when two conditions are fulfilled: (a) the times of their particular opposition will lie within ±1.7 days, and (b) the viewing angle from Earth be less than 30° with regard to the heliocentric position of the pair:

\[
L - E < 30^\circ,
\]

wherein \( L \) and \( E \) are the heliocentric longitude of the pair and of the Earth, respectively.

Triplet conjunctions make up a subset of the 20-year meetings. They occur once in 140 years on average, however, the interval may be as little as 40 years or as much as 378 years [5]. There is no pattern in the triples, and the reason is due to Earth’s orbit: while Jupiter and Saturn are locked in a 5:2-mean motion resonance, the Earth does not join in. For very long periods there could be some periodicity, however, secular effects destroy a cycle, e.g. rotation of the apsides and changes in eccentricity such that we are left with some kind of “semi-periodicity”.

Close Encounters

Most pass-bys of Jupiter and Saturn are not very spectacular, their separation would exceed 1 degree of arc quite often. We did some little exercise using the simulation software packages Guide v9.0 and Cartes du Ciel v4.1 to search for especially tight conjunctions, so-called “appulses”. Table 1 lists incidents less than 10′ in the years 1000 BCE to CE 3000. An eye-striking feature is that many events appear in doublets of 60 years.

The explanation for the 60-year gap is based on “Trigons”: after \( 3 \times 20 \) years the conjunction occurs in the same constellation, just 8° apart from the former position (Fig. 1). The missing piece makes the Trigon rotate slowly in front of the stellar background in 794 year’s time, often rounded up to 800 years. During the Middle Ages this period inspired astrologers to look for profane meanings in world history. The source of such ideas may have been Hindu (3rd to 5th century CE) transmitted via Sassanid Persia to Europe [2].

Those extraordinary close conjunctions, that we were searching for, take place when both planets meet close to their line of nodes. The orbital planes are inclined to each other at an angle of 1.2°, and the line of intersection points at Capricorn and Cancer, respectively, in our era. The nodes move very slowly retrograde, but remain for 4,000 years inside a constellation.

The latest conjunction of 2020 was observed in Capricorn, and the next of comparable apparent distance, in 2080, will come about in Capricorn again. However, Jupiter will pass northward of Saturn since both planets
Table 1: Appulses of Jupiter and Saturn between 1000 BCE and CE 3000 with a separation < 10′.

| Date   | Separ. | Elong. |
|--------|--------|--------|
| -998   | May 30 | 9′ 19″ | 39 E |
| -939   | Sep 04 | 3′ 29″ | 42 W |
| -482   | Mar 06 | 6′ 23″ | 55 W |
| -423   | Dec 28 | 1′ 29″ | 17 E |
| -85    | Aug 11 | 3′ 44″ | 20 W |
| 372    | Mar 06 | 1′ 52″ | 53 W |
| 431    | Dec 31 | 6′ 16″ | 17 E |
| 709    | Sep 13 | 8′ 22″ | 61 W |
| 769    | Jul 23 | 4′ 17″ | 2,4 W |
| 1166   | Dec 11 | 9′ 48″ | 25 E |
| 1226   | Mar 05 | 2′ 09″ | 49 W |
| 1563   | Aug 25 | 6′ 47″ | 42 W |
| 1623   | Jul 16 | 5′ 10″ | 13 E |
| 2020   | Dec 21 | 6′ 17″ | 30 E |
| 2080   | Mar 15 | 6′ 19″ | 44 W |
| 2417   | Aug 24 | 5′ 25″ | 26 W |
| 2477   | Jul 06 | 6′ 20″ | 27 W |
| 2815   | Feb 23 | 9′ 58″ | 30 W |
| 2874   | Dec 25 | 2′ 21″ | 36 E |
| 2934   | Mar 19 | 9′ 43″ | 38 W |

will have already left behind the ascending node (Fig. 2). The 8°-shift of the Trigon leads to the effect that appulses are precluded for the subsequent centuries. Only when one of its legs approaches a node, there will be tight encounter: thereafter in 2417 and 2477 at the opposite (descending) node.

**Planetary Occultations**

A brief remark in an article by Johan Stein [4] informs us about an observation by the astrologer Francesco Giuntini (1523–1590): Jupiter almost occulted Saturn on 24 August 1563. In fact, the planets passed by each other similarly close as in 2020. In the pre-telescopic era the shining objects seemed merging. The resolution of the normal eyesight is at 1′, but this turns out a matter of contrast and individual training of the observer.

Mutual occultations of any two planets in the Solar System do exist within the time span of our historic era during ±3000 years, but there is none for Jupiter and Saturn. This oddity was already noticed by Salvo de Meis [1]. We made an effort to look a bit further for an overlap of their planetary discs. A promising case is found for 16 February 7541 using the ephemeris of the DE431 theory of planetary motions. Near misses are going to happen in 4523 and 6687.

However, extrapolations of this kind can hardly be verified, as they put astronomical calculations to extremes. All motions in the Solar System are extrapolated from our narrow window of precise measurements. The movements are prone to gravitational perturbances, and even the slightest deviation might cause a delay. Moreover, the diameters of the planets are slowly varying with time by reason of secular variations of their orbits [3]. For very distant times any prediction of an accuracy smaller than the apparent diameters of the planets cannot be made, as long as we lack secure fixpoints from observation to be utilised in a wider baseline for extrapolation purposes. The characteristics considered to be stable for millions of years regard only the orbital parameters, not to be confused with the ephemeris. A comparison of various software deploying different integrators would be desirable though.

Still, there is a chance to spot a line-up of Jupiter and Saturn: that special view emerges extraterrestrially from Neptune on 29 April 2046 (Fig. 3). Gazing from this furthest planet, Saturn is on the superior arc of its orbit in a distance of 38.7 AU from Neptune while Jupiter is heading to its inferior conjunction with the sun being 26.7 AU away. The planets meet in an optical line 8° to the east of the sun. It will be the sole occultation event for these two giants visible from any planet during the entire 21st century.
Besides the case of Jupiter and Saturn, there is also no occultation for the remote Uranus and Neptune to be seen from Earth. That seems intelligible as their conjunctions take place only at 170 years on average and their orbits are inclined by $10^\circ$. An overlap of their discs will probably not occur within 1 million years.

In regard to the Jovian planets, it is actually Saturn who refuses to meet its giant colleagues. While Uranus and Neptune are hit by Jupiter once or twice during our historical time, Saturn resists any such visit with the outer planets. As viewed from Earth, it is only occulted by the inner planets. The next occultation will be performed by Venus on 12 August 2243.

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