The Great Conjunction of 2020*
A Rare Cosmic Gift

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On 21 December 2020, the world witnessed a rare celestial rendezvous when Jupiter and Saturn came together in a ‘great conjunction’. The event is popular as the ‘Christmas Star’. A conjunction is not unique to Saturn and Jupiter. Every 20 years or so, they align (i.e., are in conjunction), and during these years, these planets make a beautiful pair in the sky. Their relative motions during the conjunction year are fun to watch and provide an excellent way to learn about planetary motion. Saturn and Jupiter are the largest of the five planets visible to the unaided eye in the night sky. Hence, their conjunction is called the ‘great conjunction’. In the night sky, Jupiter is particularly bright, appearing as a brilliant point of white light, while Saturn is a fainter dull white object, as bright as a typical bright star. On 21 December 2020, during the great conjunction, Jupiter shone at a magnitude of -1.97, while Saturn was far less bright at a magnitude of +0.63. The great conjunction of 2020 coincided with the winter solstice (shortest day of the year in terms of hours of sunlight received) of the Northern Hemisphere.

What is a conjunction? Broadly speaking, conjunction refers to an event where planets or asteroids appear very close together in the sky when viewed from the Earth. The spacing between the planets varies during each conjunction. From an astronomical point of view, it is the phenomenon in which two bodies have the same apparent celestial longitude or right ascension as viewed from a third body. Here, the third body usually means the Earth. For example, during the new moon phase, the Moon is in conjunction with the Sun. At that time, it moves between the Earth and

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the Sun, and the side turned towards the Earth appears dark. Interior planets, namely, Venus and Mercury, whose orbits are smaller than the Earth’s orbit, undergo two kinds of conjunctions with the Sun—inferior conjunction and superior conjunction. When the planet passes approximately between the Earth and the Sun, the conjunction is known as an inferior conjunction. During this, if it passes exactly between the Earth and the Sun, we can observe the motion of the planet across the Sun’s face from Earth, and it is said to be in transit. During superior conjunction, the Earth and the other planet are on the opposite sides of the Sun, but all three bodies are nearly in a straight line. Exterior planets like Jupiter and Saturn, with orbits larger than the Earth’s orbit, can have only superior conjunctions with the Sun. The great conjunction of 2020 was a superior conjunction.

We know that planets Jupiter and Saturn are rotating around the Sun in their own elliptical orbit like our Earth, and their velocities are not same. The average distance between Jupiter and Saturn is 456 million miles (734 million km). Naturally, from our Earth, we cannot find them in the same directions always. During conjunction, Earth, Jupiter and Saturn align in a straight line. The time can be easily calculated using simple mathematics. For example, let us consider that the time taken by Saturn to rotate once around the Sun is 30 years, and by Jupiter it is 12 years. Then each year, Saturn completes about 12 degrees of its orbit around the Sun, whereas Jupiter completes about 30 degrees. Therefore, in one year, Jupiter closes the gap between itself and Saturn by about 18 degrees (30 – 12 = 18 degrees). In a period of 20 years, then, Jupiter gains 360 degrees on Saturn (18×20 = 360 degrees), therefore lapping the ringed planet once every 20 years.

This can be easily calculated using the synodic period formula. Let any two planets, Jupiter (J) and Saturn (S), revolve uniformly along circles of radius \( r_1 \) and \( r_2 \) in the same plane around the Sun (O) completing full revolutions in time \( t_1 \) and \( t_2 \) Earth days. The rates of revolution of the two planets measured in degrees of turn per day are:

\[
V_j = 360/t_1 \quad \text{and} \quad V_s = 360/t_2 \text{ respectively. As the rates of turn are}
\]
different for the two planets, at some point, the Sun (O) and the planets Jupiter (J) and Saturn (S) will be in line momentarily. In Figure 1, the line is indicated as OP.

![Figure 1](image_url)

Suppose after \( n \) days, the planets align again. By the time Jupiter (J) would have moved \( V_J \cdot n \) degrees and Saturn (S) would have move \( V_S \cdot n \) degrees, respectively. The number of days at which these events happen can be found by solving for \( n \)—the congruence:

\[
V_J \cdot n \equiv V_S \cdot n \pmod{360}.
\]

That is, in \( n \) number of days, the planets align, when the angle \( V_J \cdot n \) and \( V_S \cdot n \) leaves the same remainder on division by 360. As \( V_J \) and \( V_S \) are constant, the planets will line up periodically, and the time \( T_n \) will be such that \( n \in \mathbb{Z} \) (where \( z \) is an integer). This happens for the first time at \( T_1 \) after their initial line up, when the faster planet Jupiter over takes the slower planet Saturn. At that moment:

\[
V_J \cdot n - 360 = V_S \cdot n,
\]

or, \( (360/t - 1) \cdot n - 360 = (360/t_2) \cdot n \) (Replacing values \( V_J \) and \( V_S \)),

or, \( n/t_1 - 1 = n/t_2 \) (Dividing by 360 in both the sides),

or, \( n/t_1 - n/t_2 = 1 \),

or, \( n = t_1 t_2/t_2 - t_1 \).

Using this synodic period formula, we can easily calculate the conjunction periods of the planets. In words, this is the prod-
Figure 2. Jupiter–Saturn conjunction in December 2020. (Courtesy: The Planetary Society)

Figure 3. The great conjunction of Jupiter and Saturn in December 2020. ( Courtesy: BBC Sky at Night Magazine)

The period of a great conjunction is the least common multiple of the period of Jupiter, $t_1$ and the period of Saturn, $t_2$. The period of the product of the revolution times divided by their difference. Here $t_1$ and $t_2$ are the orbital periods of Jupiter (4332.59 days) and Saturn (10759.22 days), respectively. Substituting these values in the above equation, we get the conjunction period as 7253.45772 days. Now we know that one Julian year means 365.25 days. So, on average, great conjunction should occur once every 19.859 Ju-
lian years. According to the calculation, the next Jupiter–Saturn conjunction will take place as on:

- 31 October 2040
- 07 April 2060
- 15 March 2080
- 18 September 2100.

A list has been generated by Patrick Hartigan from Rice University (Great Conjunction spanning 3000 years) where he has included the close conjunctions of earlier days as follows:

- March 1226, separation 2.1’, one-third the separation of 2020.
- August 1563, separation 6.8’, slightly larger than 2020.
- July 1623, separation 5.2’, slightly less than 2020, but not likely visible.

Naturally, the question comes up: Why was the conjunction of 2020 so important? There are many reasons! Some of the reasons are:

1. Most of the time, when Jupiter overtakes Saturn (within 20 years), they usually are separated by more than a degree. This happens as they are not in a single plane. But on 21 December 2020, they were separated by just about one-tenth of a degree or 6.1
Figure 5. Galilean satellites of Jupiter during the great conjunction of 2020. (Courtesy: *BBC Sky at Night Magazine*)

arc minutes, more accurately by just 0.102 degrees.

2. We know that most planets do not have internal resources to produce visible light; they are visible to us when they reflect sunlight. This means that their lights are very faint compared to sunlight. Hence, to see the conjunction from Earth, it should be night on Earth. The great conjunction of 2020 occurred during 6.15–7.30 pm on 21 December. As it was the winter solstice (the day was the shortest day of the year), sunset occurred within 5.00 pm in most places in India. Naturally, the night was dark enough to observe this celestial event. Also, both the planets were well above the horizon. Hence, in every respect, it was an ideal situation for observing this great event.

3. Conjunction cannot be seen by the naked eye on a full moon or near the full moon phase. On 21 December 2020, the moon was only 7 days old, and the brightness was not enough to hinder observing this celestial event.

4. Moreover, being winter, the sky was clear without clouds.

These details made 2020’s astronomical spectacle all the more attractive. The last time Jupiter and Saturn appeared so close was on 16 July 1623, back when Galileo was still alive, but it was
virtually impossible to see since its apparent position was near the Sun. The last great conjunction to appear as close as the one in 2020 occurred on 14 March 1226, and there was no telescope to watch such a beautiful event. Another rendezvous where the giant planets will be separated by just six arc minutes is likely to occur on 15 March 2080. Hence, in every aspect, the conjunction of 2020 was a unique event, and those to have witnessed it are lucky.

What was actually seen on that day? Those who watched it with the naked eyes, would have seen one elongated planet like shape or a double planet like shape on the western sky, as if both the planets were merged with each other. We observed this phenomenon from the District Science Centre, Purulia, West Bengal, with our Celestron’s CPC telescope. Just one hour after sunset, during the conjunction, Jupiter was about 12° up from the horizon in the southwest, and roughly 0.1° to the lower left of Saturn. Both the planets were well-fitted into the eyepiece of our telescope. All the four Galilean satellites of Jupiter were nicely lined up along the equatorial plane of the planet. Ganymede, Io, and Calisto were on the east of Jupiter, where as Europa was on the west side of the planet. The gigantic rings of Saturn was clearly visible. After the conjunction, Jupiter gradually moved towards the east, separating from Saturn. They were close for about one week, but each evening, the planetary pair appeared lower in the sky till the end of December. Really it was a great conjunction!

Throughout history, people have taken note of such planetary conjunctions, often attributing some astrological significance to this astronomical phenomenon. Some astrologers predicted a worldwide cataclysm, which, needless to say, did not transpire. In some epics and literature, we find the description of great conjunctions, which helps the scientists to correlate the time with their mathematical calculations. For instance, Johannes Kepler investigated whether the Star of Bethlehem, which guided the Three Wise Men to Christ’s birth, as narrated in the nativity story of the Gospel of Matthew, was a great conjunction. His calculation shows us that one such conjunction did occur in 7 B.C. Scientifically we

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have seen that when the Sun, Moon, and Earth are aligned (at
the time of the new or full moon), the solar tide has an additive
effect on the lunar tide, creating extra high tides and very low
tides—commonly called spring tides. So some may think that
from gravitational point of view, conjunctions may have some in-
fluence on Earth. But we know that although the planets exert
a small gravitational tug on one another, their effect on our own
planet is negligible. So we can relax and encourage people to
observe such eternal celestial phenomenon.

Suggested Reading

[1] Patrick Hartigan, Jupiter–Saturn conjunction series from 0 CE to 3000 CE,
https://sparky.rice.edu/public-night/jupsat2.html, Rice University.
[2] Charles Q. Choi, Jupiter and Saturn’s great conjunction is the best in 800
years—here’s how to see it, Scientific American, 17 December 2020.
[3] Jamie Carter and Pete Lawrence, Great Conjunction of Jupiter and Saturn: