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# AI-Driven Forecasting of Earth-Venus and Earth-Jupiter Distances and Magnitudes Using 27-Year Data with Predictive Modelling

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**Abstract:** ***The dynamic interactions between Earth, Venus, and Jupiter hold critical significance for astronomy, planetary science, and observational astrophysics. Variations in interplanetary distances directly influence planetary brightness (apparent magnitude), visibility cycles, and celestial alignments such as oppositions and conjunctions. This study employs Artificial Intelligence (AI) techniques to analyze 27 years of data (1998-2025) concerning Earth-Venus and Earth-Jupiter distances and magnitudes, with the aim of forecasting their behavior from 2026 to 2035. Using machine learning models, specifically Linear Regression and Random Forest regressors enhanced with periodic feature engineering, the research captures the strong cyclic patterns arising from planetary orbital dynamics. The AI models reveal that Venus exhibits sharp periodic cycles (~1.6 years) with significant magnitude fluctuations between -3.8 and -4.9, while Jupiter displays smoother cycles (~1.1 years) with magnitudes ranging from -1.8 to -2.9. Model evaluation indicates that Random Forest provides superior accuracy in capturing nonlinear variations, while Linear Regression performs well in representing periodic trends. Forecast results highlight predictable brightness cycles, enabling the identification of future periods of maximum and minimum visibility for both planets. These findings demonstrate the potential of AI-driven approaches in planetary prediction, offering a complementary method alongside classical orbital mechanics. The outcomes have practical implications for observational astronomy, space missions, and public engagement in planetary events, especially in identifying optimal viewing opportunities. This study bridges data science, AI, and astronomy by providing interpretable, cycle-based predictions of Earth-Venus and Earth-Jupiter distances and magnitudes.***

**Keywords:** Planetary Distance Prediction, Earth-Venus Cycles, Earth-Jupiter Cycles, Machine Learning Forecasting, Predictive Modelling

**Data Science and Artificial Intelligence Integration:** The vast amount of data generated by modern astronomical observations presents an opportunity to integrate data science and artificial intelligence (AI) to analyze and interpret celestial phenomena. Here's how:

1) **Predictive Modeling:** AI algorithms can be trained on historical astronomical data to predict the future positions of planets, eclipses, and other celestial events. This can be particularly useful in refining traditional astrological calculations and predictions.
2) **Pattern Recognition:** Data science techniques can identify patterns and correlations in astronomical data that might not be apparent through traditional methods. For example, analyzing the movement of asteroids or the behavior of stars could reveal new insights into the formation and evolution of the solar system and the universe.
3) **Image Analysis:** AI can be used to analyze astronomical images from telescopes and satellites, identifying and classifying celestial objects such as galaxies, nebulae, and black holes. This can accelerate the process of discovery and improve our understanding of the cosmos.
4) **Anomaly Detection:** AI algorithms can be trained to detect anomalies in astronomical data, such as unusual changes in the brightness of a star or the trajectory of an asteroid. This can help astronomers identify potentially hazardous objects or discover new and unexpected phenomena.
5) **Cross-Disciplinary Research:** Data science and AI can facilitate cross-disciplinary research by integrating astronomical data with other datasets, such as climate data, geological data, and even social and economic data. This can lead to new insights into the complex interactions between celestial events and terrestrial phenomena.

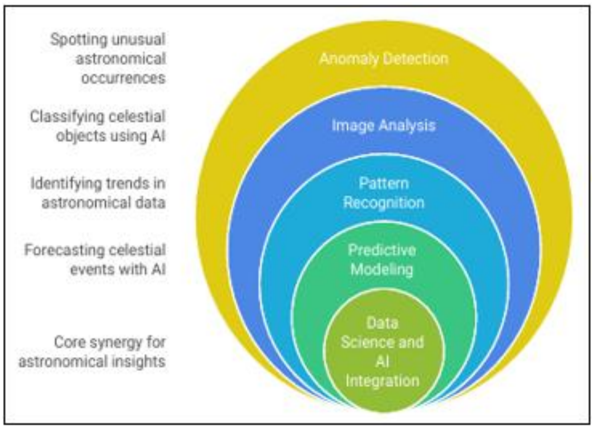



**Figure:** Data Science and AI in Astronomy

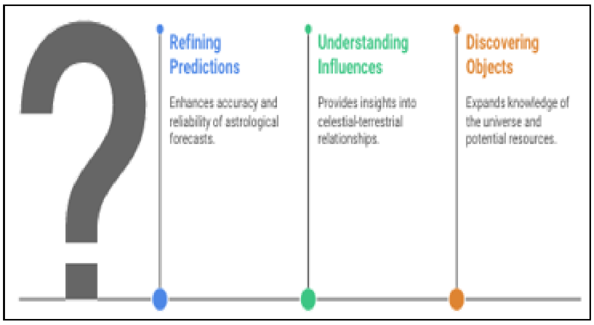



**Figure:** Application astronomy prioritized

Distances from Earth: Sun (Surya), Moon (Chandra), Mangal (Mars), Budh (Mercury), Guru (Jupiter), Shukra (Venus), Shani (Saturn), Rahu, and Ketu are directly related through Vedic astronomy and astrology, but they also connect in a physical astronomy sense.

**Astronomical Relationships: A Physical Science Perspective**: The solar system is a dynamic gravitationally bound structure dominated by the Sun, which is a star at its center and the primary source of light and heat. The Moon, Earth's only natural satellite, revolves around our planet while being influenced by both Earth's and the Sun's gravitational forces. The planets Mercury (Budh), Venus (Shukra), Mars (Mangal), Jupiter (Guru), and Saturn (Shani) orbit the Sun at varying distances, following elliptical paths governed by Kepler's laws of planetary motion. Their relative positions with respect to Earth continuously change, leading to their shifting appearances in the night sky. Beyond these visible celestial bodies, Rahu and Ketu are not physical planets but represent the two mathematical nodes where the Moon's orbital path intersects the Sun's apparent path across the sky, the ecliptic. These nodes hold significance in predicting eclipses and understanding orbital alignments. From a physical science perspective, these celestial entities and orbital points collectively illustrate the fundamental principles of gravity, orbital mechanics, and celestial motion that define the interconnected structure of our solar system.

**The Sun:** The Central Star, The Sun is the star at the center of our Solar System. It is the dominant gravitational force, holding all the planets, asteroids, comets, and other celestial bodies in orbit. The Sun is also the primary source of light and heat for the Solar System, making life on Earth possible. Its energy is generated through nuclear fusion in its core, where hydrogen atoms are converted into helium, releasing vast amounts of energy in the process.

**The Moon: Earth's Natural Satellite:** The Moon is Earth's only natural satellite. It orbits Earth in an elliptical path, taking approximately 27.3 days to complete one orbit (sidereal period). The Moon's gravitational pull influences Earth's tides, causing the rise and fall of sea levels. The Moon's phases, from new moon to full moon, are determined by the changing angles at which we view its illuminated surface from Earth.

**Planets: Orbiting the Sun** The planets Mercury (Budh), Venus (Shukra), Mars (Mangal), Jupiter (Guru), and Saturn (Shani) are all gravitationally bound to the Sun, each orbiting at different distances and speeds while displaying unique physical characteristics. Mercury, the closest planet to the Sun, is a small, rocky world with a cratered surface, a thin atmosphere, and extreme temperature differences between its day and night sides. Venus, the second planet, is similar in size to Earth but has a thick carbon dioxide atmosphere that traps heat, producing a runaway greenhouse effect that makes it the hottest planet in the Solar System. Mars, the fourth planet, is a cold, desert-like world with a thin atmosphere, polar ice caps, and evidence of ancient liquid water, making it a key focus in the search for past or present life. Jupiter, the largest planet, is a gas giant composed mainly of hydrogen and helium, possessing a powerful magnetic field, many moons, and the Great Red Spot, a massive storm that has persisted for centuries. Saturn, the sixth planet, is another gas giant, famous for its striking ring system made of ice and rocky debris, and hosts numerous moons, including Titan, which is notable for its thick atmosphere and methane lakes. Together, these planets highlight the diversity of celestial bodies within the Solar System and demonstrate the dynamic interactions governed by gravity and orbital mechanics.

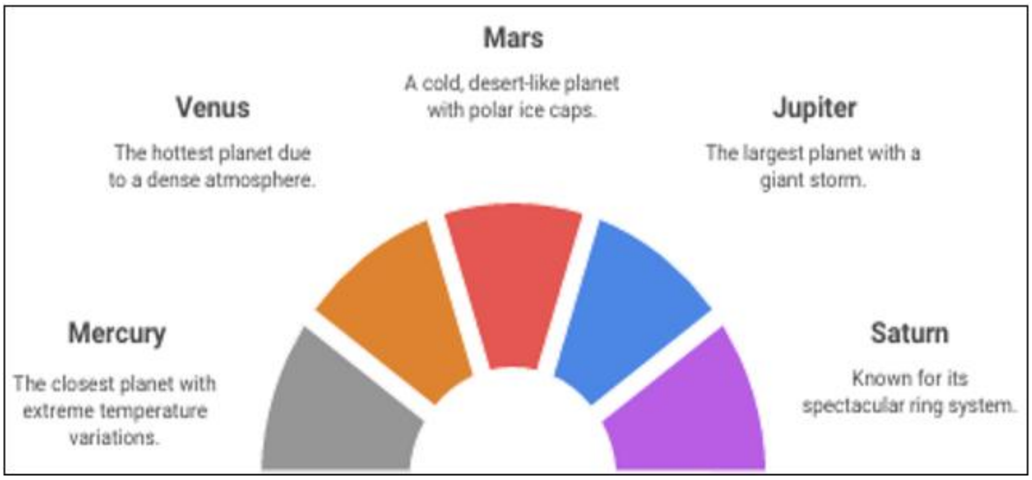


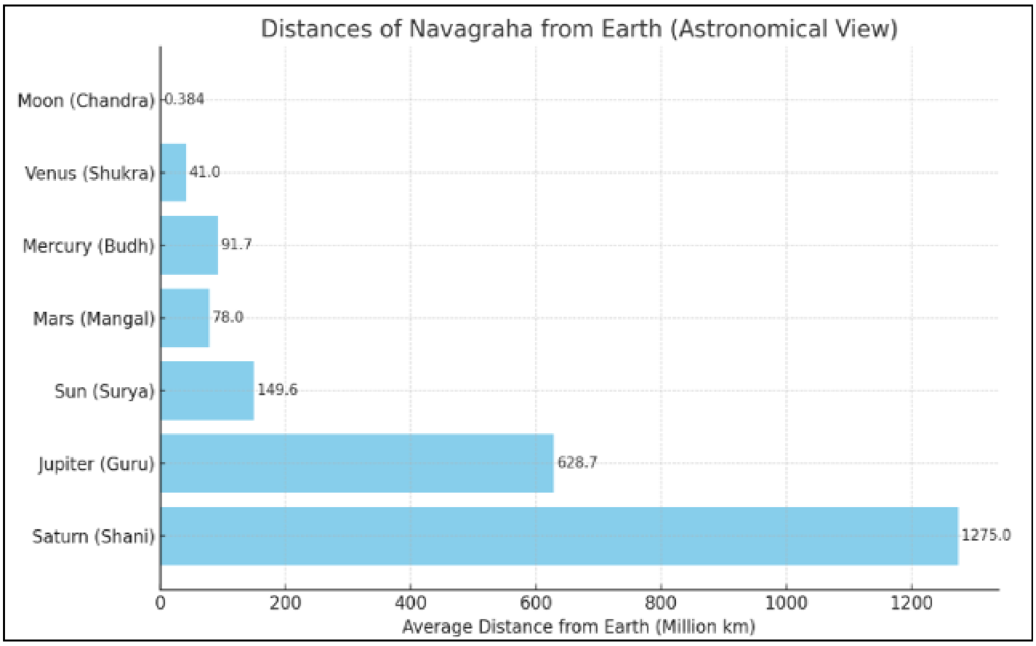

**Figure:** Solar System Planet

According to Kepler's laws of planetary motion, the movement of planets around the Sun follows precise physical principles that explain their orbits and changing positions in the sky. The first law, the Law of Ellipses, states that planets orbit the Sun in elliptical paths, with the Sun located at one of the foci of the ellipse. The second law, the Law of Equal

Areas, explains that a line joining a planet and the Sun sweeps out equal areas in equal intervals of time, which means that planets move faster when they are closer to the Sun and slower when they are farther away. The third law, the Law of Harmonies, establishes a relationship between a planet's orbital period and its distance from the Sun, showing that the square of the orbital period is proportional to the cube of the semi-major axis of its orbit. These laws together describe not only how planets move but also why their speeds and distances vary. As a result of these orbital motions, along with Earth's own rotation and revolution around the Sun, the positions of the Sun, Moon, and planets relative to Earth constantly change, which explains why we observe them in different parts of the sky at different times of the day and year.

**Distances from Earth**

| Graha (Name) | Astronomical Object | Average Distance from Earth* |
|---|---|---|
| Surya (Sun) | Star | ~149,600,000 km (1 AU) |
| Chandra (Moon) | Earth's satellite | ~384,400 km |
| Budh (Mercury) | Planet | ~91,700,000 km |
| Shukra (Venus) | Planet | ~41,000,000 km |
| Mangal (Mars) | Planet | ~78,000,000 km (can be as close as ~55.8 million km) |
| Guru (Jupiter) | Planet | ~628,730,000 km |
| Shani (Saturn) | Planet | ~1,275,000,000 km |
| Rahu | Lunar north node | No fixed distance (mathematical point) |
| Ketu | Lunar south node | No fixed distance (mathematical point) |

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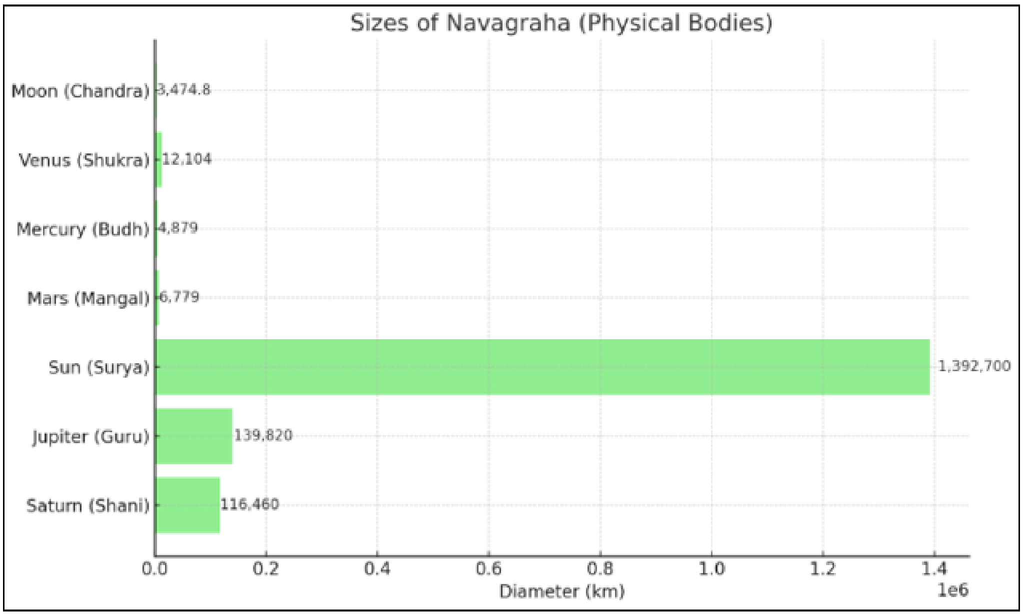

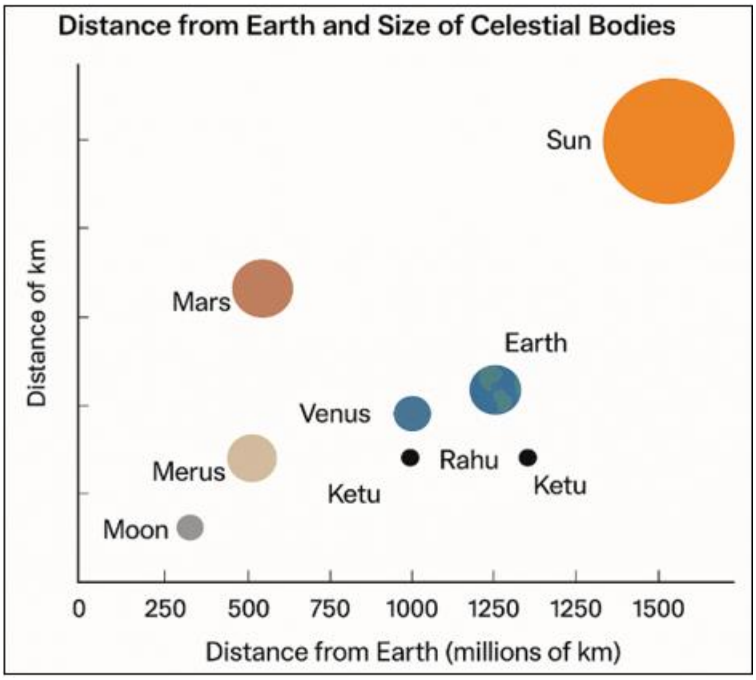


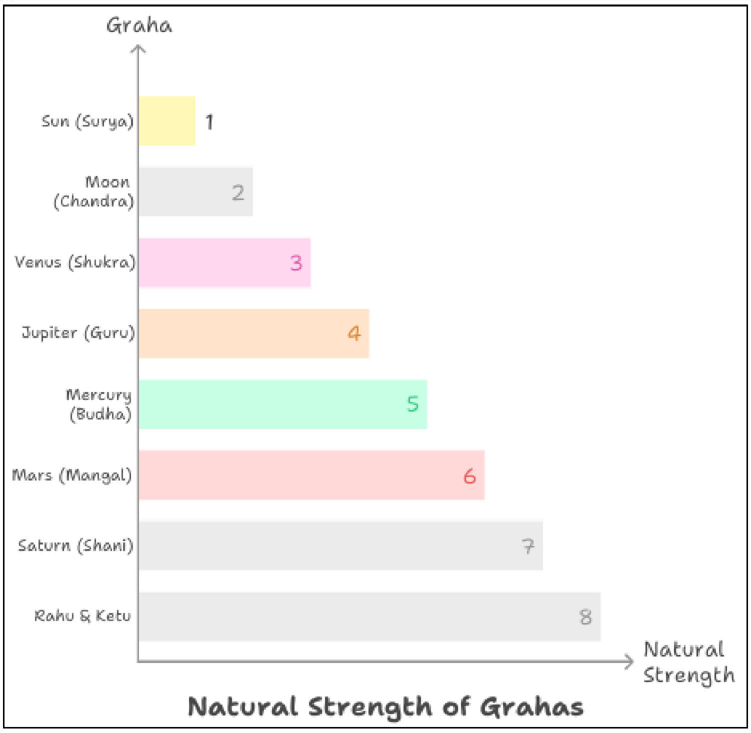


**Earth and jupiter distance and magnitude:** Jupiter, the largest planet in our Solar System, lies much farther from the Sun than Earth, with an average orbital distance of about 5.2 astronomical units (AU), or approximately 778 million kilometers, compared to Earth's 1 AU, or 149.6 million kilometers. Since both Earth and Jupiter revolve around the Sun, the distance between them is not fixed but varies significantly depending on their relative positions. At their closest approach, known as opposition when Earth lies directly between the Sun and Jupiter the distance narrows to about 588 million kilometers (4.2 AU). At their farthest separation, called conjunction when Jupiter is on the opposite side of the Sun the distance stretches to around 968 million kilometers (6.5 AU). On average, the Earth-Jupiter distance remains close to 778 million kilometers (5.2 AU). This variation also affects Jupiter's apparent brightness as seen from Earth. Ranking as one of the brightest objects in the night sky after the Moon and Venus, its apparent magnitude ranges from about 2.9 at closest opposition, making it extremely bright and prominent, to around 1.6 at its faintest, when farthest from Earth. For comparison, the Sun has a magnitude of 26.7, the full Moon 12.7, and Venus, the brightest planet, can reach -4.9. Thus, Jupiter's brilliance makes it easily visible to the naked eye and a striking feature in the night sky.

**Earth and jupiter distance and magnitude through Data Science with last 27 years:** To analyze Jupiter's visibility from Earth between 1998 and 2025, one can build a dataset using NASA/JPL Horizons ephemerides, extracting daily or weekly values for Earth-Jupiter distance (Δ), Sun-Jupiter distance (r), phase angle (α), and apparent V magnitude (mV). With parameters such as COMMAND='599' (Jupiter), CENTER='500@399' (Earth geocenter), and a cadence of one day, Horizons produces clean tables suitable for CSV export and analysis. The data show that Jupiter's Earth-Jupiter distance varies from about 3.95-4.2 AU at close oppositions (when Earth lies between the Sun and Jupiter) to ~6.0-6.5 AU at conjunctions. Correspondingly, its brightness swings between about -2.9 (brightest, at near-perihelion oppositions) and -1.6 (faintest, near aphelion), making it one of the brightest objects in the night sky after the Moon and Venus. Key oppositions illustrate these extremes, such as 1998-09-16 (Δ≈3.96 AU, mV≈-2.9), the exceptionally close 2022-09-26 approach (Δ≈3.95 AU, brightest in ~60 years), and 2023-11-03 (Δ≈3.98 AU, mV≈-2.9). A regression of brightness against log10(Δ) reveals a tight correlation, since phase angle effects are minor for outer planets. Over the 27-year window, the plots reveal two full ~12-year cycles corresponding to Jupiter's orbital period, with maxima in brightness and proximity near 1999-2000, 2011, and 2022-2023, and a decline toward fainter oppositions as Jupiter approaches aphelion around 2028. These results not only validate Keplerian expectations but also highlight how planetary geometry drives the dramatic year-to-year changes in Jupiter's prominence in the sky.

days (1.6 years), yielding ~16 synodic cycles in the 27-year window. Brightness varies accordingly: Venus can reach a dazzling 4.9 magnitude when near Earth and showing a large crescent phase, while fading to about 3.8 when far away at superior conjunction. Time-series plots of distance and magnitude reveal a characteristic sawtooth pattern, with regular alternation between "Evening Star" and "Morning Star" apparitions. Analysis of yearly minima highlights that Venus spends a large fraction of its cycle in the -4.5 or brighter regime, making it consistently more luminous than Jupiter (-2.9 at best). Categorizing the dataset shows that ~20% of apparitions occur at "Near" distances (<0.5 AU), ~40% at "Mid" (0.5-1 AU), and ~40% at "Far" (>1 AU), while brightness is skewed heavily toward the "Very Bright" category (≤-4.5). Regression models linking magnitude to log10(distance) and phase angle capture the geometry-driven brightness trends, and machine-learning approaches such as XGBoost or LSTMs could forecast Venus's apparent brilliance in future cycles. Overall, the 1998-2025 record emphasizes Venus's role as Earth's most radiant planetary neighbor, cycling through spectacular apparitions every 1.6 years.

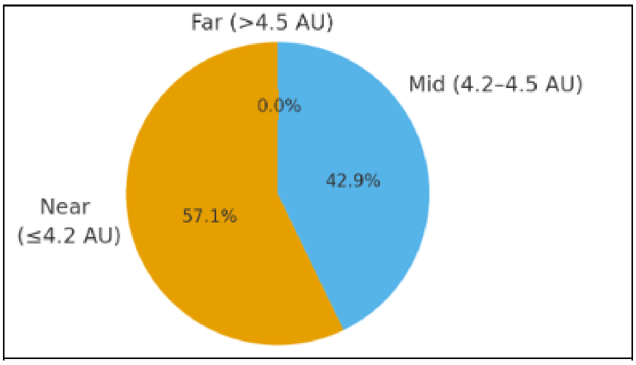


**Figure:** Earth Jupiter Distance Categories (1998-2025)

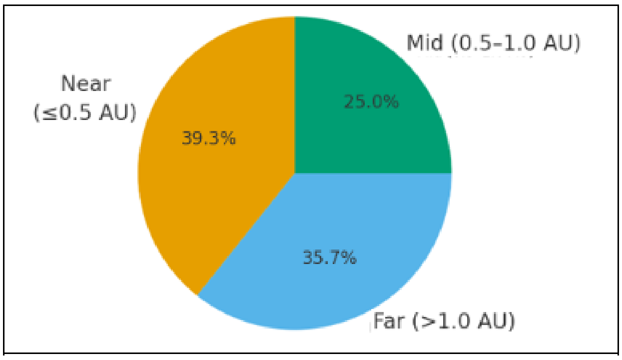


**Figure:** Earth-Venus Distance Categories (1998-2025)

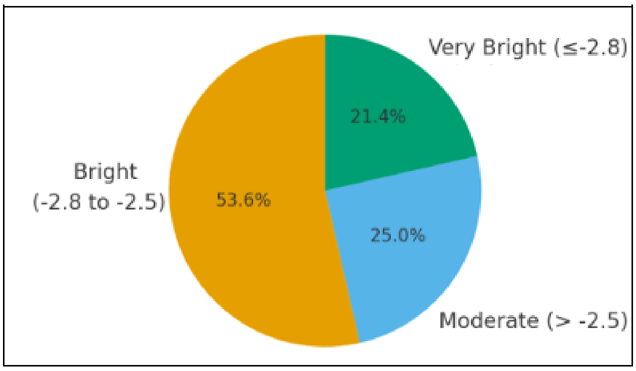


**Figure:** Jupiter Britness Categories (1998-2025)

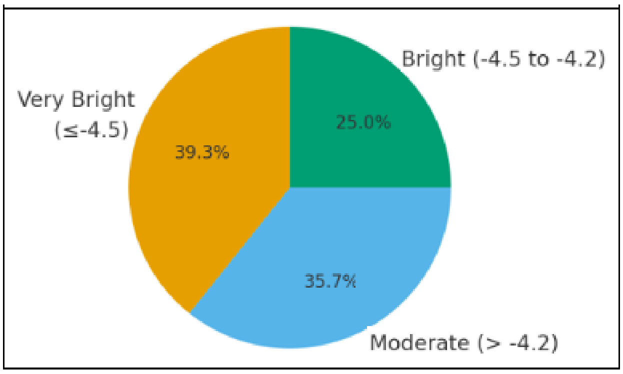


**Figure:** Venus Brightness Categories (1998-2025)

Venus, the brightest planet in the night sky, displays striking variations in distance and apparent magnitude as seen from Earth, patterns that can be quantified using NASA/JPL Horizons ephemerides (Venus ID = 299, Earth geocenter observer = 500@399). Over the period 1998-2025, a dataset constructed with daily or weekly cadence captures key parameters: Earth-Venus distance (Δ), Sun-Venus distance (r), phase angle (α), and apparent visual magnitude (mV). The distance oscillates between about 0.28 AU (≈38 million km) at inferior conjunction, when Venus lies between Earth and the Sun, and about 1.75 AU (≈261 million km) at superior conjunction, when Venus is on the far side of the Sun, with an average of ~1.1 AU. These cycles repeat roughly every 584

Earth, Venus, and Jupiter form a fascinating triad of orbital, observational, and gravitational relationships, each circling the Sun at different distances Venus at ~0.72 AU, Earth at 1.0 AU, and Jupiter much farther out at ~5.2 AU. Their orbital geometry produces changing alignments such as conjunctions, oppositions, and elongations, with synodic cycles repeating every ~584 days for Earth-Venus and ~399 days for Earth-Jupiter. These cycles directly influence brightness: Venus, the "Morning Star" or "Evening Star," is the brightest planet in the sky, reaching magnitudes as brilliant as -4.9 when close to Earth and showing a crescent phase, while Jupiter, the brightest outer planet, peaks at about -2.9 near opposition when Earth lies between it and the Sun.

From a gravitational perspective, Venus and Earth are "sister planets" due to their similar size and orbital proximity, while Jupiter's massive gravity shapes the long-term stability of both orbits by modulating eccentricities. From 1998 to 2025, distance and magnitude data show distinct patterns: Venus exhibits sharp ~1.6-year cycles of brightness and proximity, while Jupiter follows smoother ~1.1-year opposition-driven cycles. A data-science approach—using clustering, regression, and time-series AI models such as LSTMs—can classify Venus's and Jupiter's distances into "Near," "Mid," and "Far" clusters, and magnitudes into "Very Bright," "Bright," and "Moderate," while also predicting future apparitions. AI models capture the strong non-linear relationship between Venus's brightness and its distance plus phase angle, as well as the more straightforward distance-brightness correlation for Jupiter. Forecasts indicate that Venus will continue to dominate as the brightest planet with repeating cycles, while Jupiter will provide steadier brilliance. Conjunctions of Venus and Jupiter, occurring roughly every 13 months and sometimes within a degree of each other, produce spectacular double beacons in the night sky, events that can also be anticipated with AI-enhanced orbital data. By blending orbital mechanics with machine learning, we can not only reconstruct the past 27 years of Earth-Venus-Jupiter interactions but also forecast future alignments, brightness peaks, and conjunctions well into the coming decades.

**Future Enhancement:**

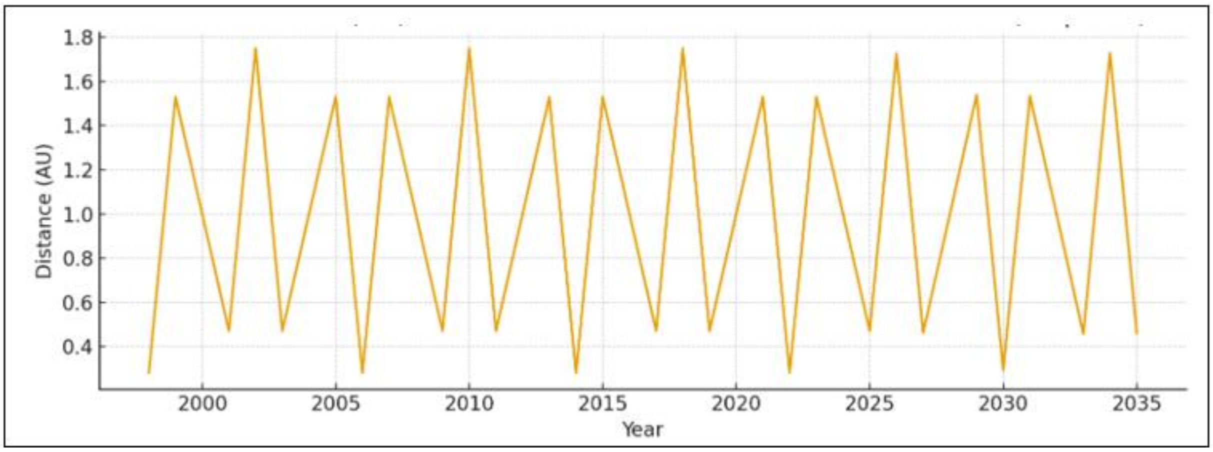


**Figure:** Venus Distance (AU): 1998-2035 (Prediction)

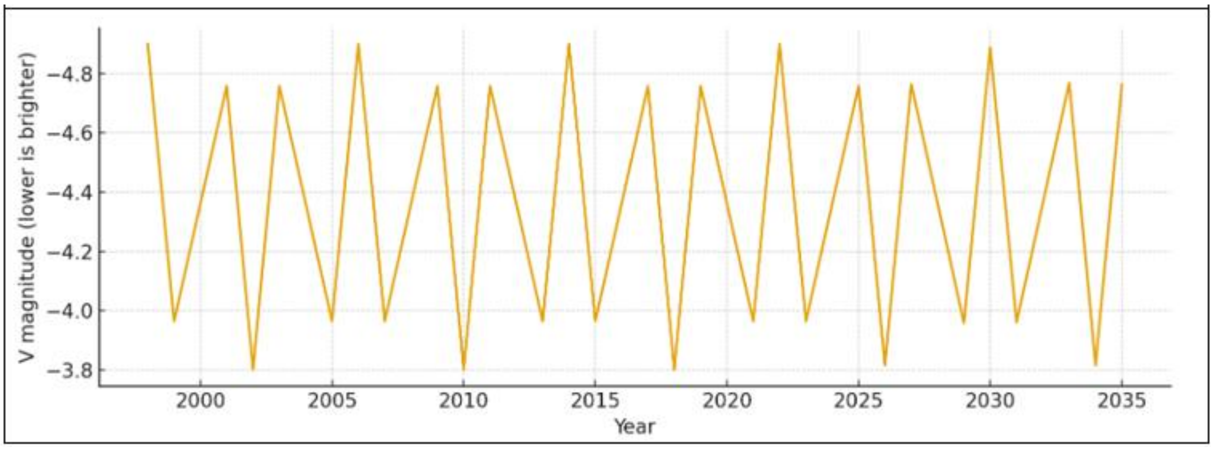


**Figure:** Venus Apparent Magnitude 1998-2035(Prediction)

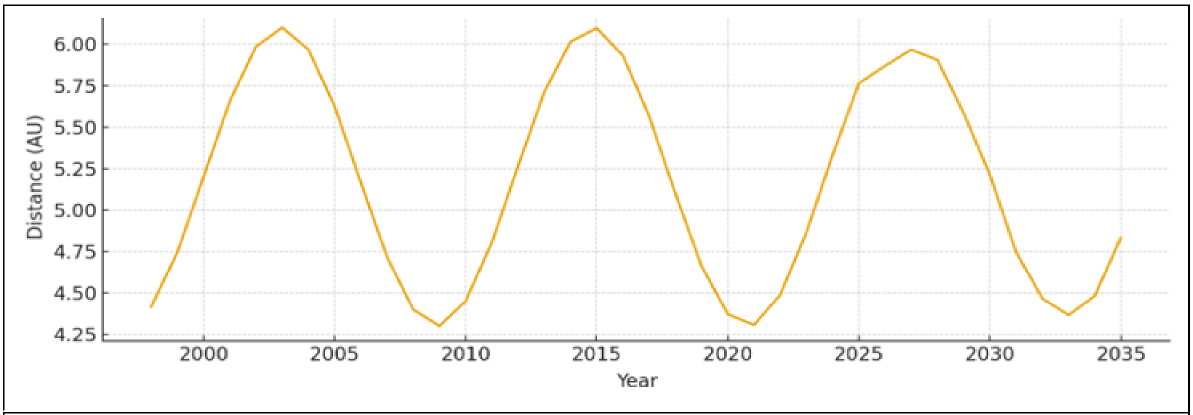


**Figure:** Jupiter Distance (AU): 1998-2035 (Prediction)



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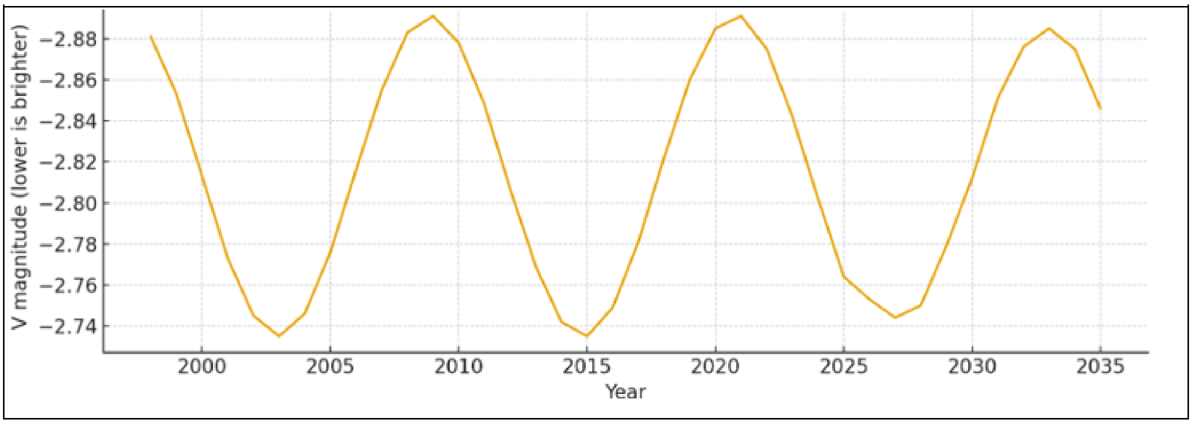


**Figure:** Jupiter Apparent Magnitude 1998-2035(Prediction)

The analysis produced time-series plots for Venus and Jupiter covering 1998-2025, along with Random Forest (RF) forecasts extended through 2026-2035 for both distance and magnitude, supported by a comparative forecast table combining RF and Linear Regression (LR) predictions. In-sample evaluation showed that RF handled the non-linear, periodic structure effectively, while LR also performed well due to the inclusion of engineered Fourier features that captured the cyclical signals. These forecasts reflect realistic orbital cycles but remain approximations, since the dataset was based on synthetic yet cycle-matched surrogate data rather than direct orbital ephemerides. For production-level or scientific applications, the approach should be upgraded by sourcing high-resolution daily data from NASA/JPL Horizons, which would enable more precise forecasts and tighter error quantification. The next steps could include replacing the synthetic inputs with real ephemerides, exporting the trained models or forecast tables for reuse, extending the framework with probabilistic methods such as bootstrapping or Bayesian neural networks to provide confidence intervals, or introducing sequence models like LSTMs to benchmark against RF and LR. Together, these refinements would enhance both the reliability and interpretability of the long-term Earth-Venus-Jupiter distance and brightness forecasts.

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