

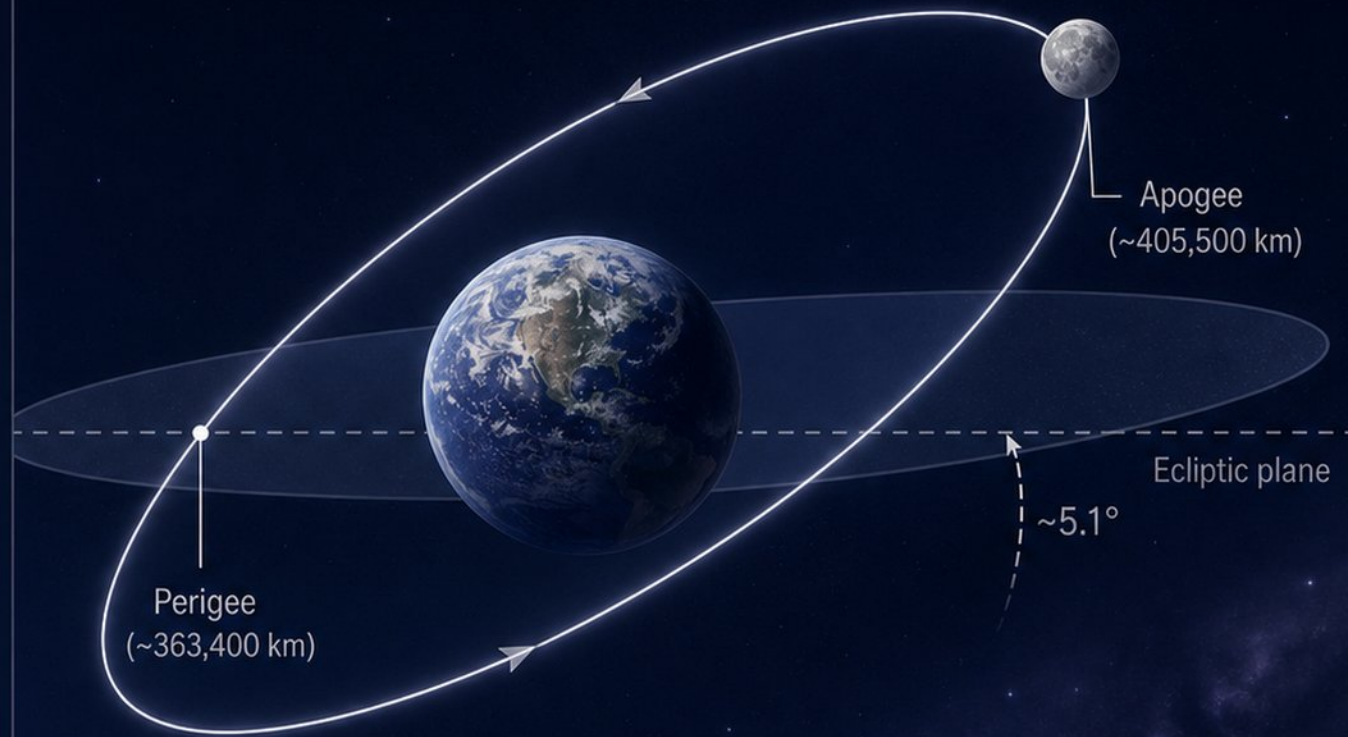
Introduction to The Moon: Phases, Eclipses, and Orbits

- Covers predictable, recurring Moon patterns observable from Earth
- Interprets phases, eclipses, and orbits from geometry, not memorization
- Structured flow: orbit → phases → eclipse geometry → tides
- Addresses key misconceptions: Earth's shadow causes phases; monthly eclipses



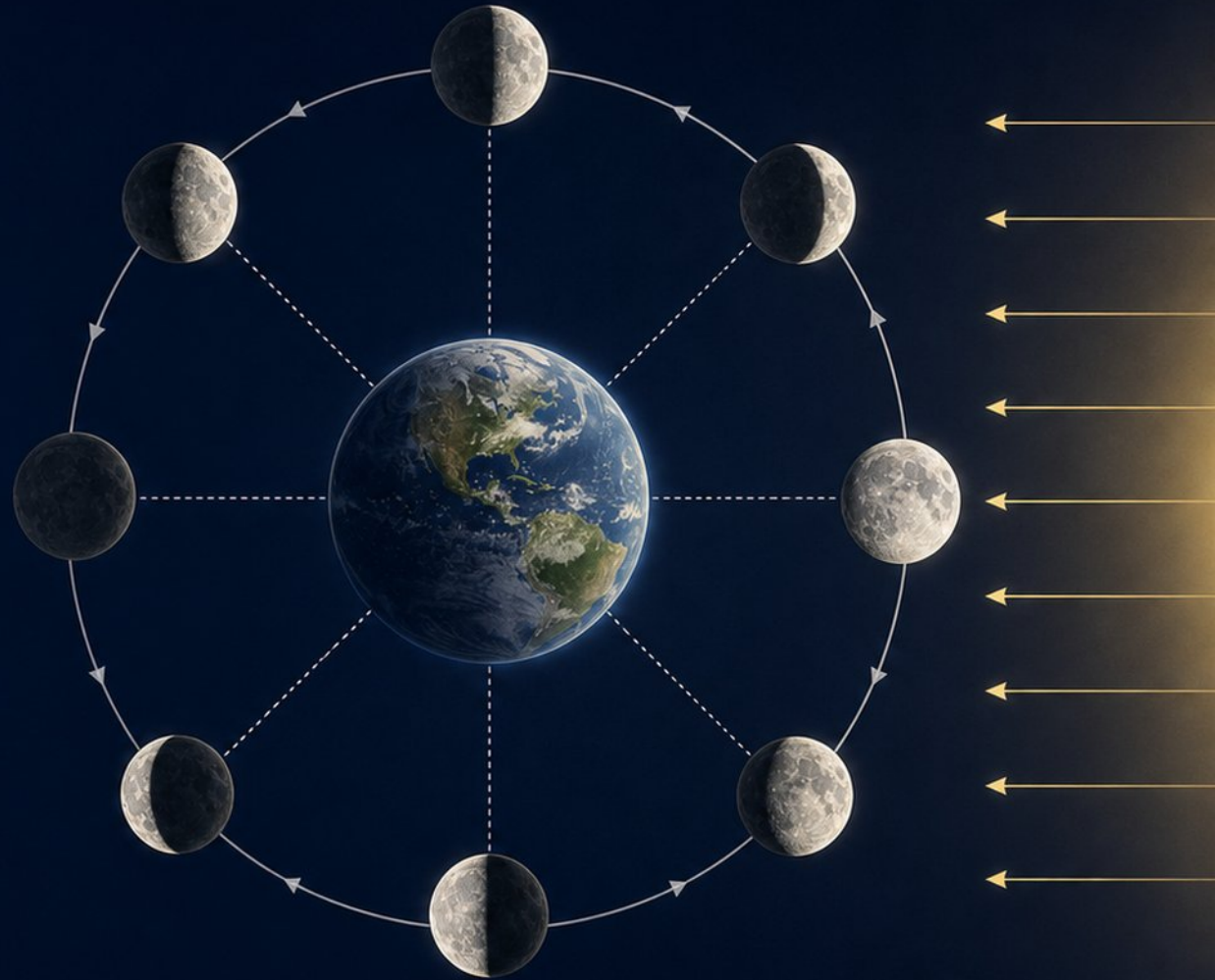
The Moon's Orbit: Shape, Speed, and Orientation

- **Elliptical orbit:** distance varies from ~363,400 km at perigee to ~405,500 km at apogee
- **Sidereal month** (~27.3 days): true 360° orbit relative to the distant stars
- **Synodic month** (~29.5 days): phase cycle; longer because Earth moves around the Sun
- **Orbital plane tilted ~5.1° to the ecliptic** — the single biggest reason eclipses are occasional, not monthly



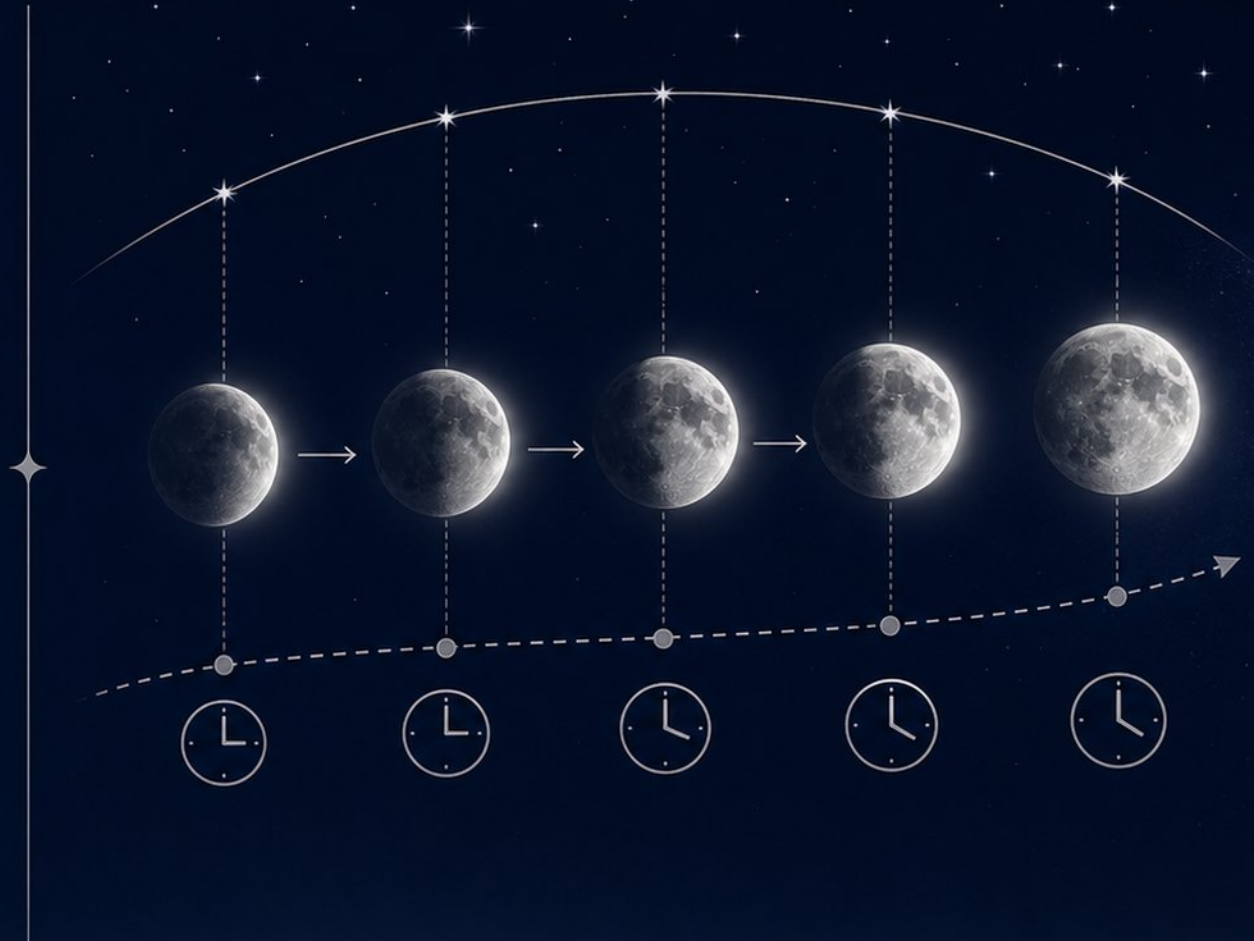
What Causes Moon Phases: The Sunlit Half

- The Moon shines by reflected sunlight; one half is always illuminated
- Phases arise from our changing view of the sunlit half as the Moon orbits—not Earth's shadow
- Key alignments: new Moon (near Sun), first quarter, full Moon (opposite Sun), last quarter
- The “dark side” is a misnomer: the far side cycles through day and night just like the near side



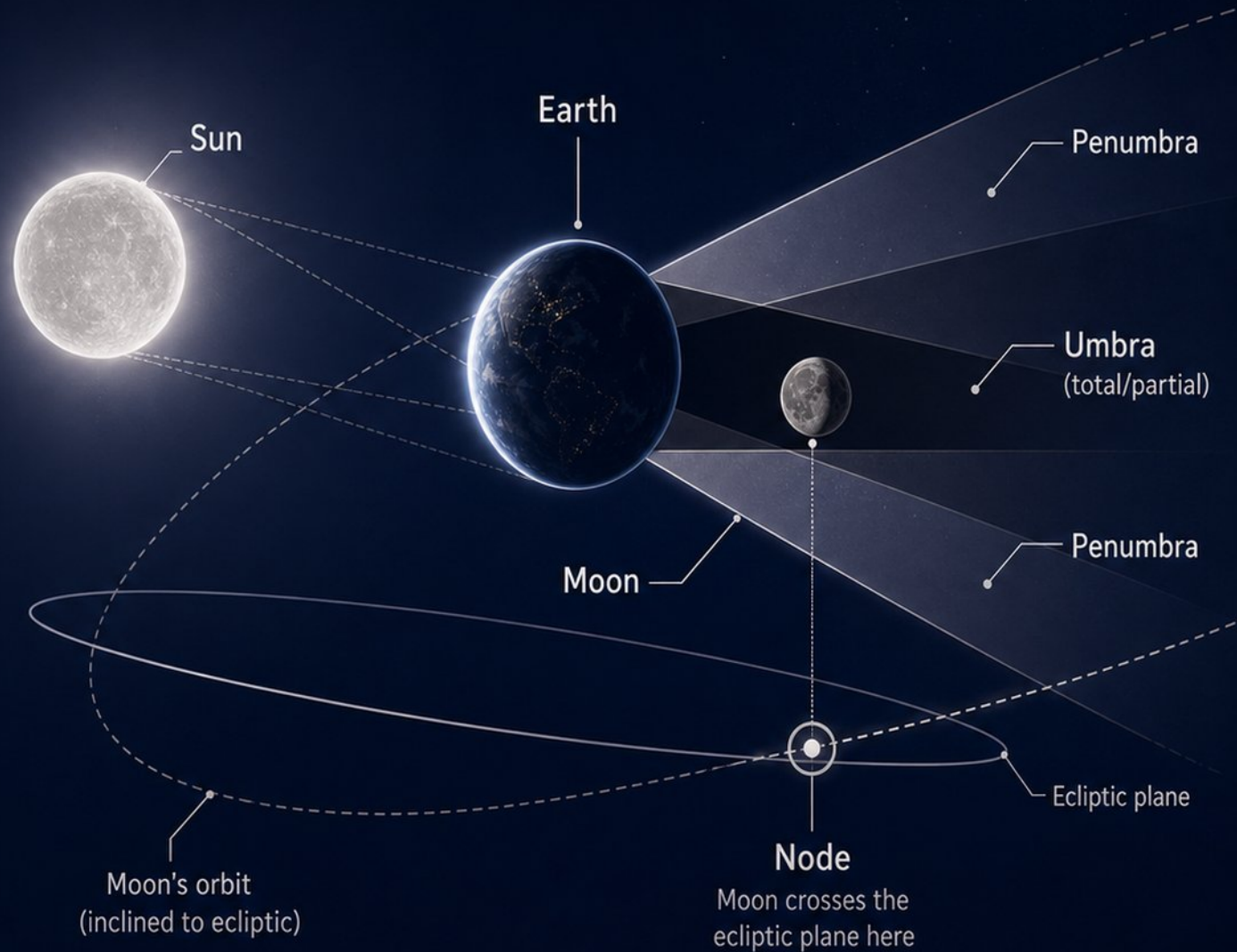
Predicting the Phase Cycle

- Synodic month (~29.5 days) governs the full phase cycle, new Moon to new Moon.
- Waxing: sunlit portion grows after new Moon. Waning: shrinks after full Moon.
- The Moon rises about 50 minutes later each day.
- Daily eastward shift of $\sim 13^\circ$ against the stars drives changing phases and rise times.



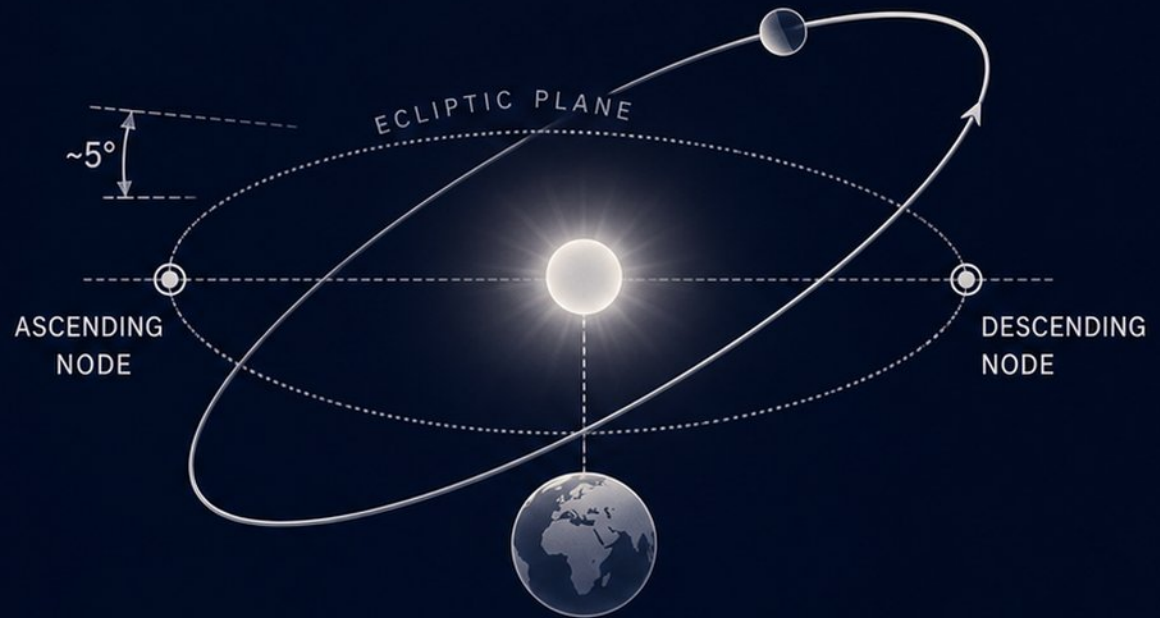
Eclipses: When the Shadows Align

- Lunar eclipse: Full Moon enters Earth's shadow, visible from the entire night side.
- Solar eclipse: New Moon's shadow falls on Earth, visible only along a narrow path.
- Eclipses occur only when the Moon crosses the ecliptic plane at a node during new or full Moon.
- Umbra (total/partial) and penumbra (subtle dimming) determine eclipse type.



Why Eclipses Don't Happen Every Month

- Moon's orbit tilted $\sim 5^\circ$ to ecliptic; usually passes above/below shadow at syzygy
- Eclipse seasons: Two ~ 34 -day windows per year when Sun is near a node
- Nodes precess westward $\sim 19^\circ$ per year, completing a cycle in ~ 18.6 years
- Eclipse seasons shift ~ 19 days earlier each year; Saros cycle repeats every ~ 18 years



Types of Lunar Eclipses



TOTAL LUNAR ECLIPSE

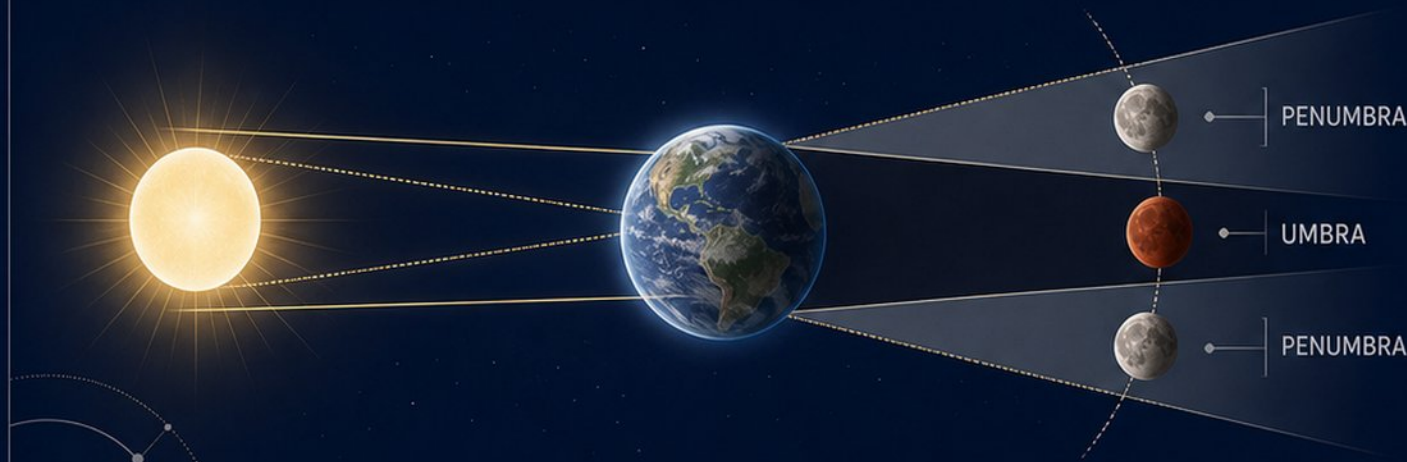


PARTIAL LUNAR ECLIPSE



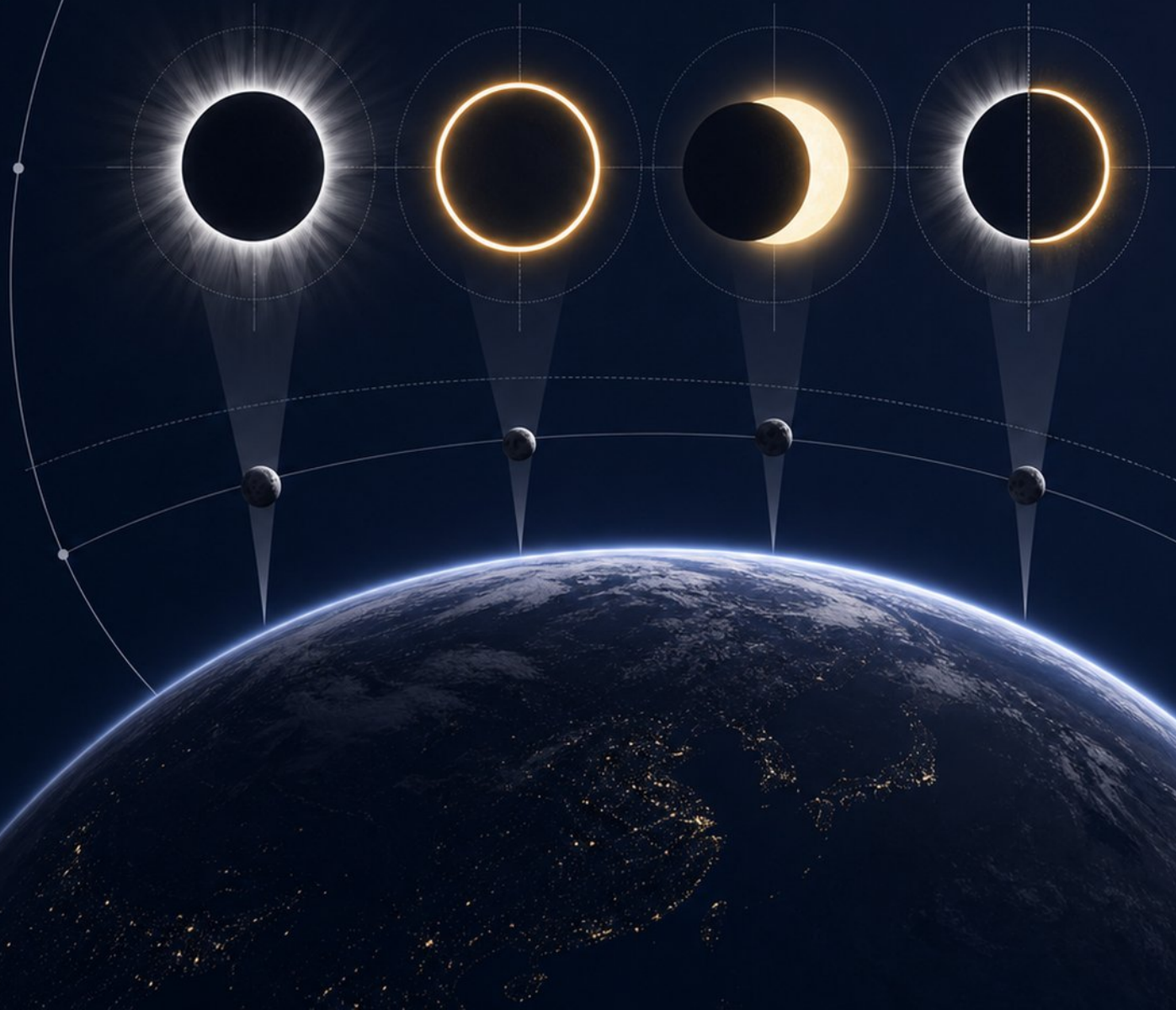
PENUMBRAL LUNAR ECLIPSE

- Total lunar eclipse: entire Moon in Earth's umbra, often coppery red
 - Partial lunar eclipse: only part of the Moon enters the umbra
 - Penumbral lunar eclipse: Moon passes only through faint penumbra, subtle dimming
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- Redness from sunlight filtered through Earth's atmosphere
 - All sunrises and sunsets projected onto the eclipsed Moon



Types of Solar Eclipses

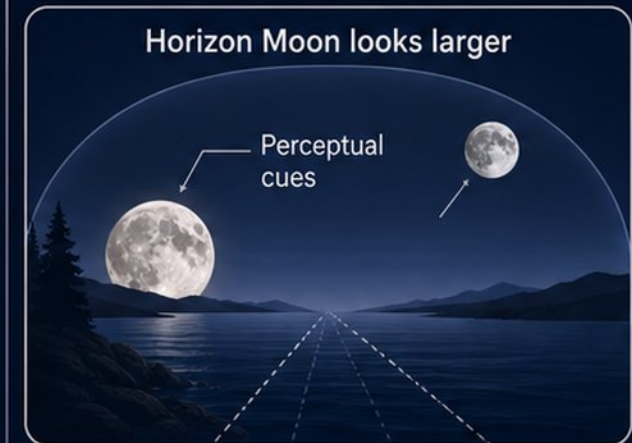
- **Total:** Moon completely covers the Sun, revealing the corona
- **Annular:** Moon at apogee appears smaller, leaving a 'ring of fire'
- **Partial:** Only part of the Sun is covered
- **Hybrid:** Shifts between total and annular along the path
- Eclipse type depends on the Moon's varying apparent size



The Moon's Size and Distance: Perception and Reality

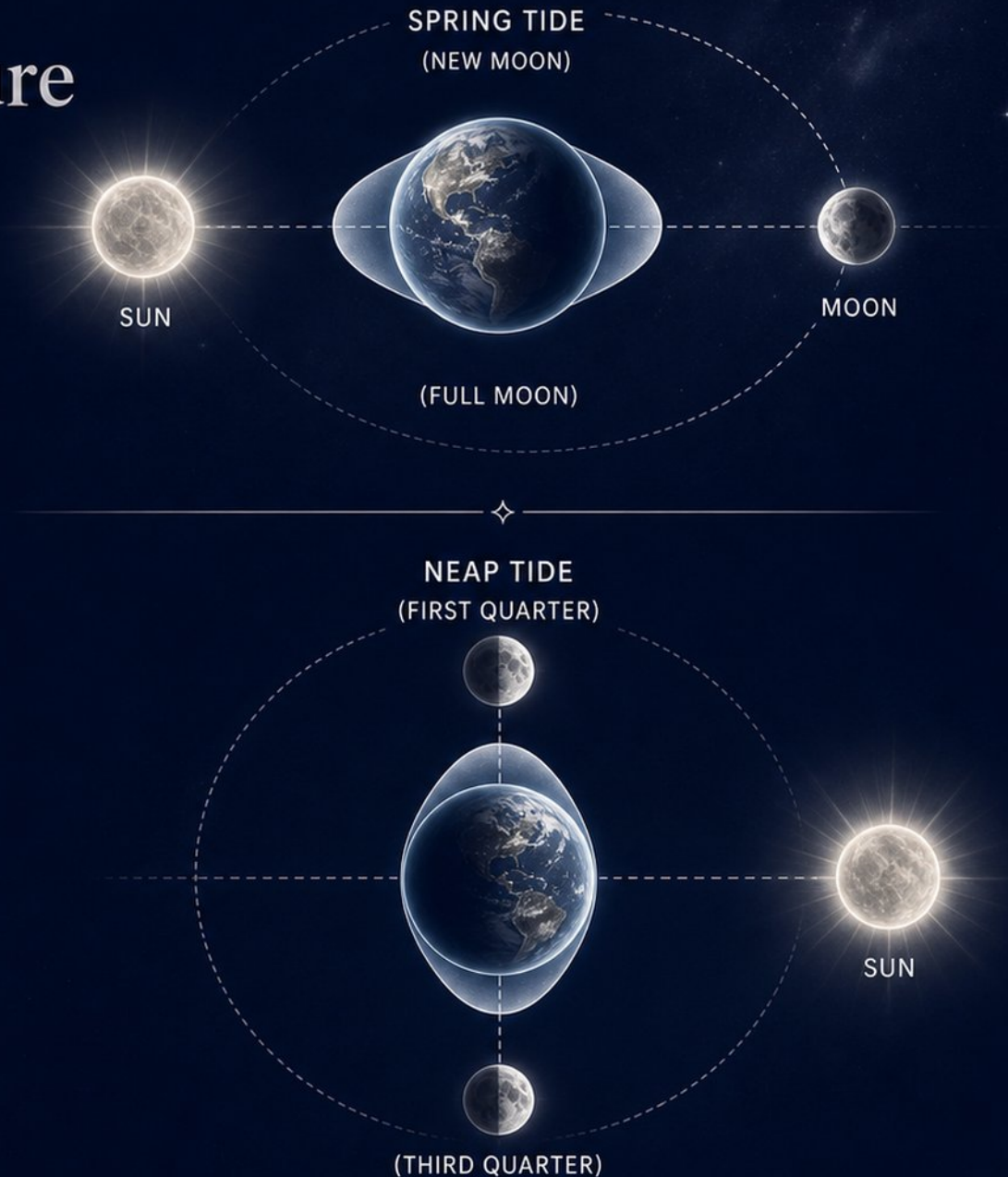


- Moon illusion: horizon Moon looks larger due to perceptual cues, not atmospheric magnification
- Ponzo illusion and flattened sky dome trick the brain into perceiving greater distance
- Angular size varies from ~ 29.3 to 33.5 arcminutes because the orbit is elliptical
- Supermoon (perigee) and micromoon (apogee) describe full Moons at distance extremes
- Apparent size nearly matches the Sun—a coincidence enabling total solar eclipses

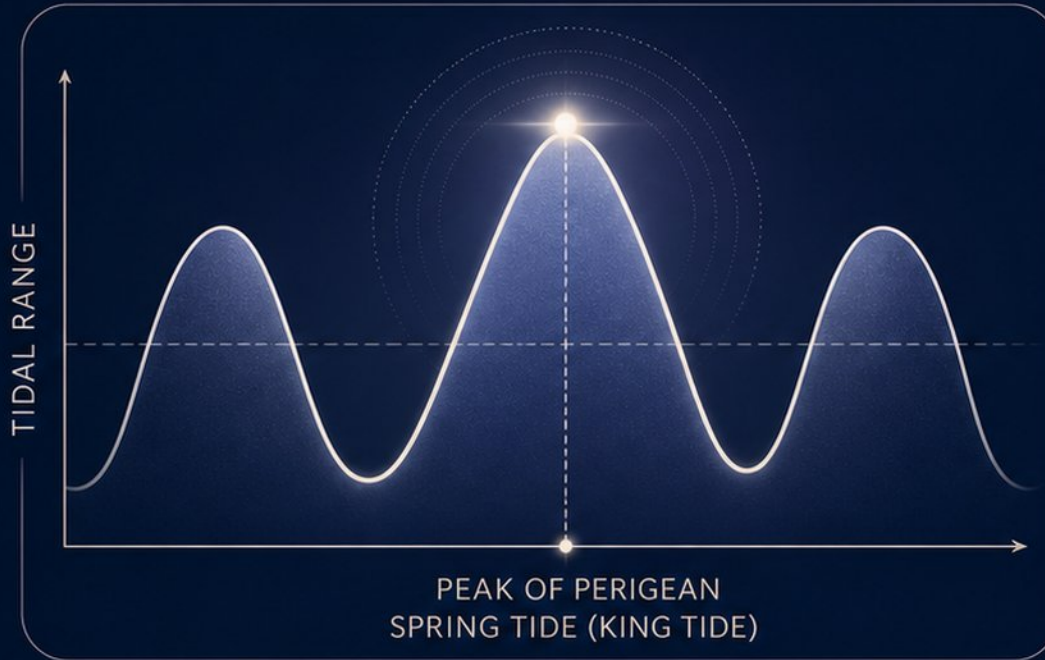


Tides: The Moon's Gravitational Signature

- Tides are caused by differential gravitational pull of the Moon and Sun on Earth's oceans, creating two bulges.
- Spring tides occur at new and full Moon when solar and lunar tidal forces align, producing the highest highs and lowest lows.
- Neap tides occur at first and third quarter Moons when the Sun and Moon pull at right angles, producing the smallest tidal range.
- Tidal locking: the Moon's rotation period equals its orbital period, so the same side always faces Earth.



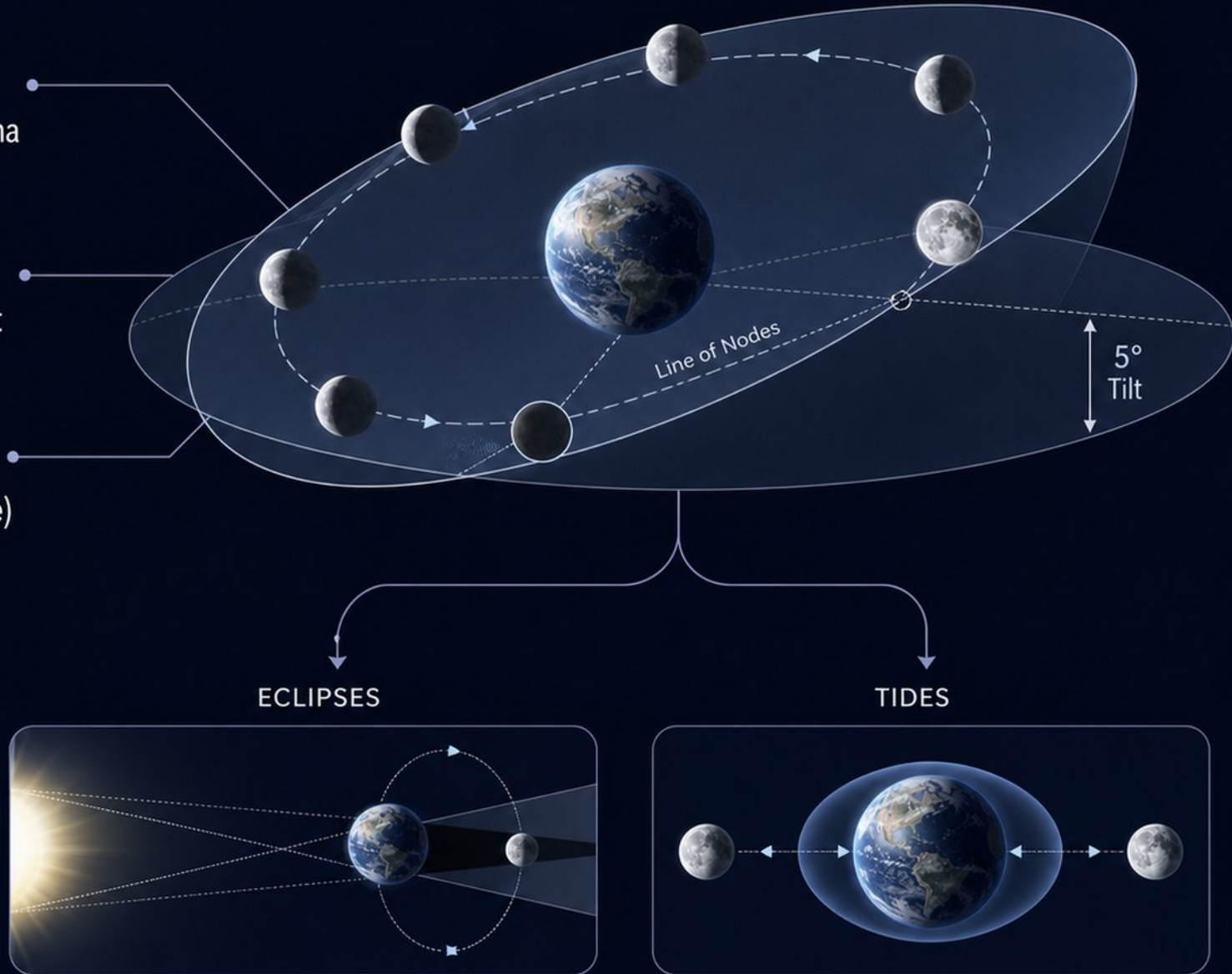
King Tides and Perigean Spring Tides



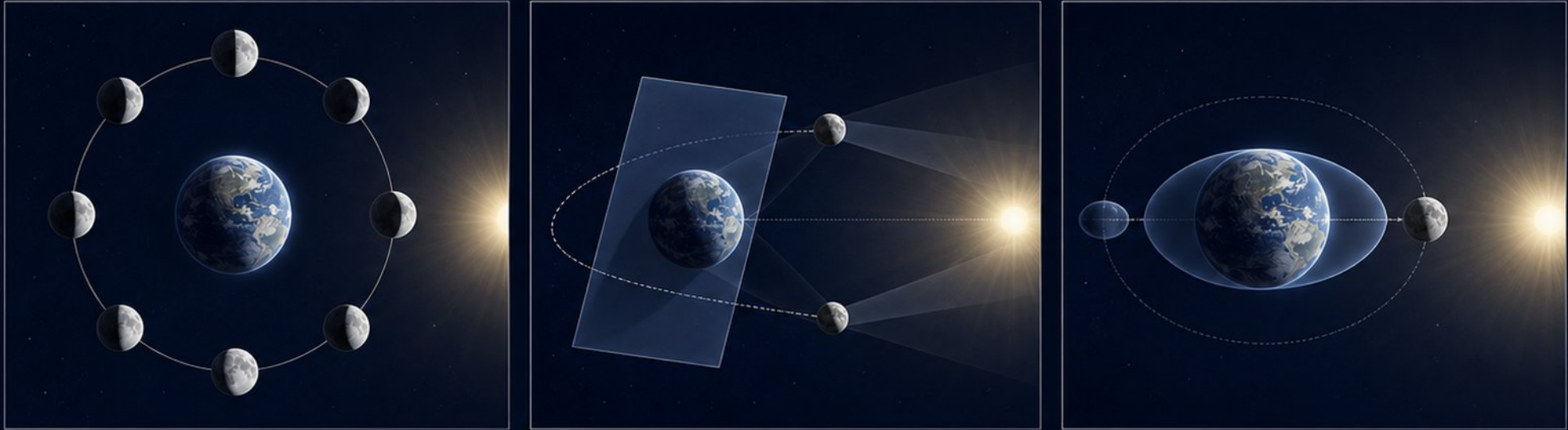
- A king tide occurs when a spring tide (new/full Moon) aligns with lunar perigee.
- At perigee, gravitational pull is ~20% stronger, amplifying the tidal range.
- Earth's perihelion/aphelion cycle further modulates the Sun's tidal contribution.
- The largest annual tides often happen near the equinoxes in March and September.

Connecting the Patterns: From Orbits to Eclipses and Tides

- Elliptical orbit, 5° tilt, and phase cycle work together to create all Moon phenomena
- Eclipse type depends on Moon's distance (perigee/apogee) and node alignment
- Largest tidal ranges occur at perigee spring tides (new/full Moon near perigee)
- Visualizing 3D geometry replaces memorizing names and dates



Key Takeaways and Applying the Patterns



- Phases, eclipses, and tides share the same Earth-Moon-Sun geometry.
- The Moon's 5° orbital tilt explains why eclipses are occasional, not monthly.
- Visualize the 3D geometry to predict phases, eclipse seasons, and spring tides.
- Common misconceptions (phases from Earth's shadow, monthly eclipses) are resolved by seeing the spatial relationships.

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