

# LUNAR PHASES AND ECLIPSES

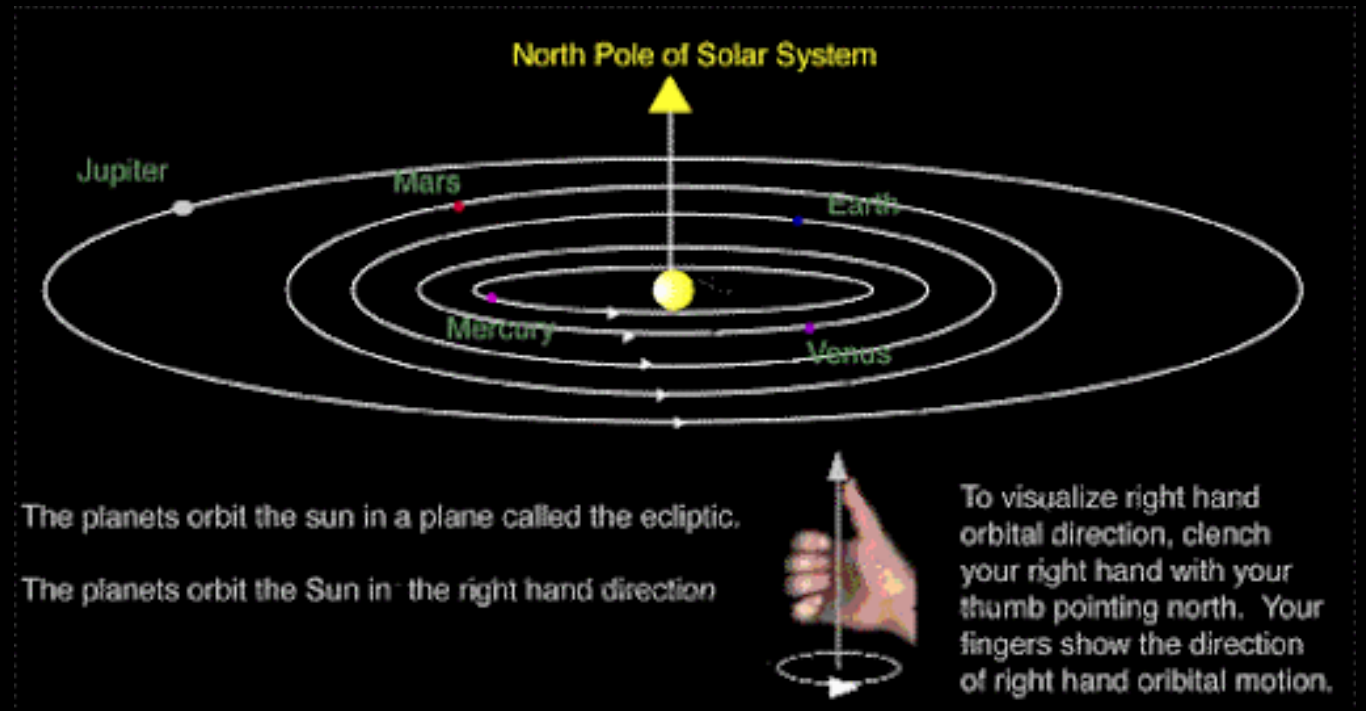


# ECLIPSES: WHAT ARE THEY?

- Earth's revolution around Sun
- Moon's revolution around Earth
  - Lunar phases
- Angular size of Sun and Moon as viewed from Earth

# EARTH'S REVOLUTION

- Earth revolves around the Sun once every 365 days, 6 hours, 9 minutes.
- Earth revolves in a counterclockwise direction (right hand rule)



# HOW LONG IS A YEAR?

- Julian Calendar (Julius Caesar, 45 B.C.)
  - 365.5 days long (leap year every 4 years)
- Gregorian Calendar (Pope Gregory XII, 1582)
  - 365.2425 days long (leap year every 4 years except in years that are divisible by 100 but not by 400...1700, 1800, 1900 not leap years but 2000 was)
- Easter: “the first Sunday after the day with the first full moon after the spring equinox of the year”

IL  
CALENDARIO  
GREGORIANO  
PERPETVO.

CON PRIVILEGIO DEL SOMMO  
Pontefice, del Senato Veneto, e d'altri Principi.

Tradotto dal Latino nell'Italiano idioma dal Reuerendo  
M. Bartholomeo Dionigi da Fano.



*Di consenso dell'Auttoze.*

IN VENETIA, Appresso Gio. Baptista Sella,  
& Fratelli. M D LXXXII.



Júlio César



Gregório XIII

1582		OUTUBRO				1582	
Dom	Seg	Tër	Qua	Qui	Sex	Sáb	
	1	2	3	4	15	16	
17	18	19	20	21	22	23	
24	25	26	27	28	29	30	
31							

Ao ser o calendário Juliano corrigido pelo Papa Gregório, em 1582, foram dele eliminados dez dias, como aí se vê. O dia que teria sido sexta-feira, 5, ficou sendo sexta-feira, 15. A continuidade dos dias da semana não foi alterada nem interrompida, nem o foi em alteração nenhuma do calendário.

**Table 3.1**

The Seven Days of the Week and the Astronomical Objects They Honor

<b>Object</b>	<b>Germanic God</b>	<b>English</b>	<b>French</b>	<b>Spanish</b>
Sun	—	Sunday	dimanche	domingo
Moon	—	Monday	lundi	lunes
Mars	Tiw	Tuesday	mardi	martes
Mercury	Woden	Wednesday	mercredi	miércoles
Jupiter	Thor	Thursday	jeudi	jueves
Venus	Fria	Friday	vendredi	viernes
Saturn	—	Saturday	samedi	sábado

*The seven days were originally linked directly to the seven objects. The correspondence is no longer perfect, but the pattern is clear in many languages; some English names come from the corresponding names of Germanic gods.*

# MOON'S REVOLUTION

- Moon revolves around the Earth once every 27.3 days
- Moon revolves in a counterclockwise direction
- As viewed from Earth, the Moon undergoes cycles of Lunar Phases
  - 29.5 days from New Moon to New Moon

# ACTIVITY

- Experience the lunar phases for yourself.
  - Hold the stick between your fingers at arm's length. The 'ball' will be the moon, and your head will be the Earth.
  - Stand with the ball directly in the way of the light ("New Moon"). Then, rotate your arm/body in a counterclockwise direction and observe how the appearance of the Moon changes.
- 1) What side of the moon becomes visible (lit up) first?
  - 2) Draw the appearance of the moon every  $1/8^{\text{th}}$  of a rotation.

Video: <https://www.youtube.com/watch?v=SDhIPEMkiOo>



new

Crescent

first quarter

gibbous

full

gibbous

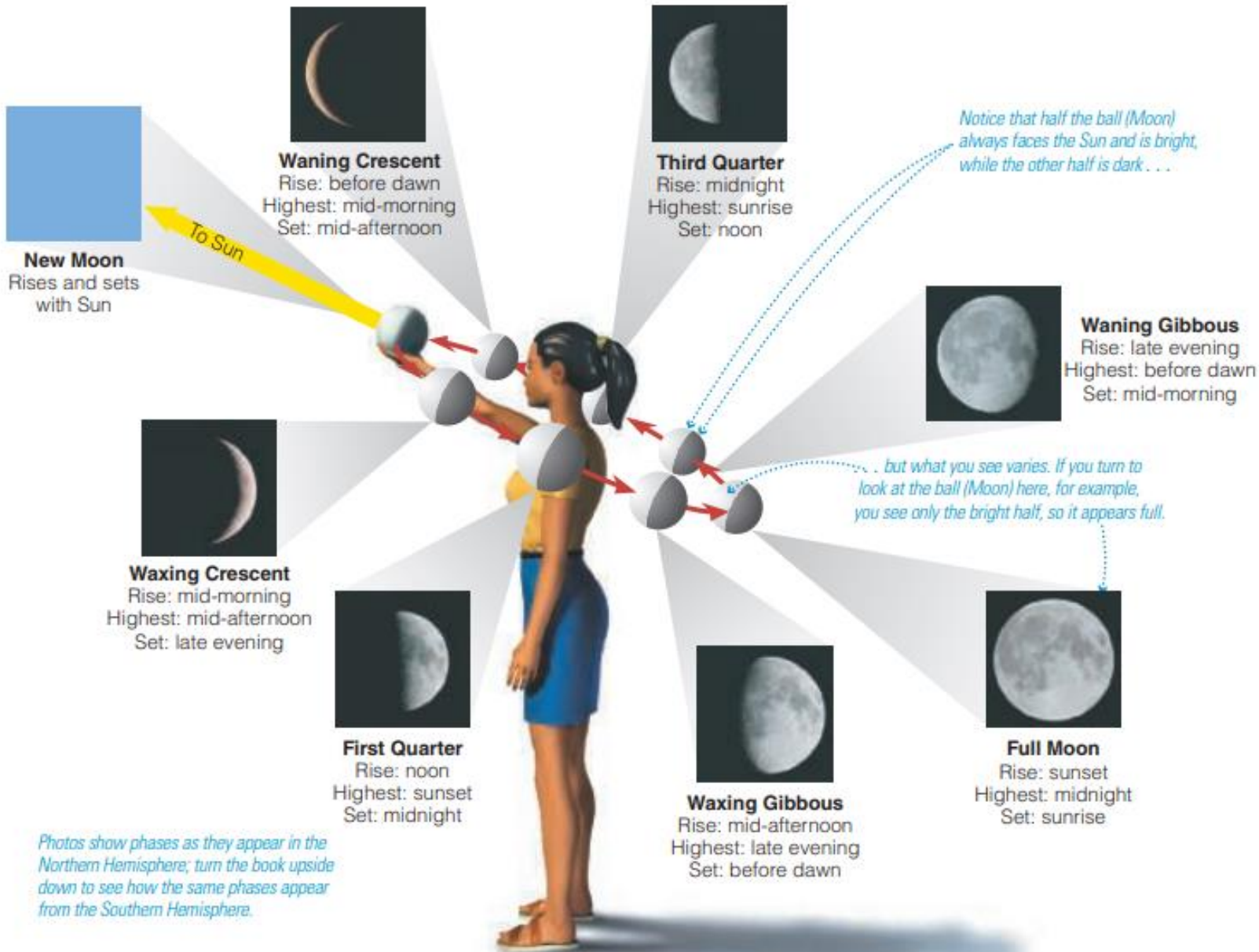
last quarter

crescent

**Waxing**

**Waning**





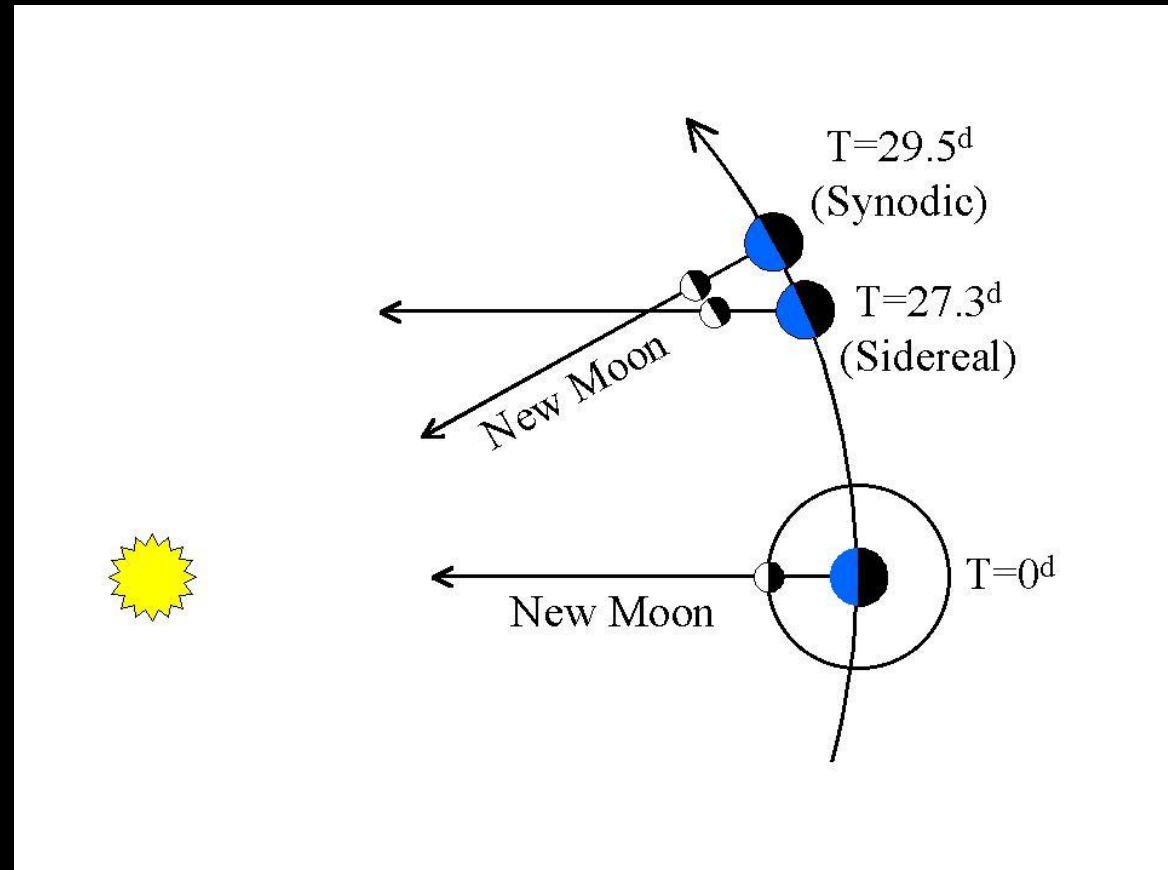
# MOON'S REVOLUTION

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  - 29.5 days from New Moon to New Moon
  - Why 29.5 days vs 27.3 days? Discuss.

# MOON'S REVOLUTION

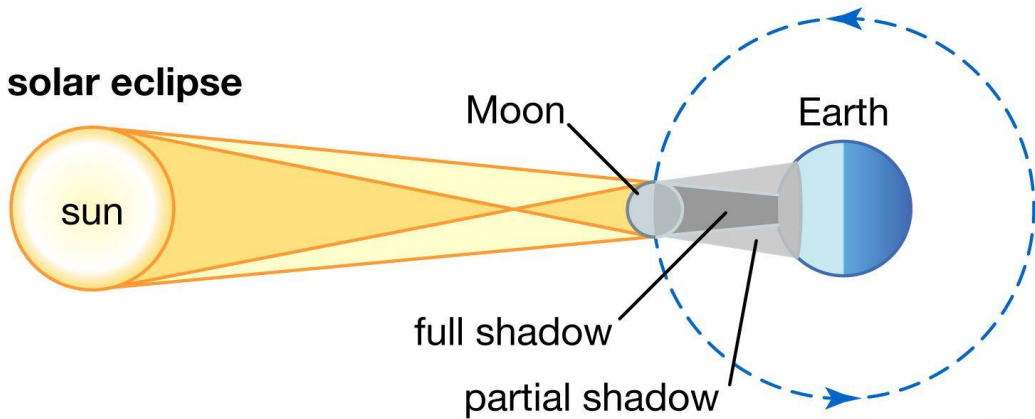
## Demonstration

- Rotate a full turn in place, but then take a step about  $1/12^{\text{th}}$  of the way around the Sun. Are you facing the Sun?

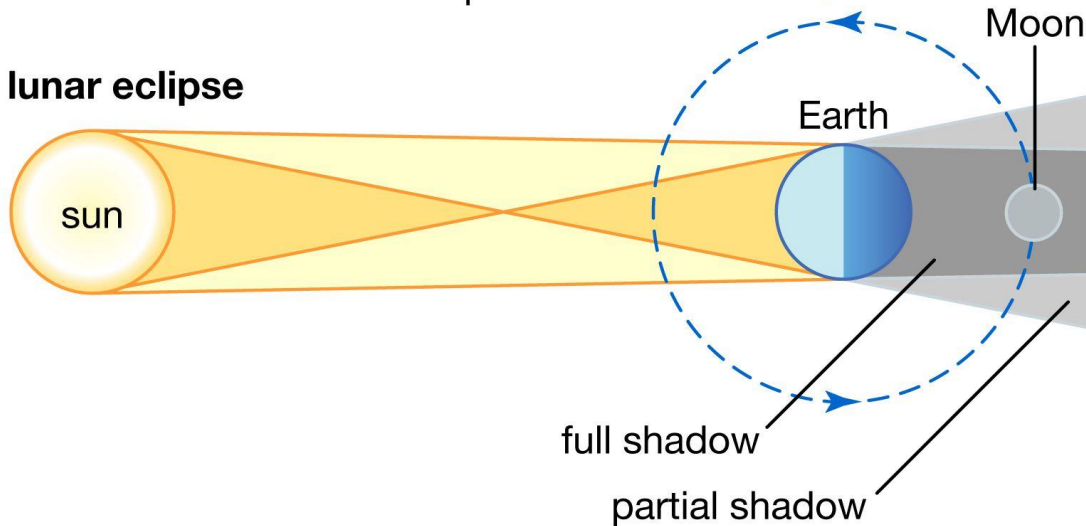


# WHAT IS AN ECLIPSE?

**solar eclipse**

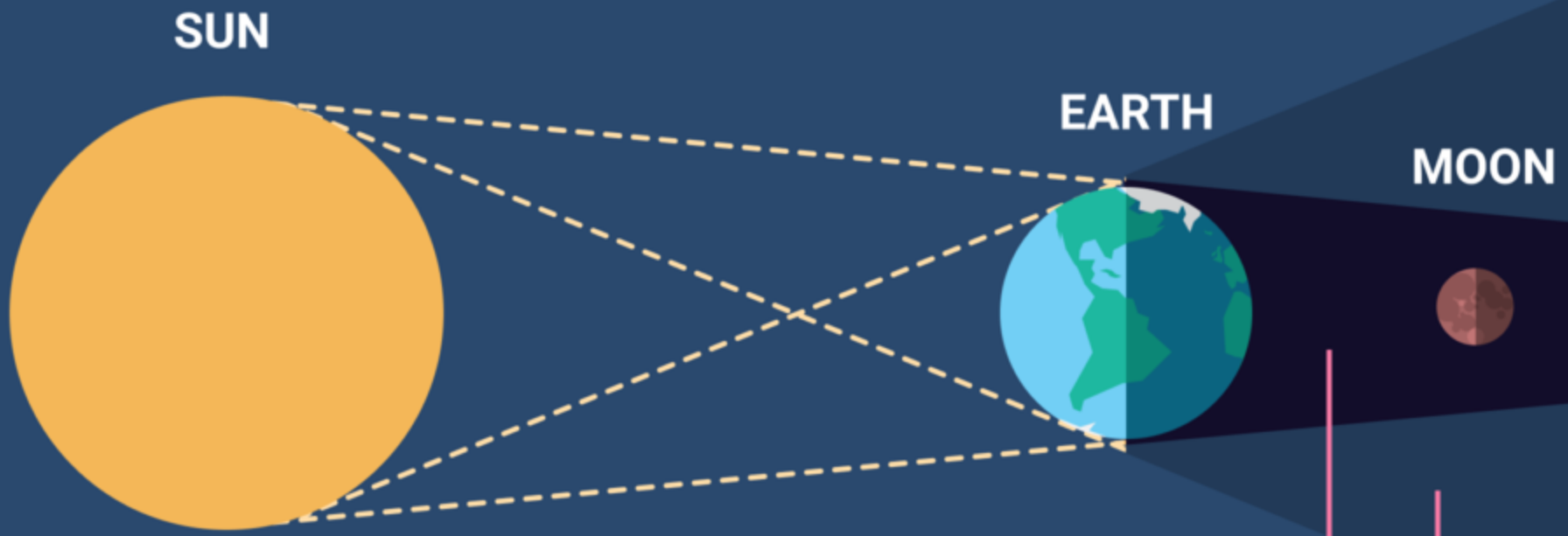


**lunar eclipse**



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- A solar eclipse occurs when the Moon blocks the Sun when viewed from Earth.
- A lunar eclipse occurs when the Earth is in between the Sun and Moon and blocks the ability of sunlight to light up the Moon.
- **Umbra**: area of full shadow
- **Penumbra**: area of partial shadow



Umbra  
Penumbra

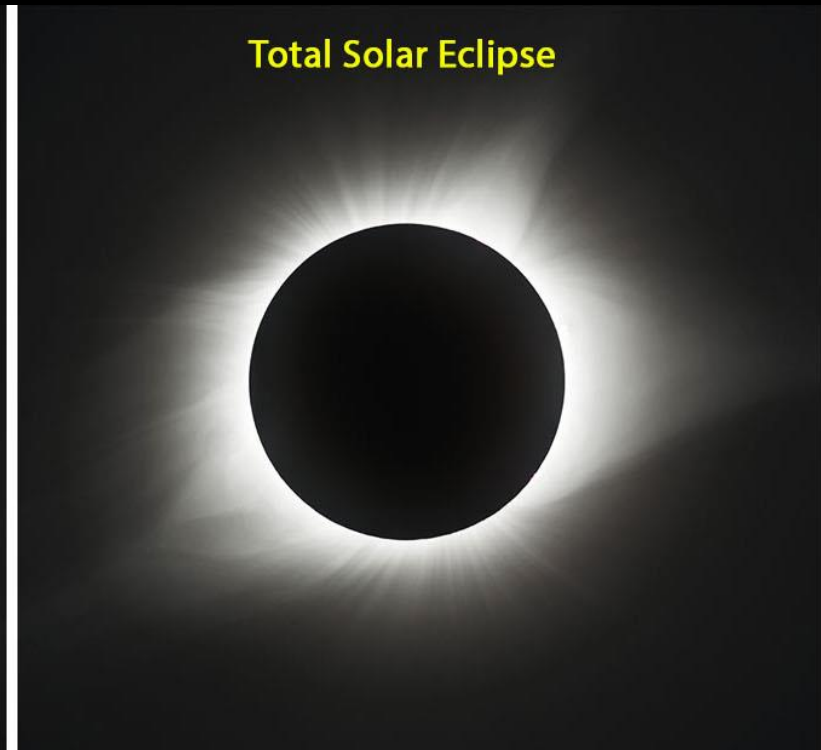
# SOLAR ECLIPSES ARE AWESOME

Partial Solar Eclipse

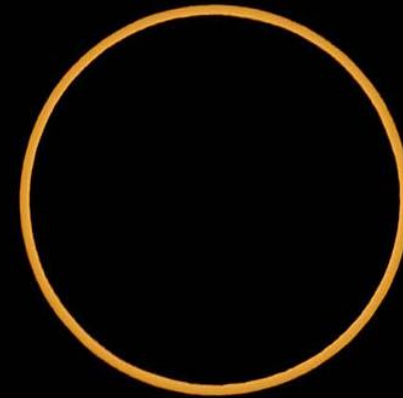


[www.MrEclipse.com](http://www.MrEclipse.com)

Total Solar Eclipse

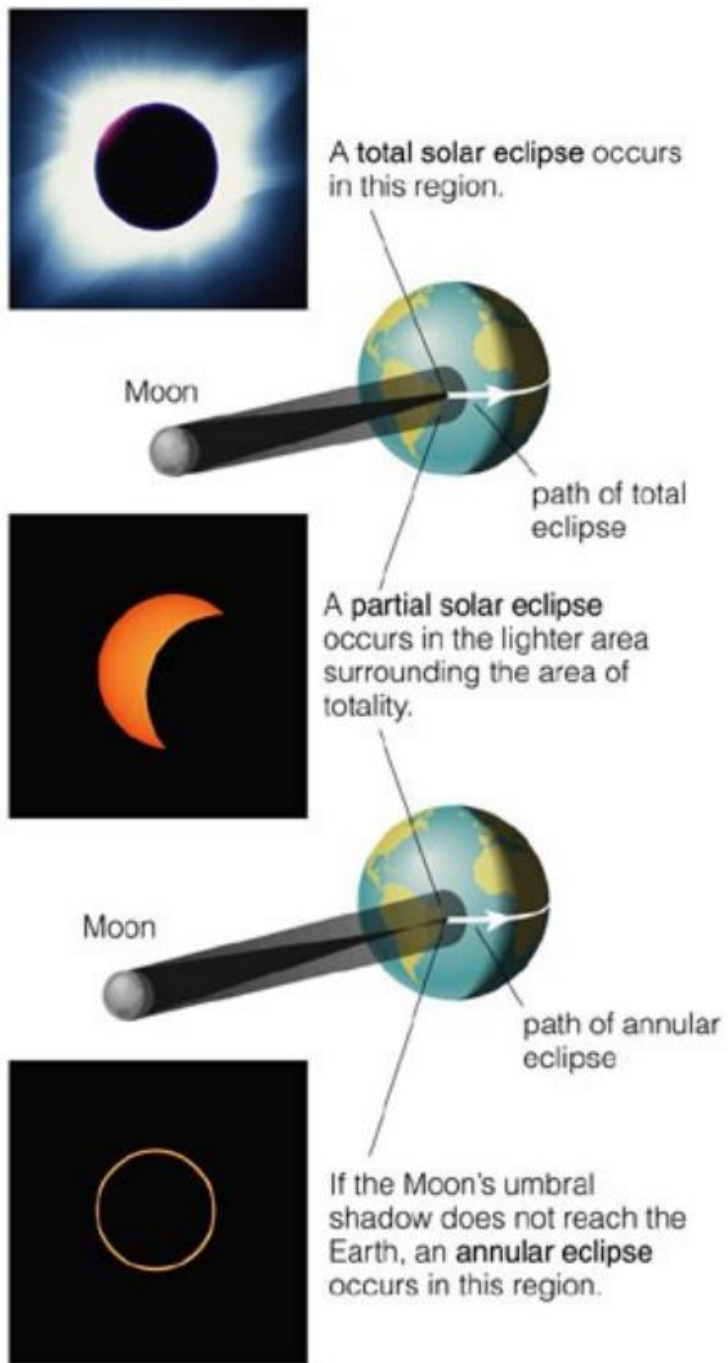


Annular Solar Eclipse



©2020 Fred Espenak

# Solar eclipse geometries



Total (seen only from small patch on Earth)

Partial (seen from much larger region where penumbra falls)

Annular (rare; only when Moon far from Earth at instant of eclipse)





# THE TIMING OF ECLIPSES

Discuss: What **moon phases** are required for solar eclipses? Lunar eclipses?

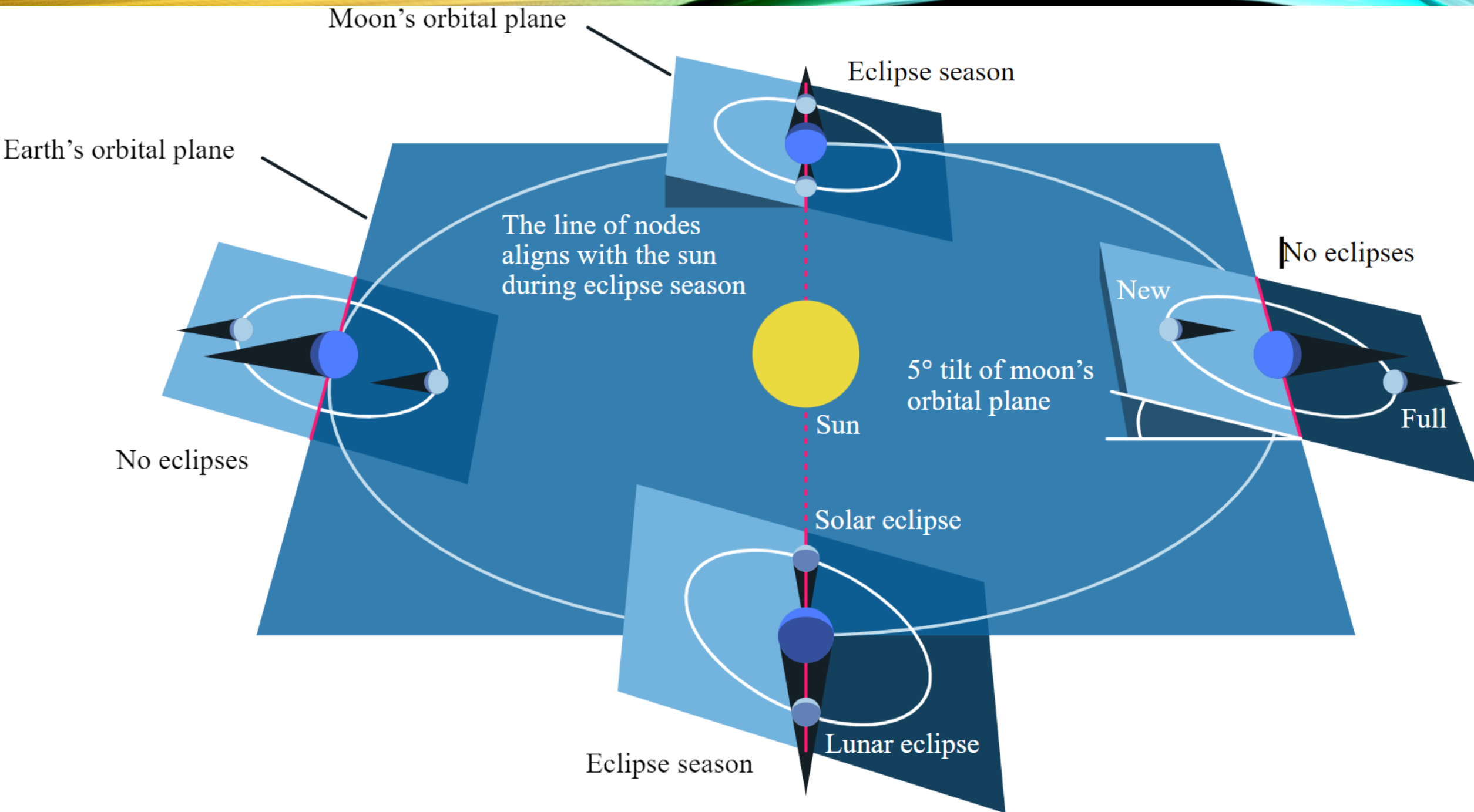
Optional simulation <https://ccnmtl.github.io/astro-simulations/lunar-phase-simulator/>

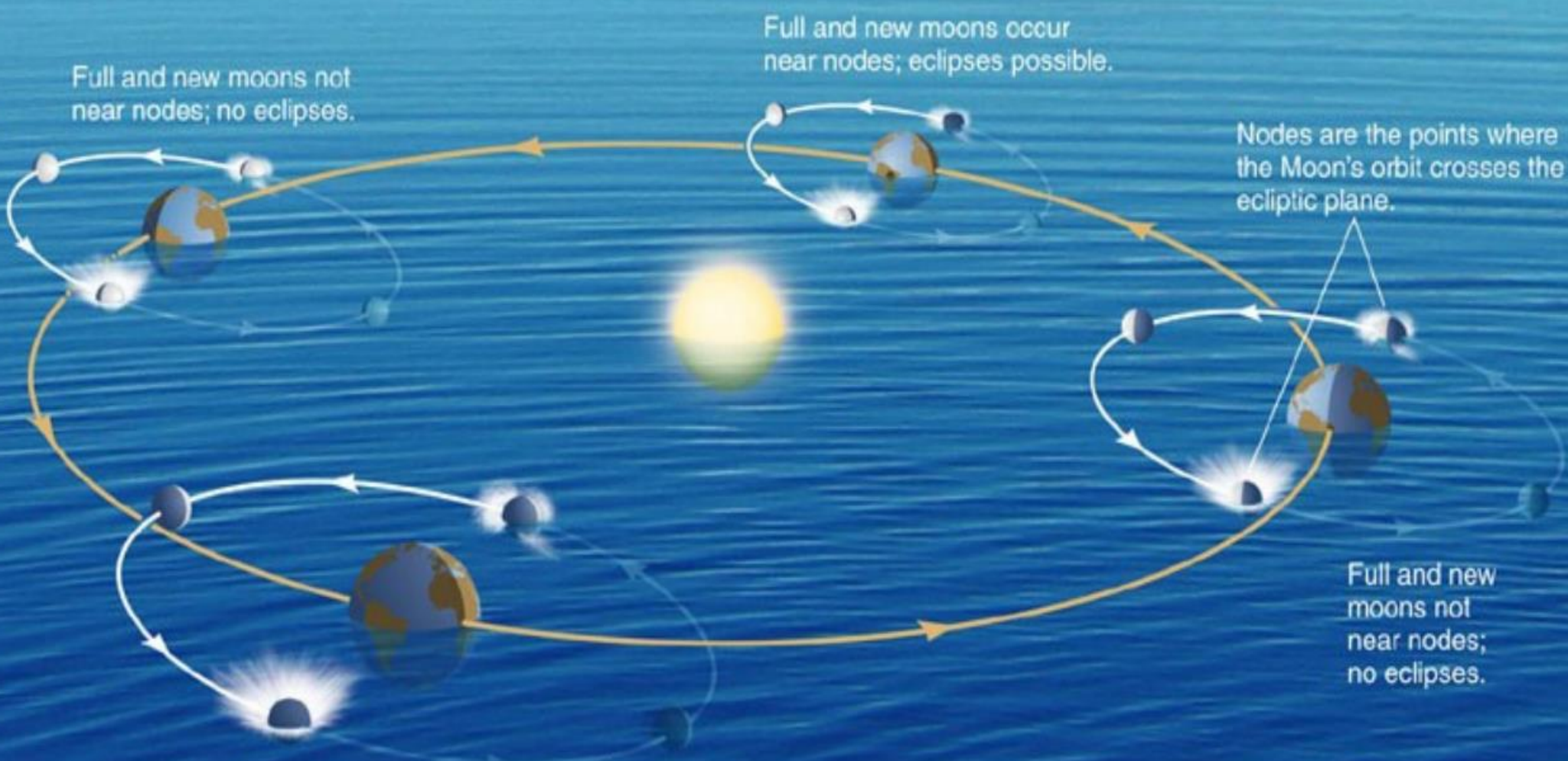
So...why don't we get an eclipse every month?

Simulation:  
[https://www.earthspacelab.com/app/eclipse/#google\\_vignette](https://www.earthspacelab.com/app/eclipse/#google_vignette)

The screenshot shows the 'Lunar Phase Simulator' interface. At the top, there are links for 'Reset', 'Help', and 'About'. The main display area is divided into several sections:

- Diagram:** A central diagram shows the Sun on the left, Earth in the center, and the Moon in its orbit on the right. Sunlight is represented by yellow arrows pointing towards Earth. The Moon is shown in a 'Waning Crescent' phase.
- Moon Phase:** A dropdown menu is set to 'Waning Crescent'. Below it is a circular image of the Moon showing a thin crescent. Text below the image indicates '31.9% illuminated' and 'Time since new moon: 23 days, 21 hours'. A 'Hide' button is present.
- Animation and Time Controls:** Includes a 'Pause Animation' button, an 'Animation rate' slider, and 'Increment animation' controls for Day, Hour, and Minute.
- Diagram Options:** Three checkboxes: 'Show angle', 'Show lunar landmark', and 'Show time tickmarks'.
- Horizon Diagram:** A circular diagram showing the Earth's horizon from an observer's perspective. The Sun is at the bottom, and the Moon is visible above the horizon. Text below indicates 'Observer's local time: 06:27 PM'. A 'Hide' button is present.





Full and new moons not near nodes; no eclipses.

Full and new moons occur near nodes; eclipses possible.

Nodes are the points where the Moon's orbit crosses the ecliptic plane.

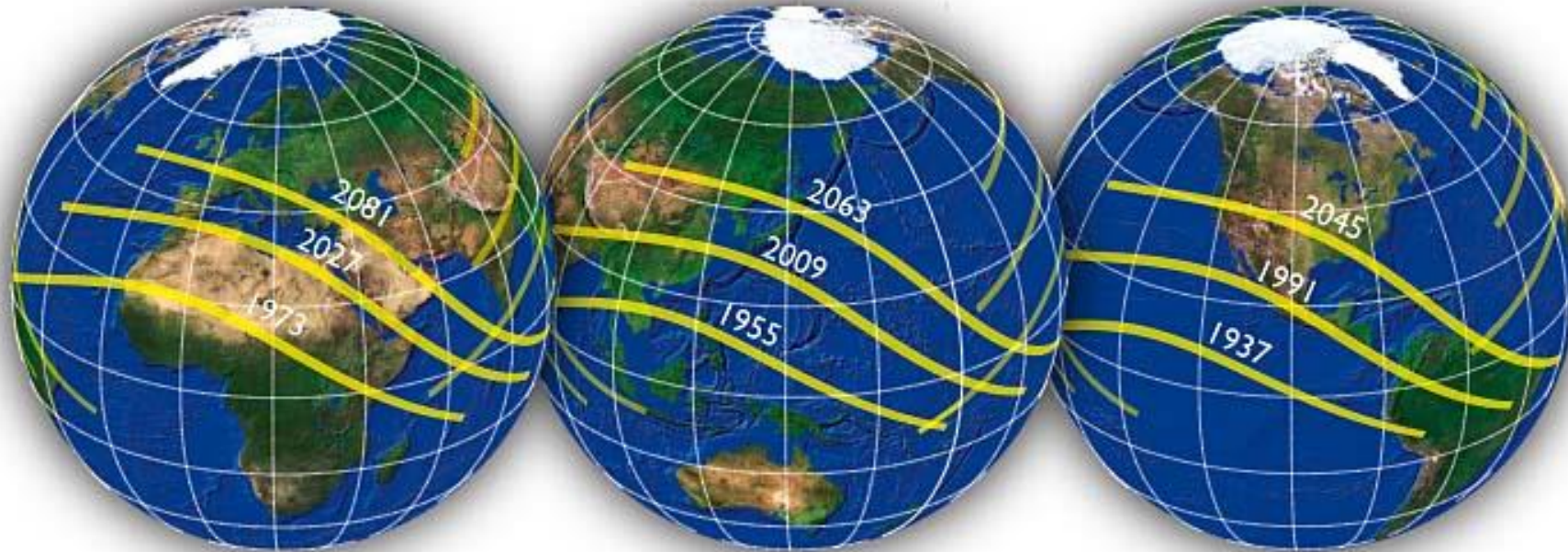
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The pond surface represents the ecliptic plane (the plane of Earth's orbit around the Sun).

# THE TIMING OF ECLIPSES

Saros 136



Each eclipse path shifts  $\sim 120^\circ$  west of the previous one.

Orthographic projection centered  
at  $26^\circ$  North,  $22^\circ$  East

Orthographic projection centered  
at  $26^\circ$  North,  $142^\circ$  East

Orthographic projection centered  
at  $26^\circ$  North,  $98^\circ$  West

Map illustration by Michael Zeiler

Eclipse predictions by Fred Espenak, NASA, Goddard Space Flight Center

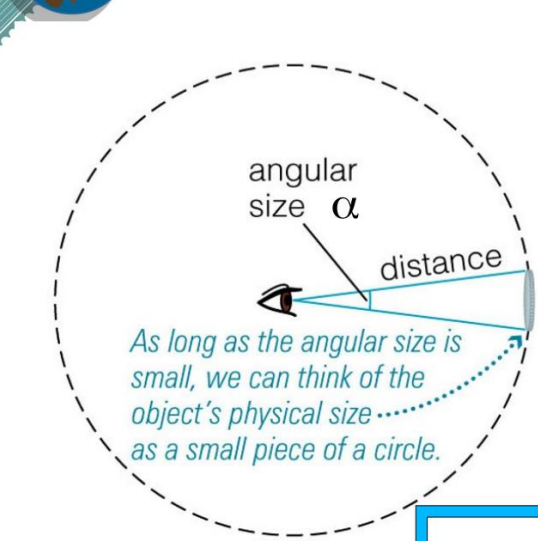
Paths of totality from eclipse calculator by Xavier Jubier

# THE TIMING OF ECLIPSES

- Eclipses can only occur at the 'nodes' between the Moon's plane of revolution and the Earth's plane of revolution, approximately once every six months.
- Every six months is an 'eclipse season' where there is usually one lunar and one solar eclipse.
- Eclipses until 2050 <https://www.astrologyzone.com/eclipse-dates/>
- Problem: Because of the interaction between Earth's elliptical orbit, the Saros cycle, and other factors, total solar eclipses are very rare!!!!

# WHY SOLAR ECLIPSES ARE SPECIAL

- Solar eclipses require the Moon and Sun to appear roughly the same size as viewed from Earth...
- Let's try some trigonometry:
  - Sun is 150,000,000 km away.
  - Sun is 1,392,700 km diameter.
  - Moon is 384,000 km away.
  - Moon is 3,475 km diameter.
  - What is the angular size of the Moon and Sun?



In radians:

$$\alpha/2\pi = s/2\pi d$$

so :

$$\alpha = s/d$$

In degrees:

$$\alpha^\circ/360^\circ = s/2\pi d$$

so :

$$\text{angular size} = \text{physical size} \times \frac{360 \text{ degrees}}{2\pi \times \text{distance}}$$

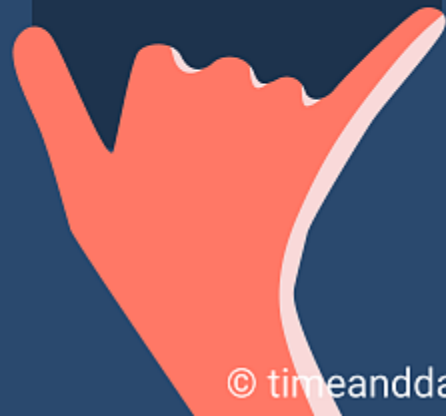
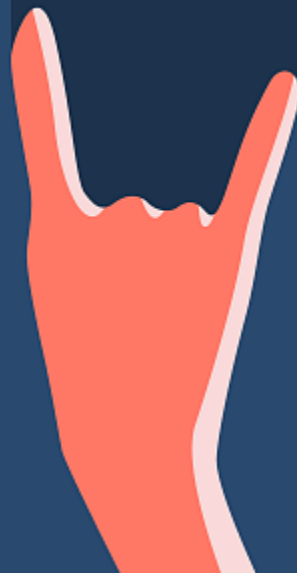
1°

5°

10°

15°

25°



# WHY SOLAR ECLIPSES ARE SPECIAL

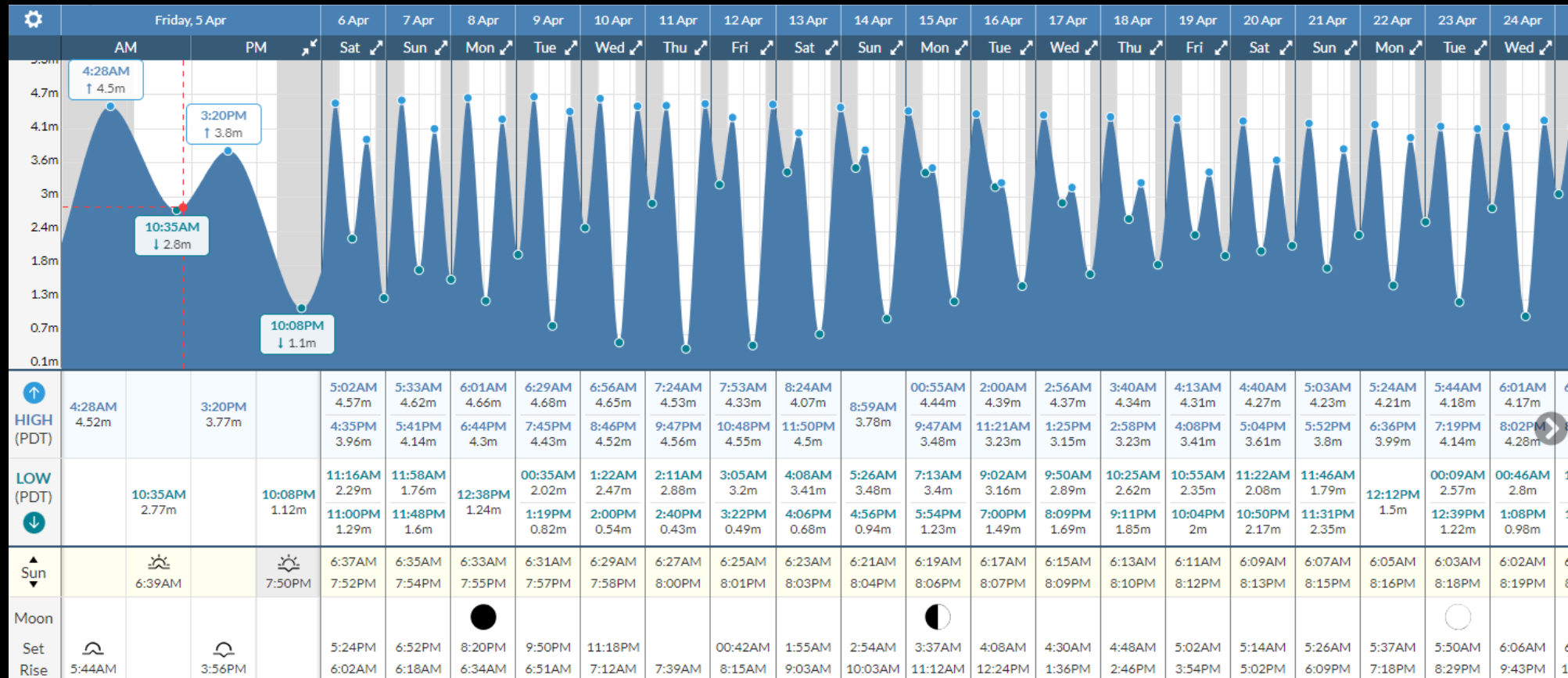
- Solar eclipses require the Moon and Sun to appear roughly the same size as viewed from Earth...
- The Moon and Sun both have an angular size of approximately 0.5 degrees.
- But the Moon is slowly spiralling away from Earth (because of physics reasons); eventually, the Moon will appear too small to completely block the Sun.
- More reading: <https://eos.org/features/the-end-of-the-eclipse>



# TIDES

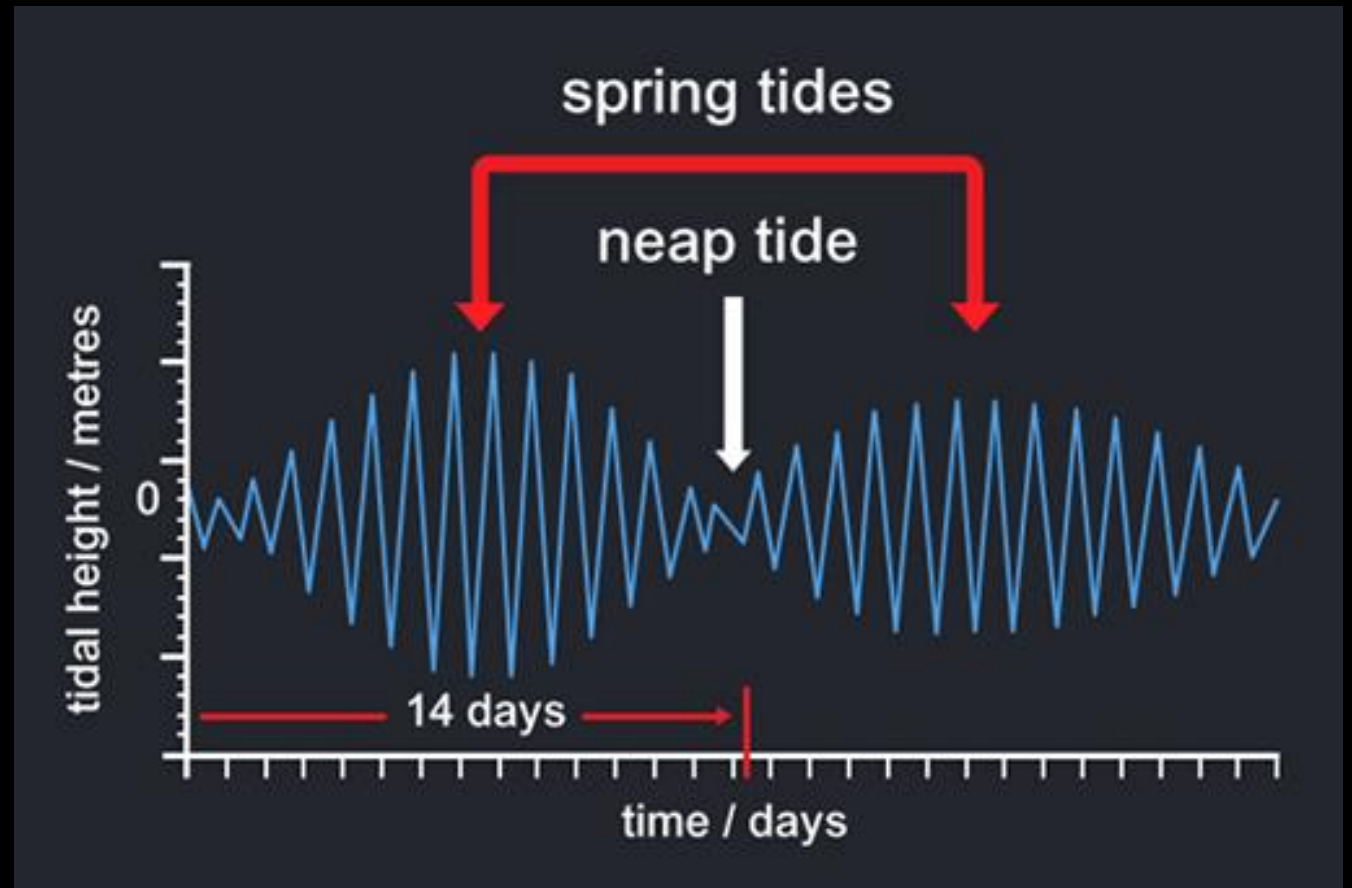
Discuss: What are tides? Why do they occur?

<https://www.tide-forecast.com/locations/Vancouver-British-Columbia/tides/latest>



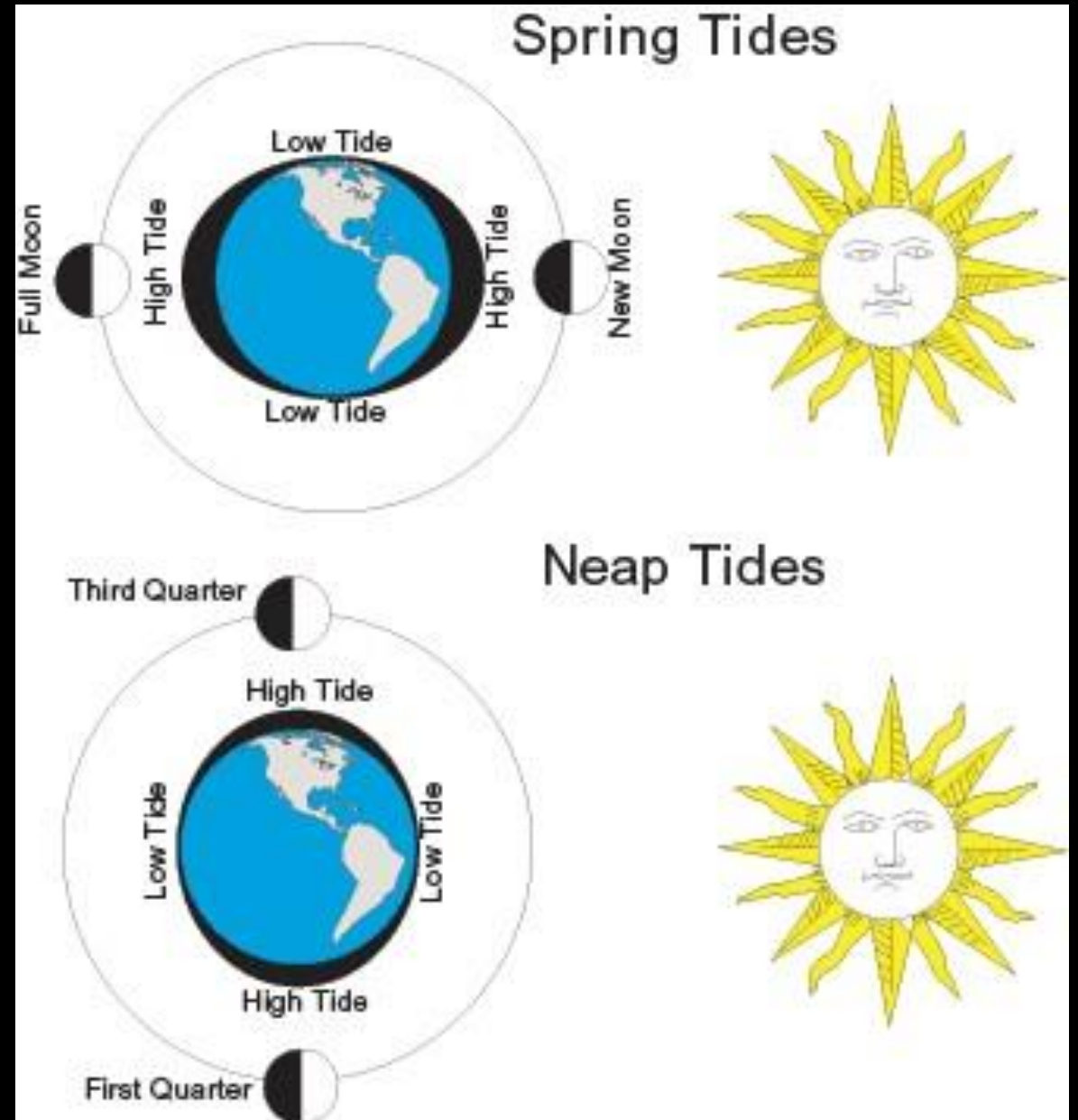
# TIDES

- The Earth, Moon, and Sun all pull on each other with gravitational force. This results in tides.
- **Tide**: the rising and falling of water levels (usually twice a day)
- **Spring** tides: very dramatic; when the gravity of the Moon and Sun pull in the same direction
- **Neap** tides: weak; when the Moon and Sun pull in different directions



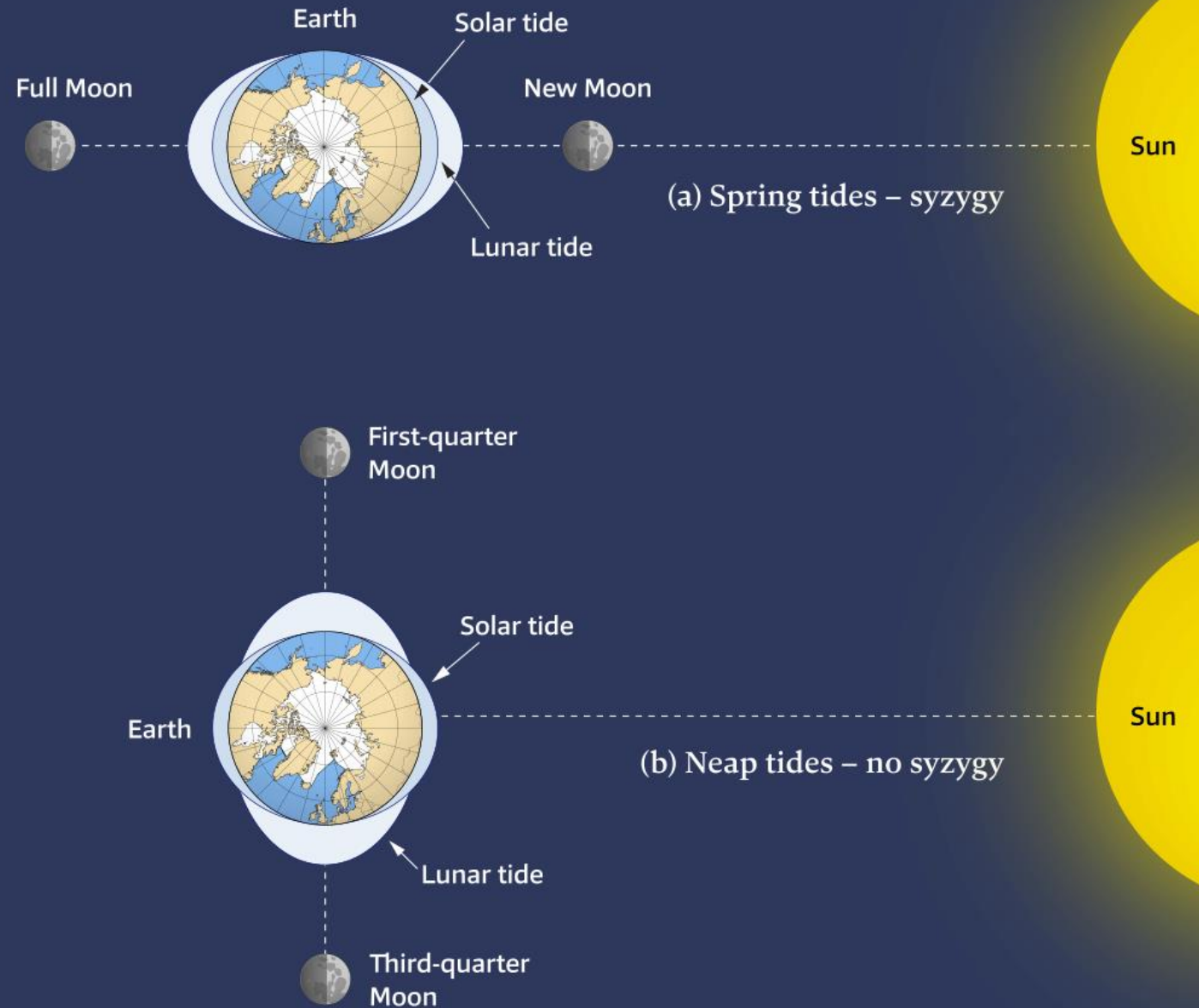
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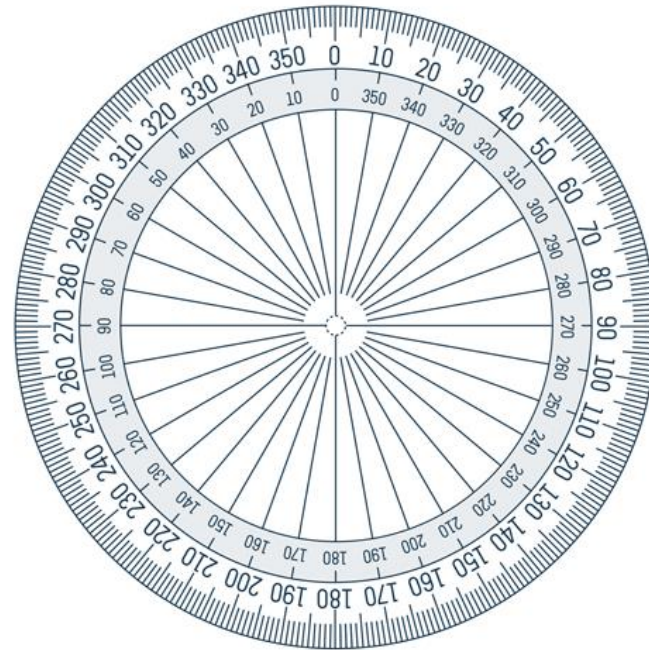
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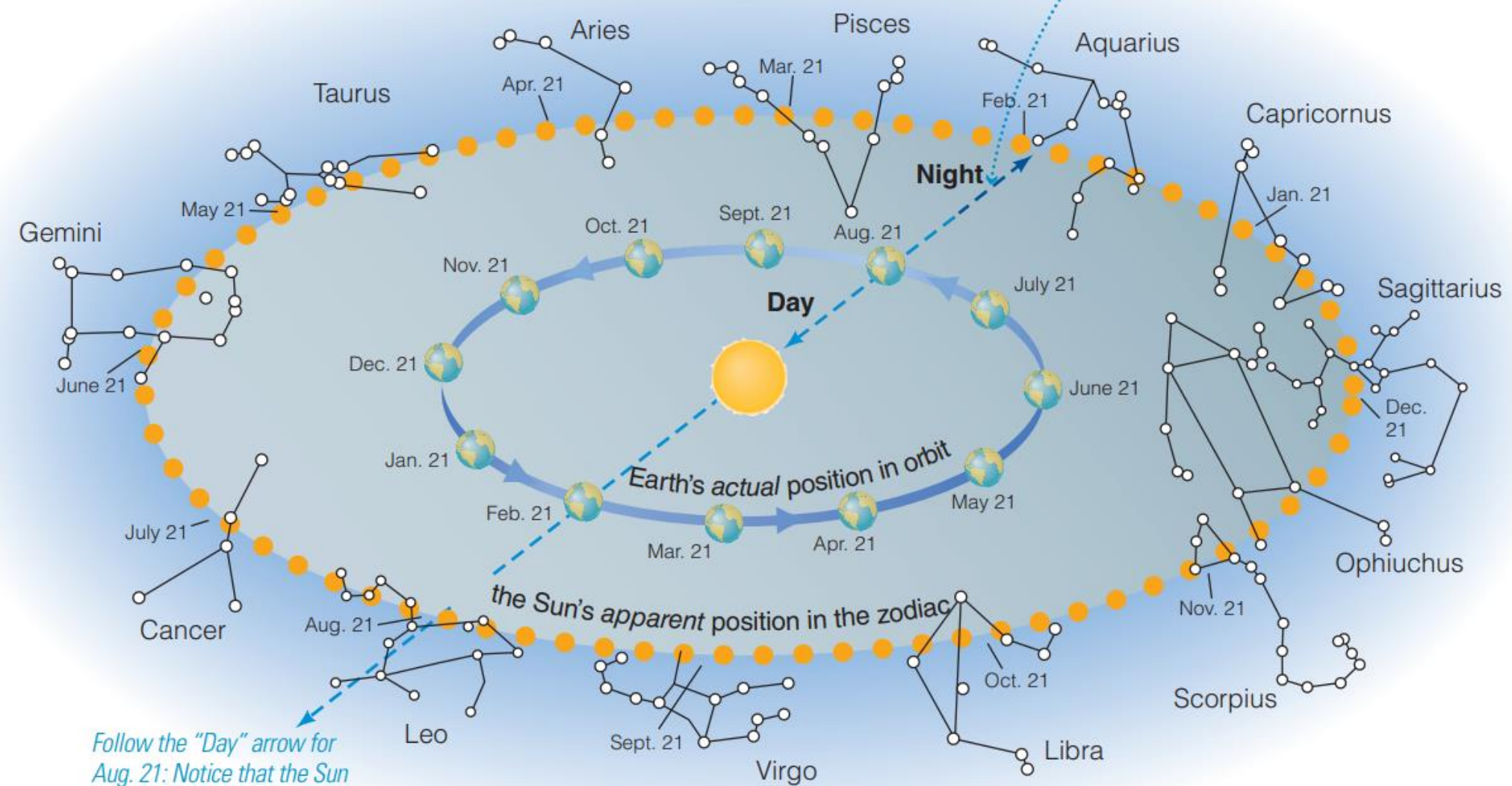
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Follow the "Night" arrow for Aug. 21; Notice that Aquarius is opposite the Sun in the sky, and hence visible all night long.



Follow the "Day" arrow for Aug. 21; Notice that the Sun appears to be in Leo.