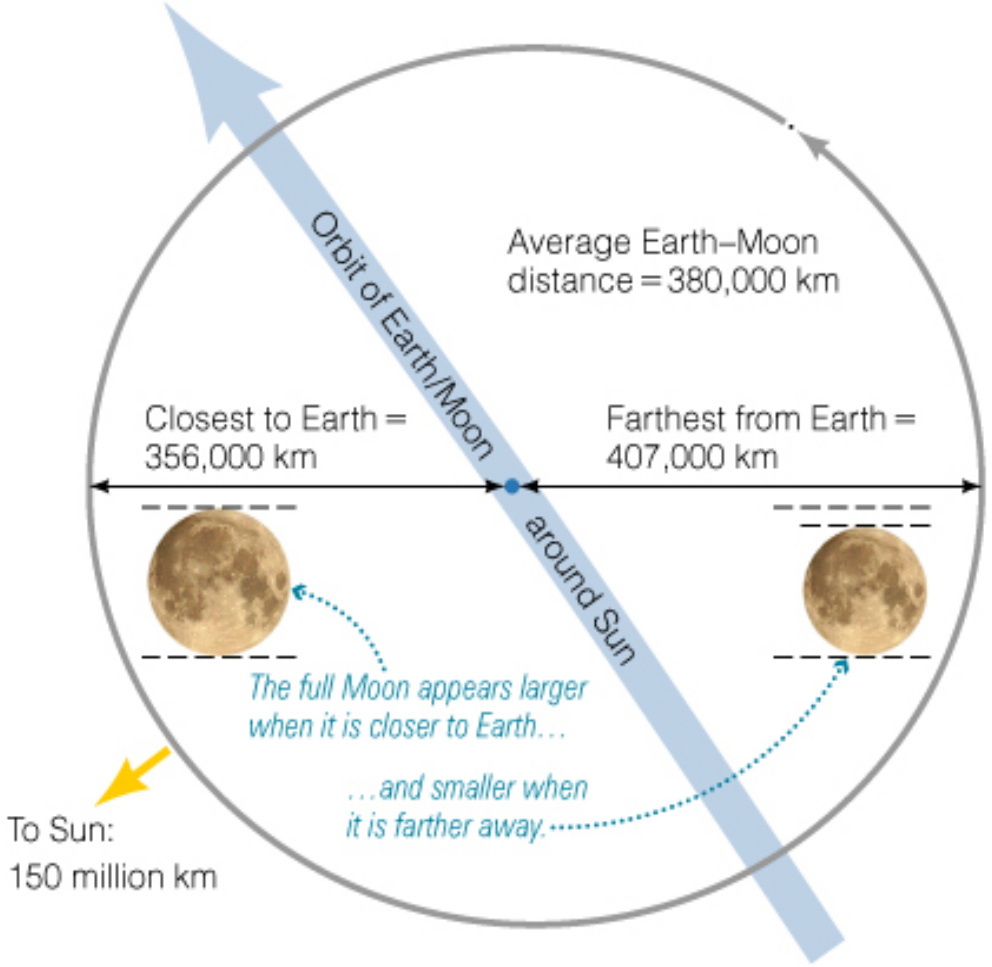
Lecture 3 –
Cycles of Moon & Time

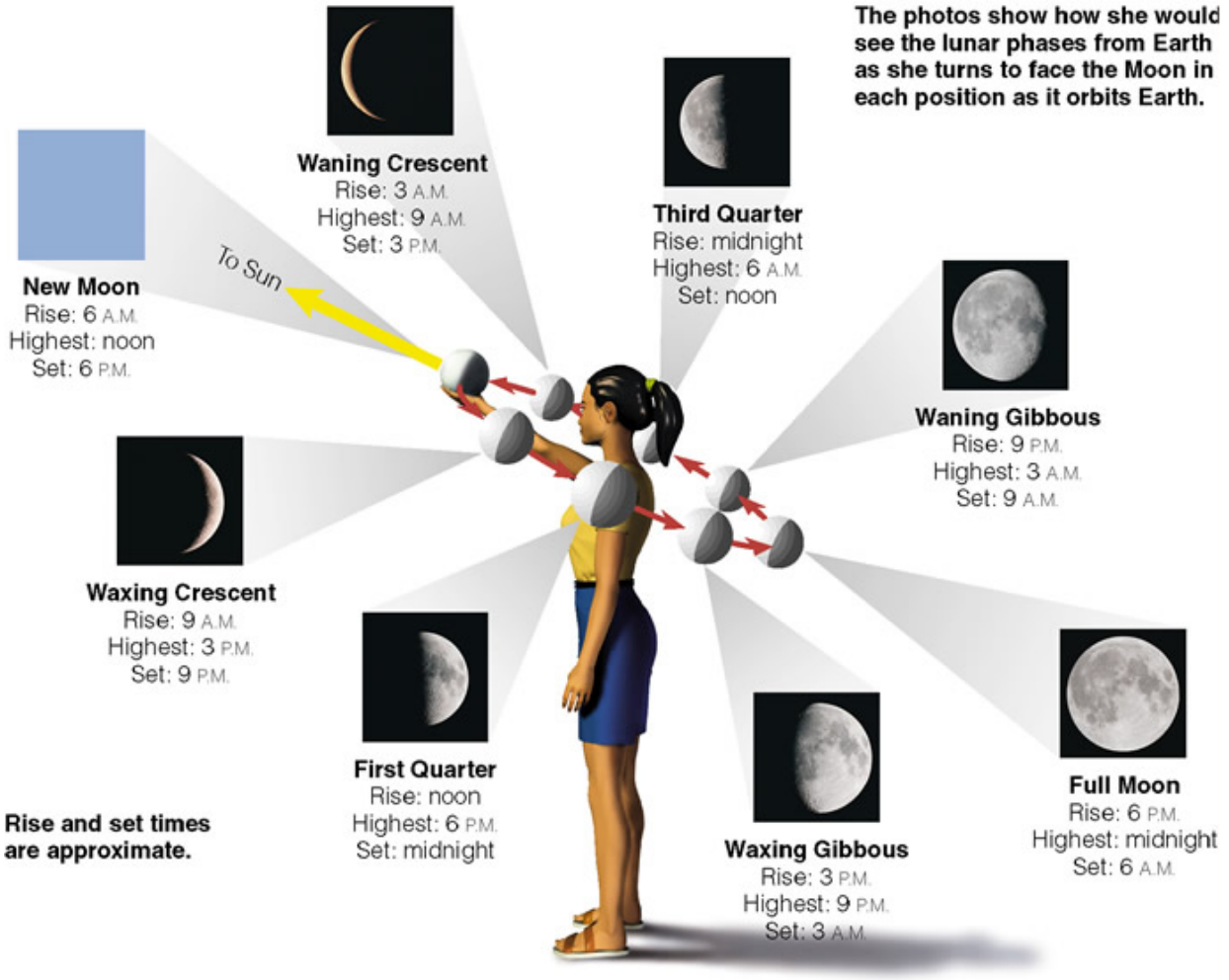
Why do we see phases of the Moon?



- Lunar phases are caused by the Moon's 27.3-day orbit around Earth.
- The cycle of *phases* takes 29.5 days.

Phases of Moon

- Half of the Moon is illuminated by the Sun and half is dark.
- We see a changing combination of the bright and dark faces as the Moon orbits Earth.



Phases of the Moon: 29.5-day cycle


new


crescent


first quarter


gibbous


full


gibbous


last quarter


crescent

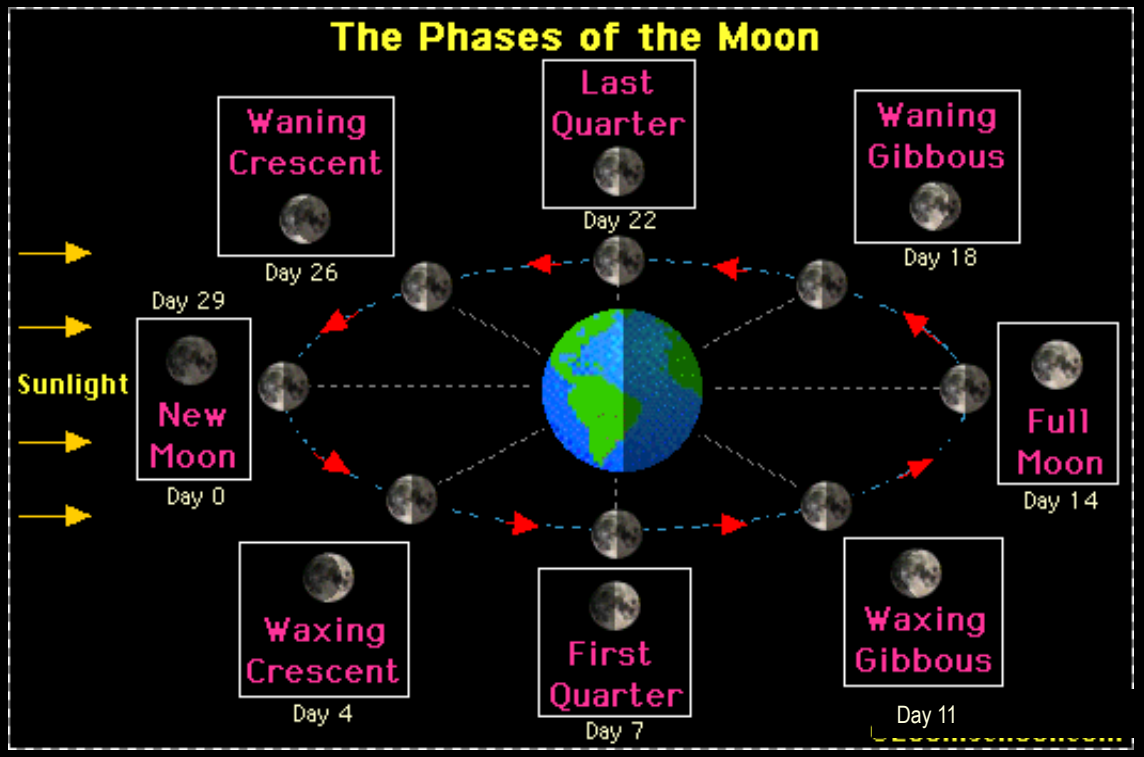
Waxing phases

- Moon visible in afternoon/evening
- Gets “fuller” and rises later each day

Waning phases

- Moon visible in late night/morning
- Gets “less full” and sets later each day

Phases of the Moon: 29.5-day cycle



- At **new moon** we see only the dark side
- At **first quarter**, we see one-half of the moon illuminated.
- At **full moon** we see the entire moon illuminated
- At **last quarter**, we see the *other* half of the moon illuminated than we saw at first quarter.
- In-between phases are called **crescent** and **gibbous.**
- Can you identify these phases at right?

Think/Pair/Share

It's 9 A.M. You look up in the sky and see a moon with half its face bright and half dark.
What phase is it?

A. First quarter
B. Waxing crescent
C. Half Moon
D. Waning gibbous
E. Third quarter

Think/Pair/Share

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What phase is it?

A. First quarter
B. Waxing crescent
C. Half Moon
D. Waning Gibbous
E. Third Quarter

Synchronous rotation

The Moon rotates exactly once with each orbit around the earth.

- All parts of the moon receive sunlight
- *Only one side is ever visible from Earth*.
- We watch the sunlight slowly move across this side.

What have we learned?

Begin 3 minute review

What have we learned?

Why do we see phases of the Moon?

Moon phases are caused by the moon's orbit around Earth.

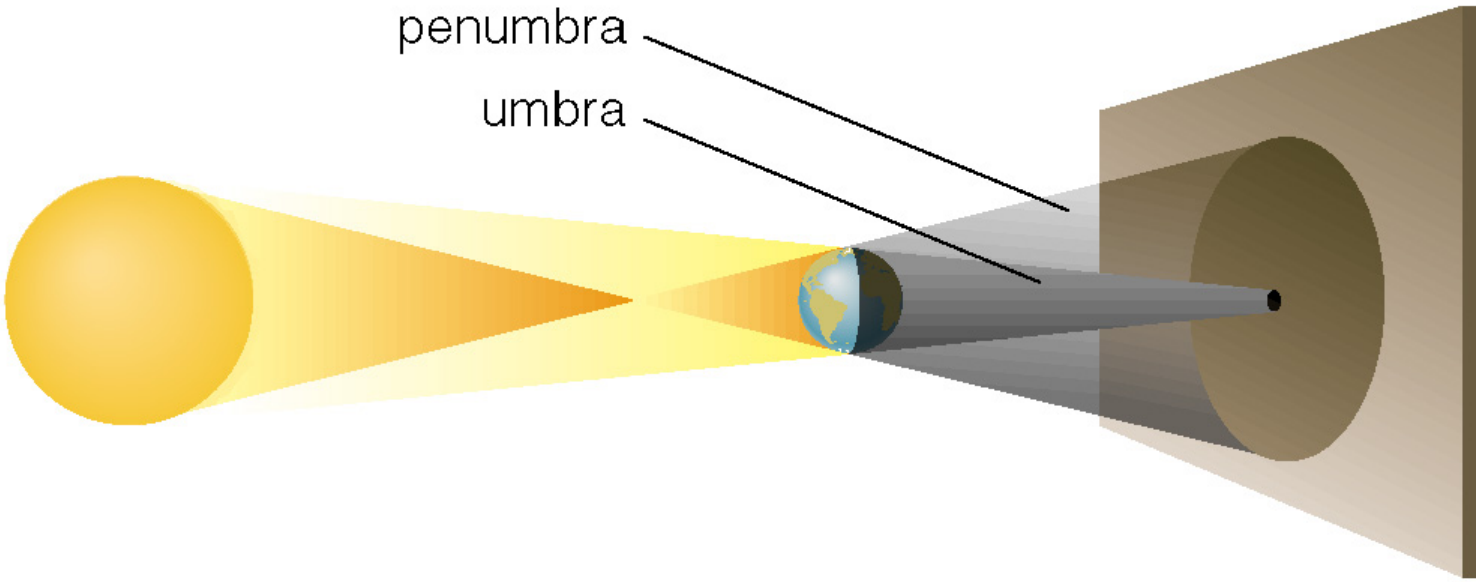
Half of the Moon is always lit by the Sun; half is in shadow, and its appearance to us is determined by the relative positions of Sun, Moon, and Earth.

The moon progresses thru the waxing and waning phases:

- Crescent, first quarter, gibbous
- Full moon
- Gibbous, third quarter, crescent

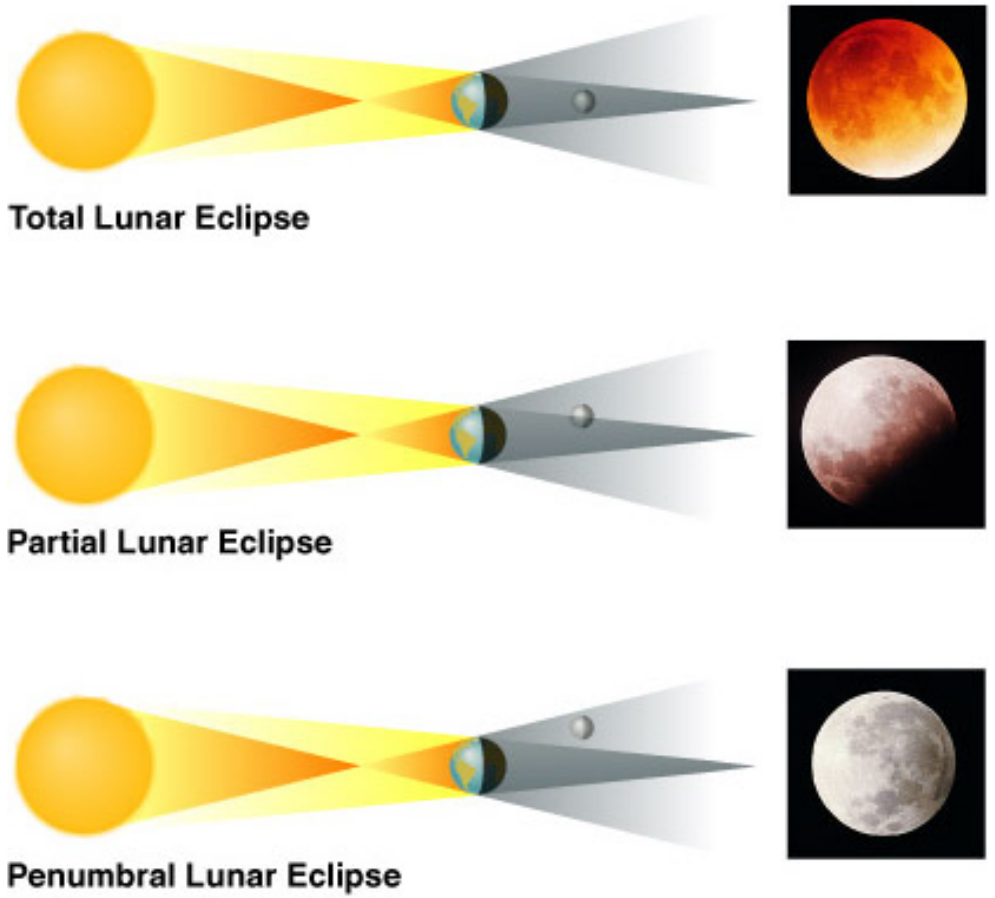
What causes eclipses?

- The Earth and Moon cast shadows.
- *When either passes through the other's shadow*, we have an **eclipse**.
- During a **lunar** eclipse, the moon passes into Earth's shadow.
- Earth's shadow has two parts:

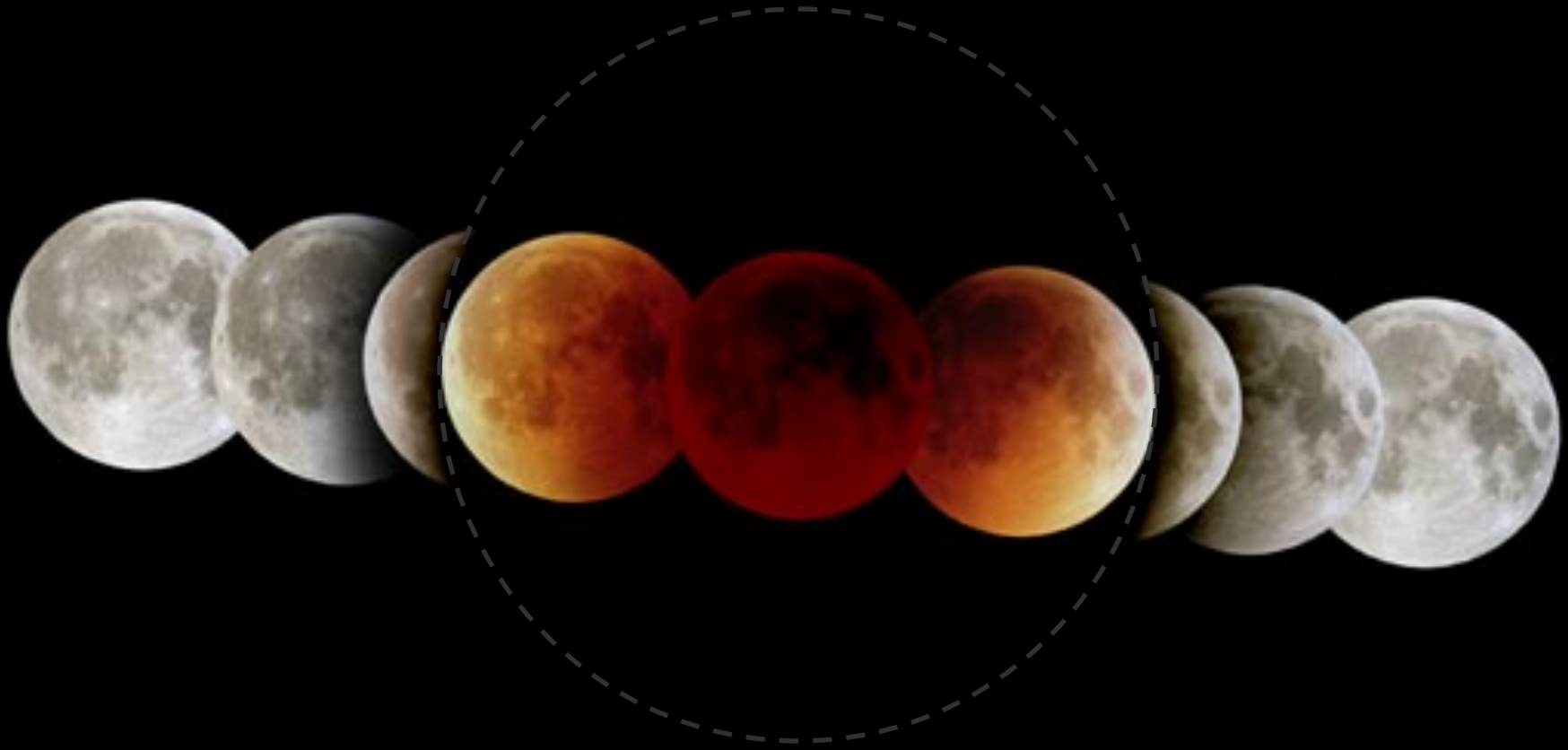


Lunar eclipses

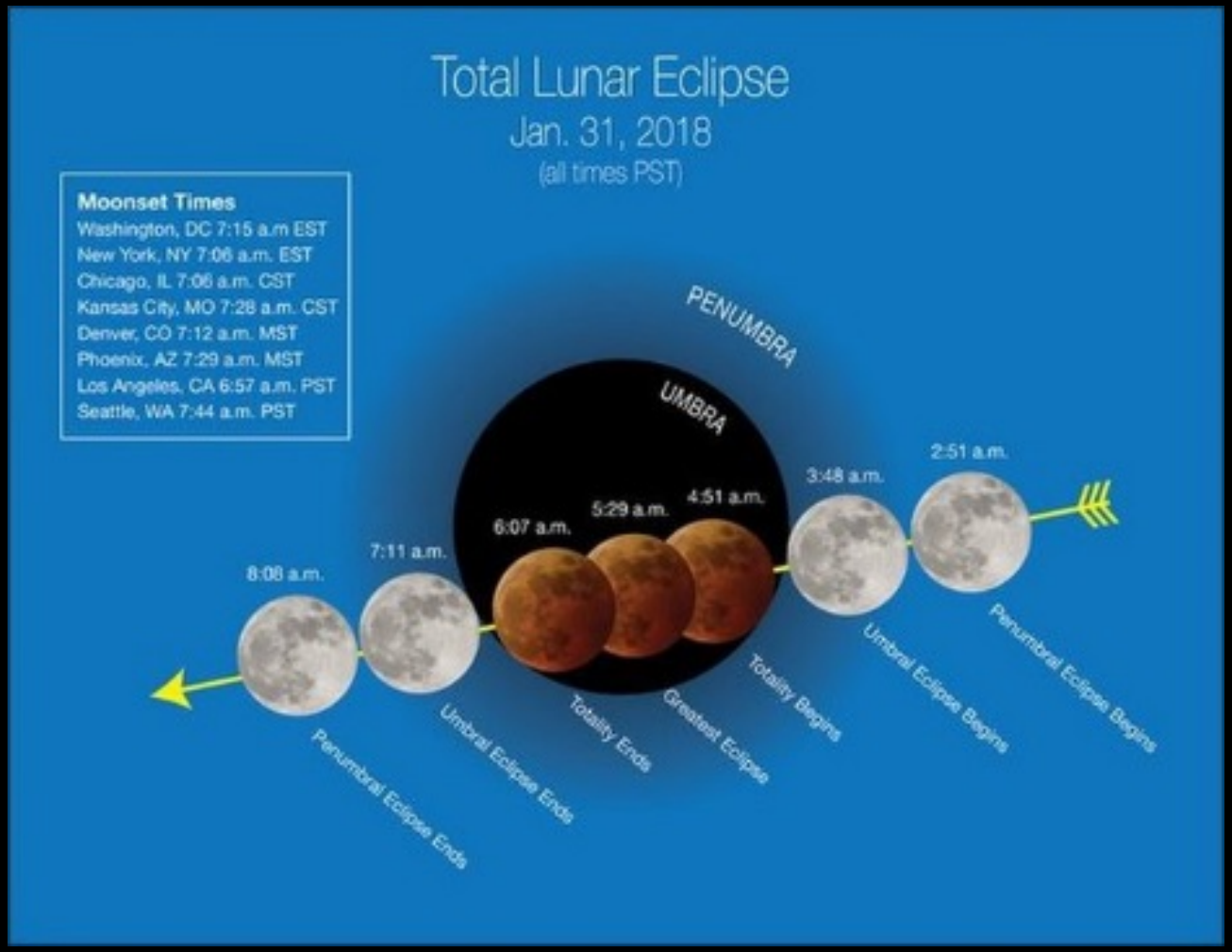
- **Lunar eclipses** can occur only at *full moon*.
- Lunar eclipses can be **penumbral**, **partial**, or **total**.



Earth's shadow

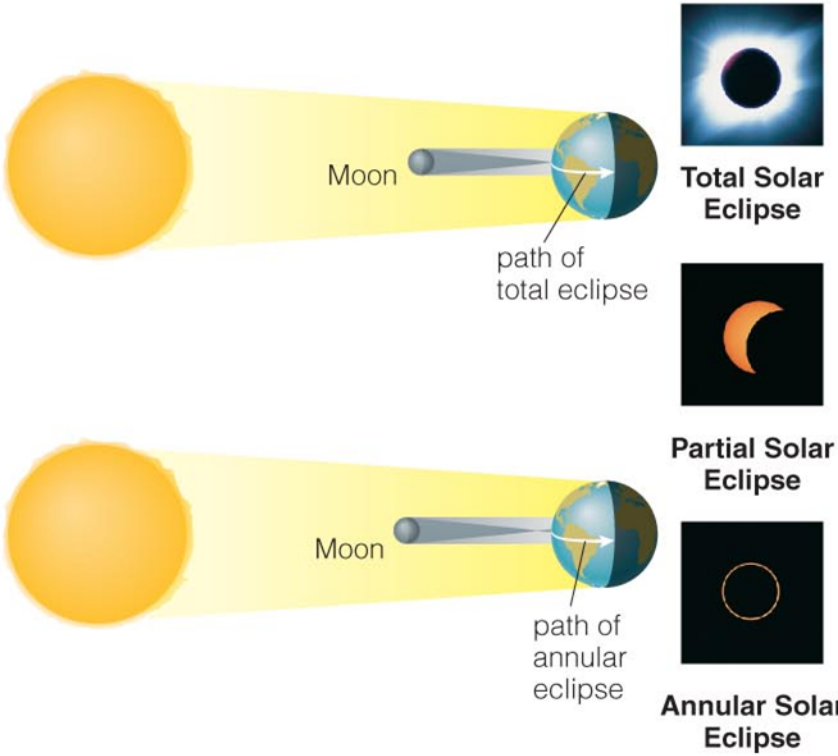


Jan 2018 lunar eclipse



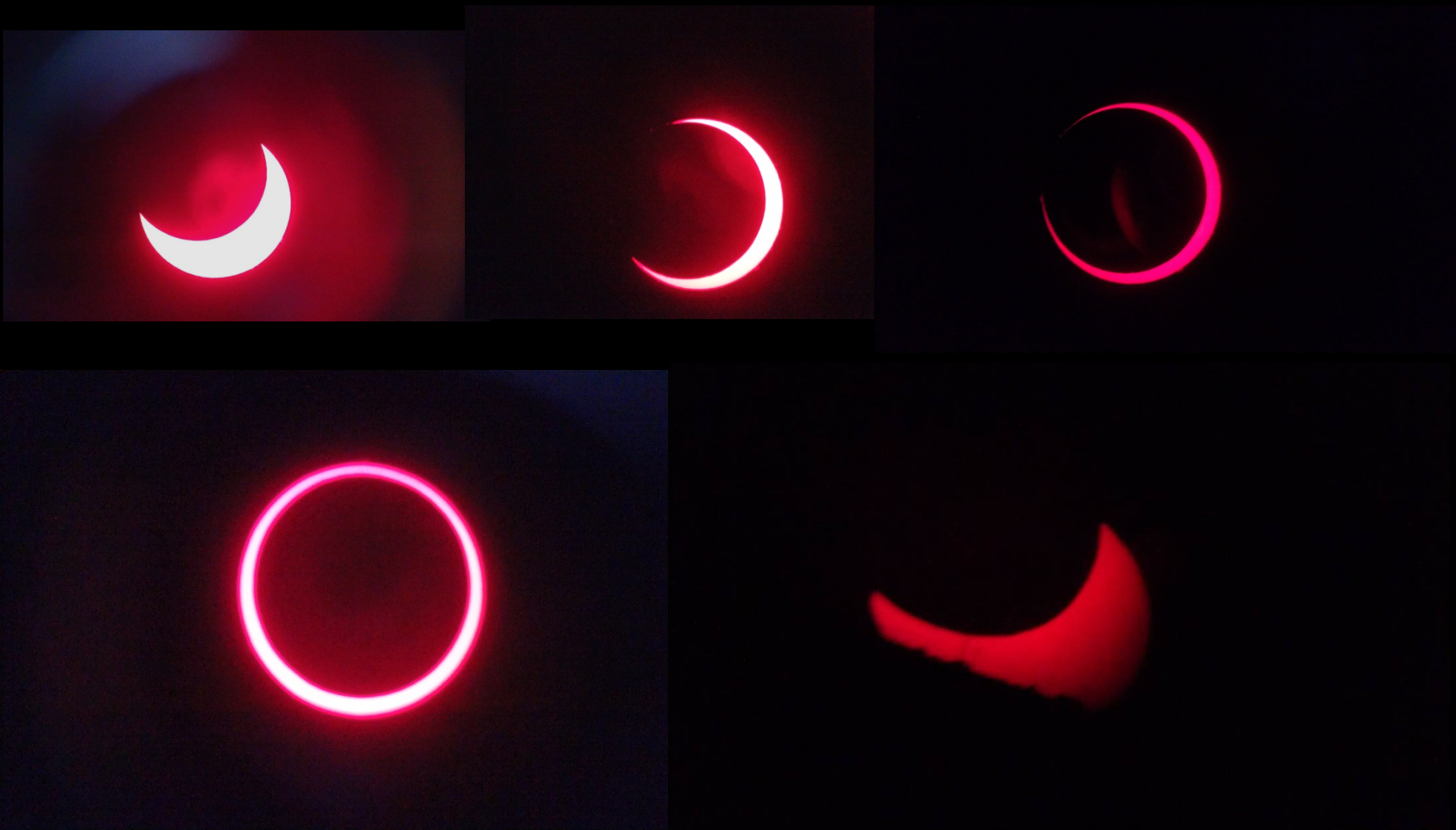
Solar eclipses

The moon's shadow falls on the Earth



- **Solar eclipses** can occur only at *new moon*.
- Solar eclipses can be **partial**, **total,** or **annular**.

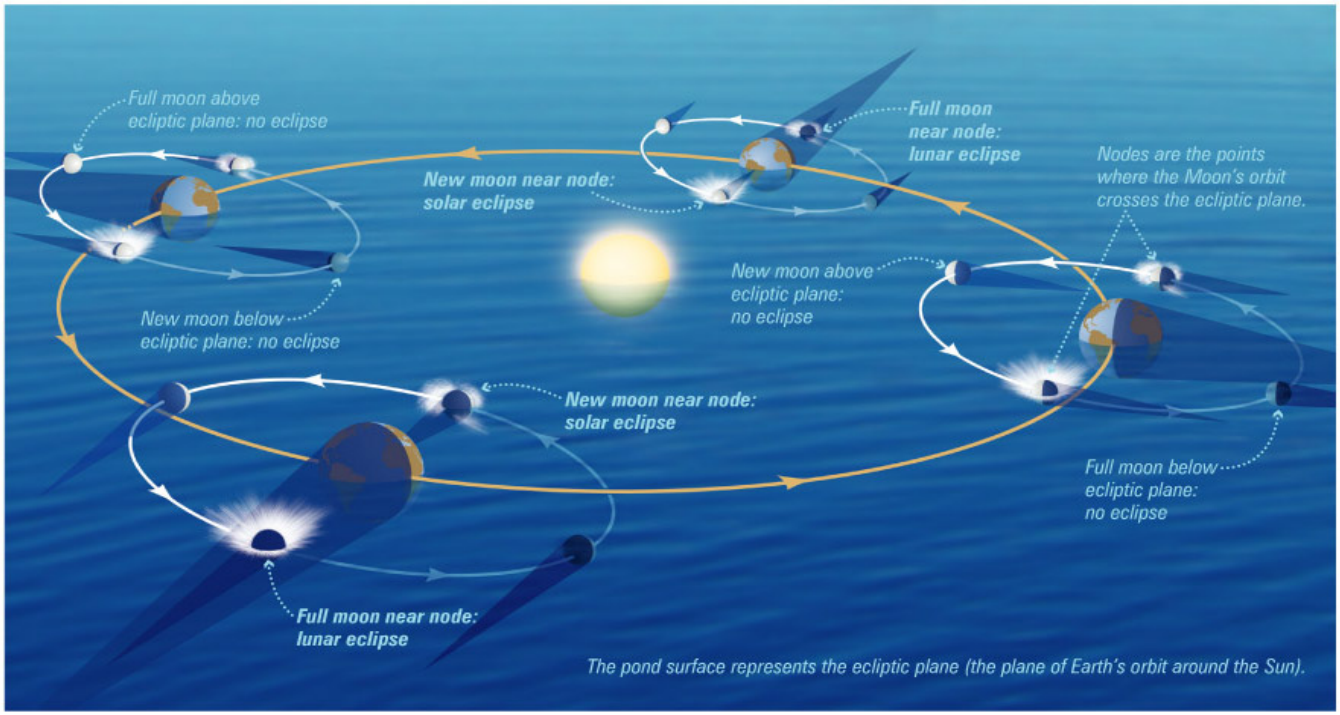
Annular eclipse May 2012



Total solar eclipse

Why don't we have an eclipse at every new and full moon?

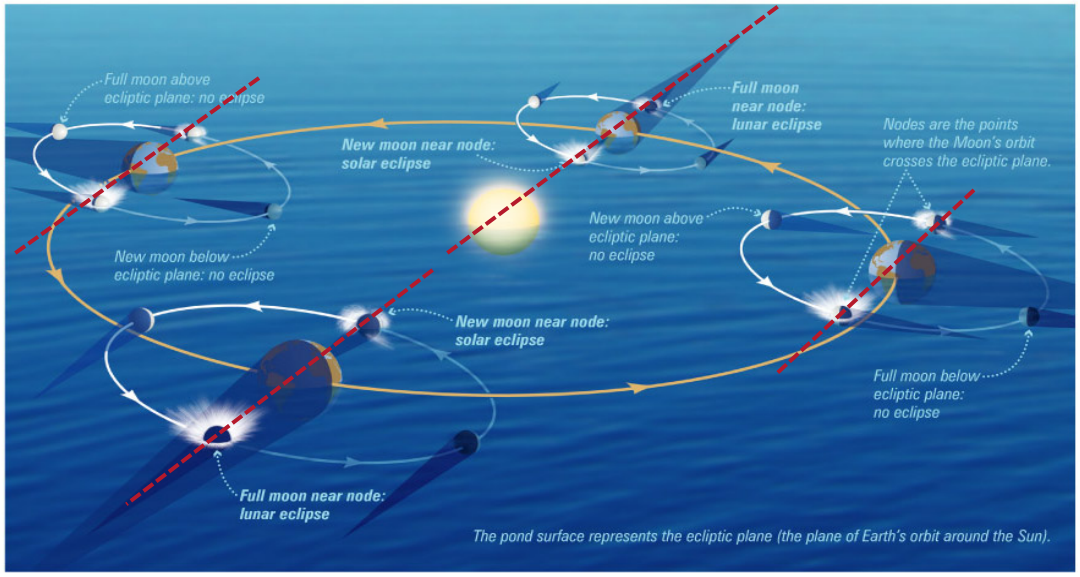
- The Moon's orbit is tilted 5° to ecliptic plane – *usually the moon passes above or below the ecliptic at new or full moon*.
- We have about two **eclipse seasons** each year, with a lunar eclipse at full moon and solar eclipse at new moon.

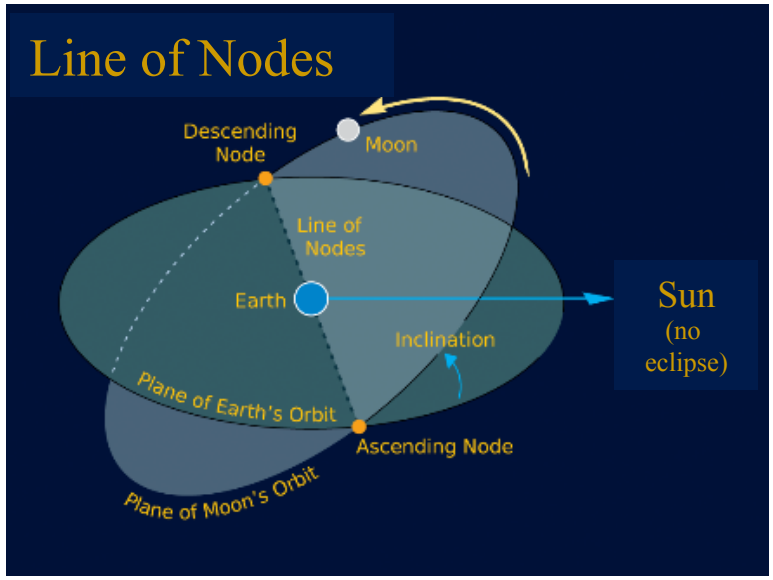


Two conditions for an eclipse:

1. It must be full moon (lunar eclipse) or new moon (solar eclipse) AND
3. The Moon must be near one of the two points in its orbit where it crosses Earth's orbit. *These **nodes** are the intersection of the moon's orbit with the Earth's orbit (ecliptic).*

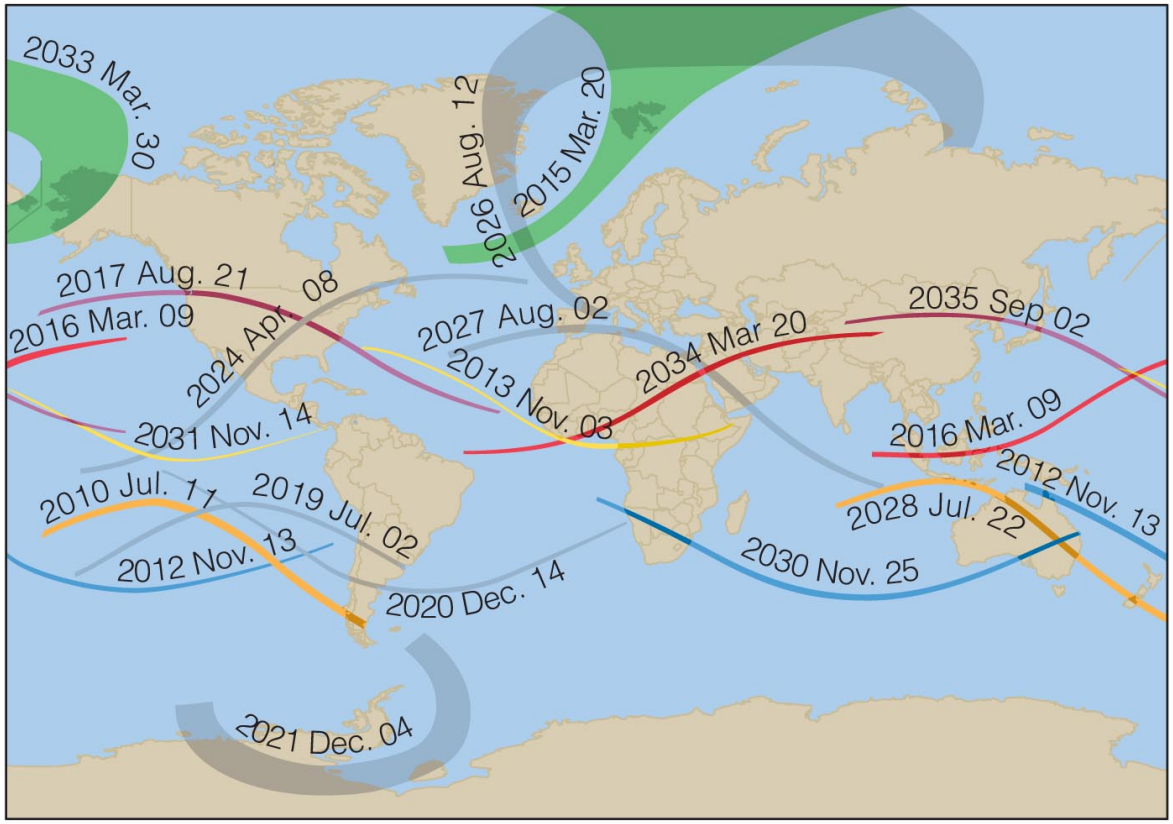
*4. This line of **nodes** is also aligned with the Sun.*

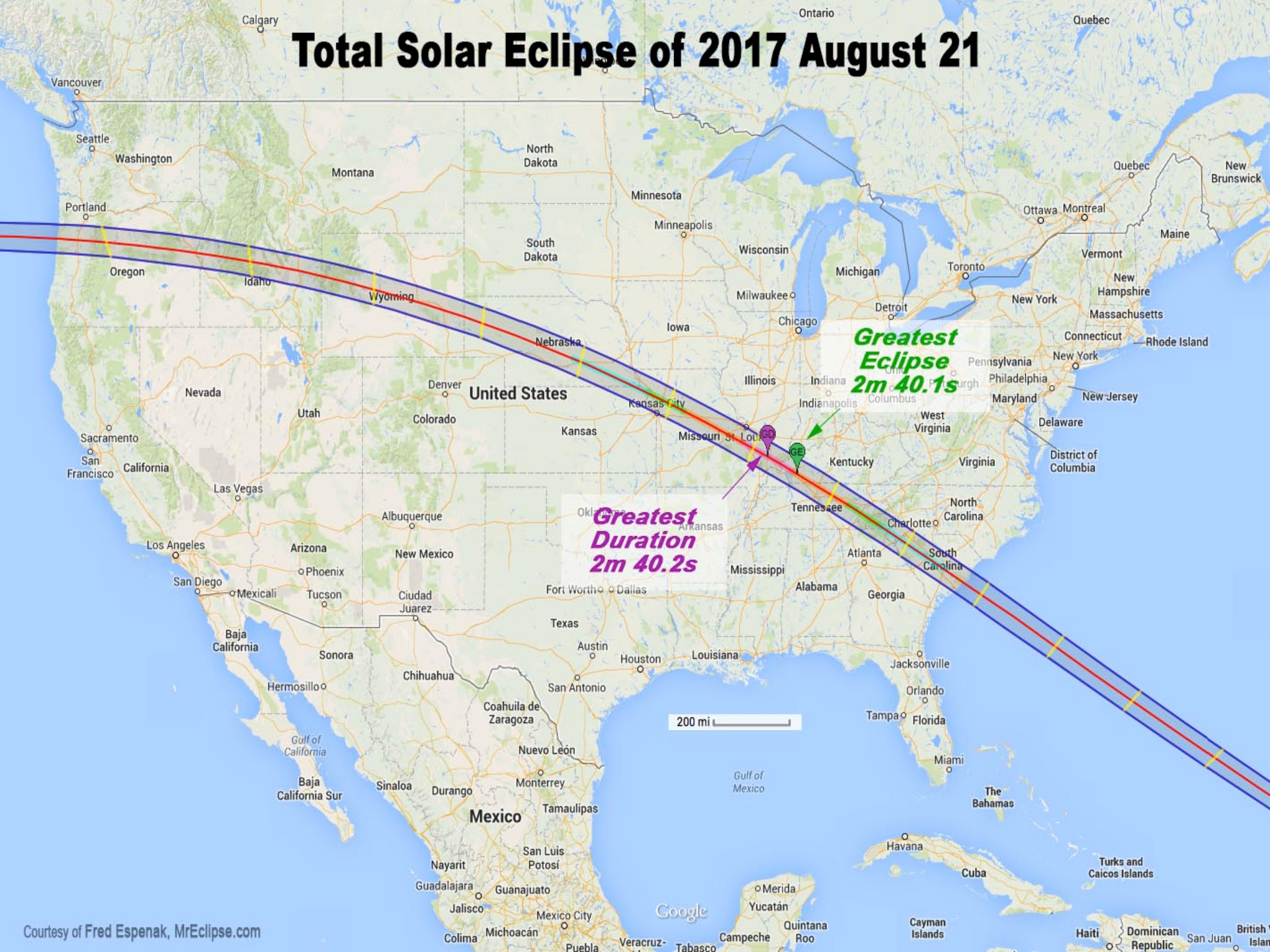




Predicting Eclipses

- Eclipses recur with a **saros cycle (**18 years,11 days, 8 hours) but type (e.g., partial, total) and location may vary.




Total Solar Eclipse of 2017 August 21
Greatest Eclipse 2m 40.1s
Greatest Duration 2m 40.2s
200 mi
Courtesy of Fred Espenak, MrEclipse.com

What have we learned?

Begin 3 minute review

What have we learned?

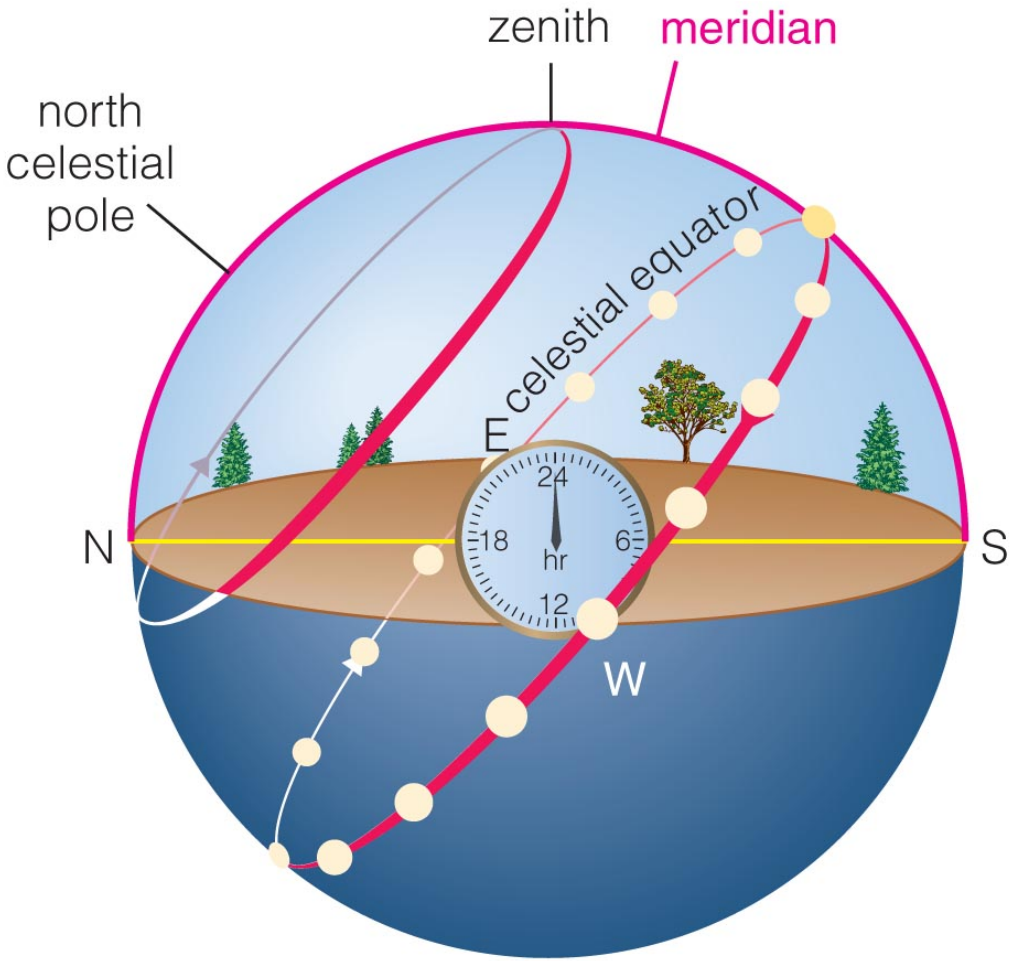
What causes eclipses?

Lunar eclipse: Earth's shadow on the Moon; partial or total

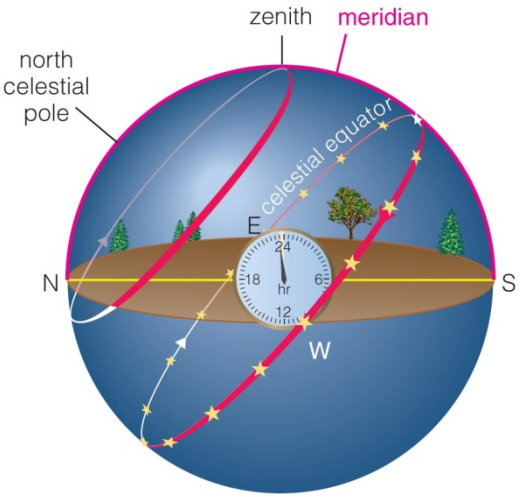
Solar eclipse: Moon's shadow on Earth; partial or total

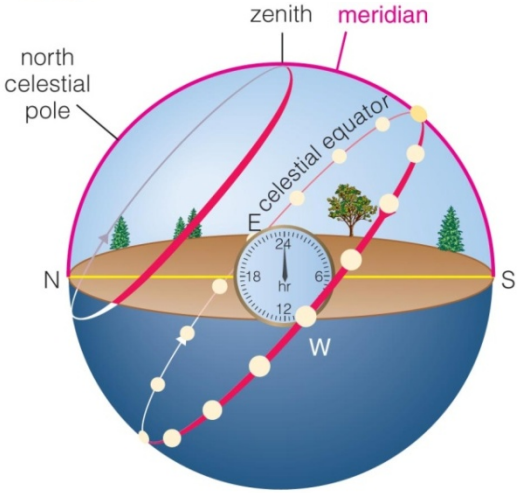
Tilt of Moon's orbit means eclipses occur during two periods each year.

How do we define the day, month, and year?



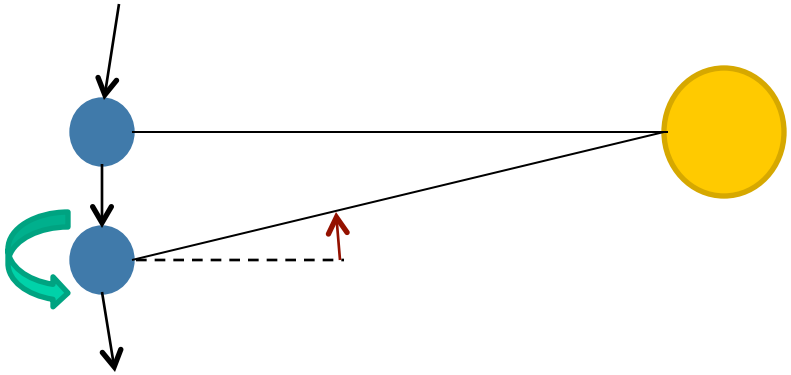
How we define the length of a day





- **Sidereal day:** Earth rotates 360 degrees on its axis in 23 hours, 56 minutes, and 4.07 seconds.

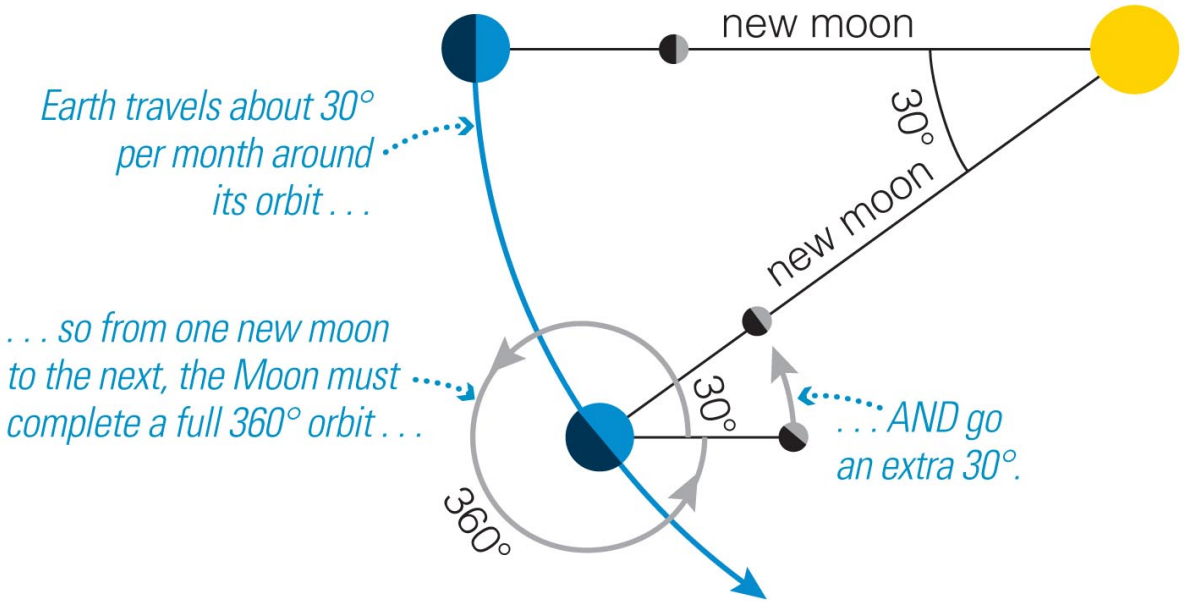
- **Solar day:** The Sun moves 360 degrees around the sky in 24 hours.



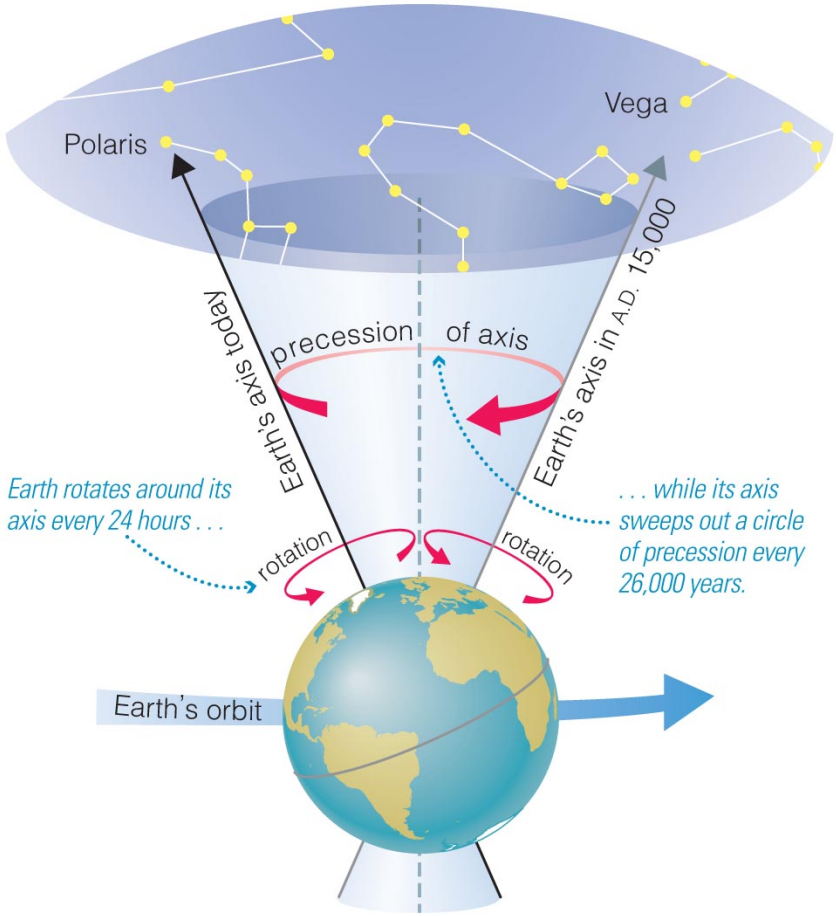
- A solar day is 4 minutes longer than a sidereal day because Earth moves 1° in orbit each day and *must rotate another 4 minutes* to line up with Sun.

How we define the length of a month

- **Sidereal month:**
  - Moon orbits Earth in 27.3 days.
  - Earth and Moon travel 30° around Sun during that time (30°/360° = 1/12).
- **Synodic month:**
  - A cycle of lunar phases takes about 29.5 days, because moon must travel another 30 degrees to line up with Sun



How we define the length of a year

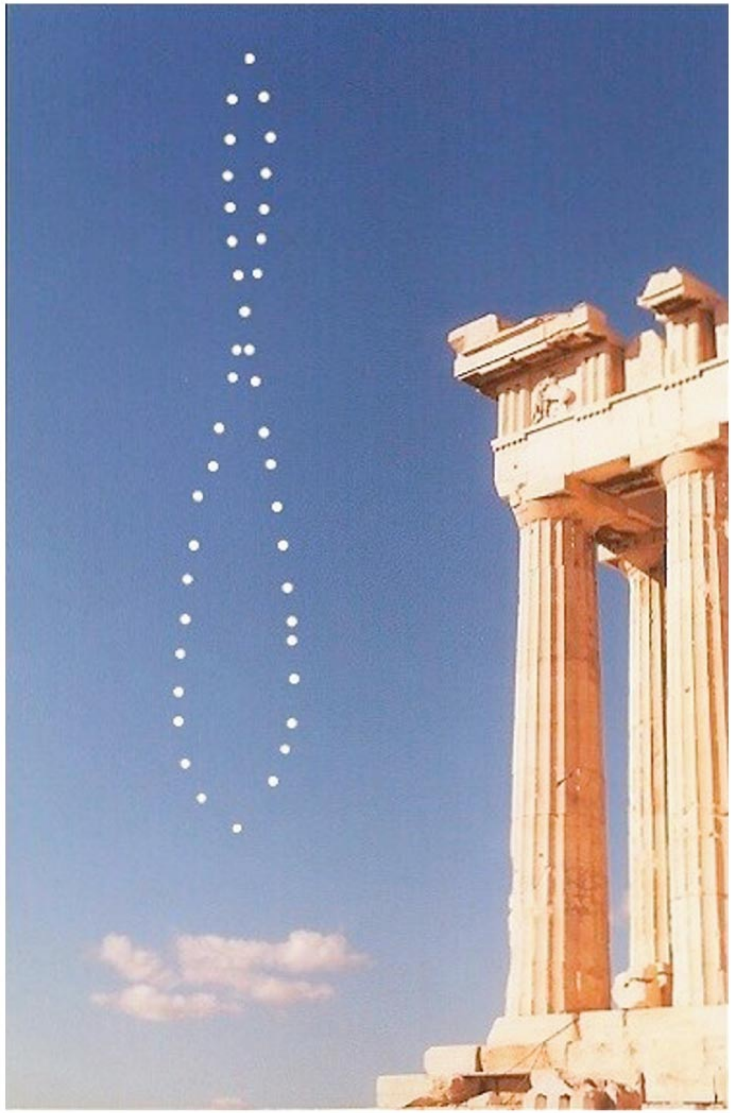


- **Sidereal year:** Time for Earth to complete one orbit of Sun
- **Tropical year:** Time for Earth to complete one cycle of seasons. Tropical year is about 20 minutes (1/26,000) shorter than a sidereal year because of precession.

How do we tell the time of day?

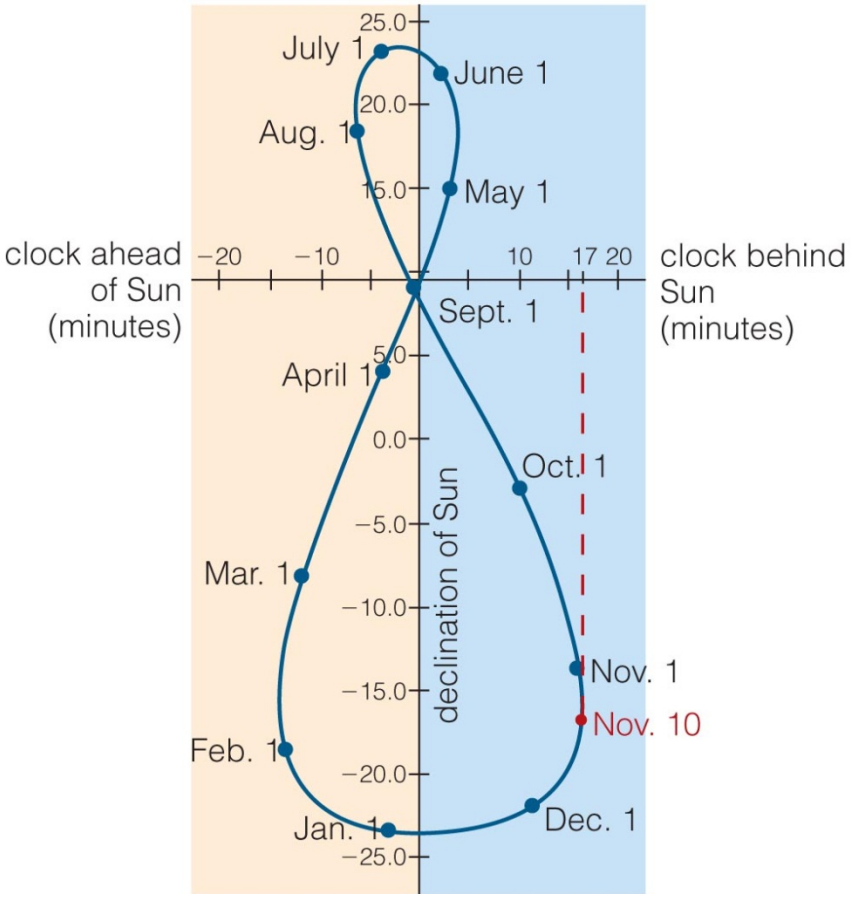
- **Apparent solar time** depends on the position of the Sun in the local sky.
- A sundial gives *apparent* solar time.
- But the length of an apparent solar day varies!

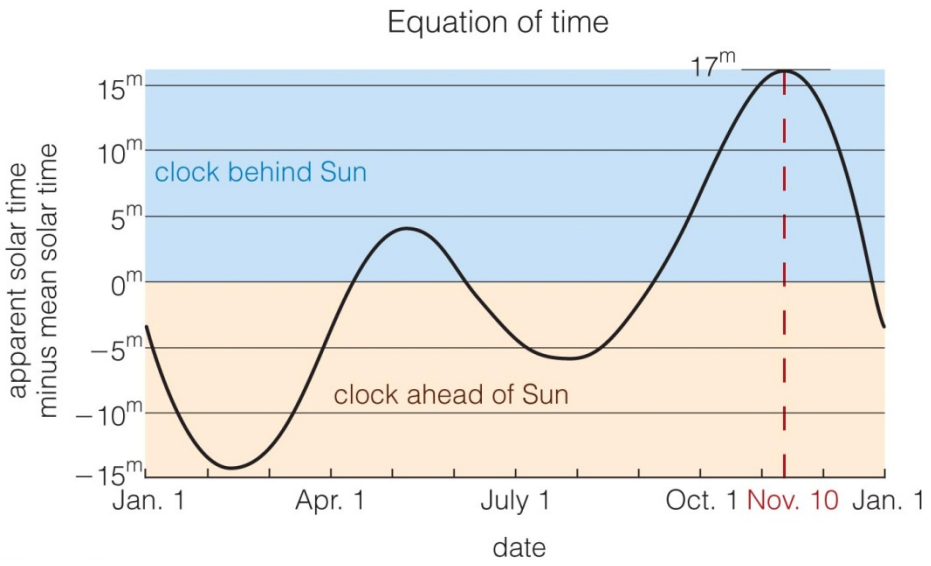
Mean Solar Time



- Length of an apparent solar day varies because Earth's orbit is slightly elliptical - Earth moves faster & slower - so Sun *appears* to move faster & slower.
- **Mean solar time** is based on the *average* length of a day – 24 hours.
- Noon is *average* time at which Sun crosses meridian.

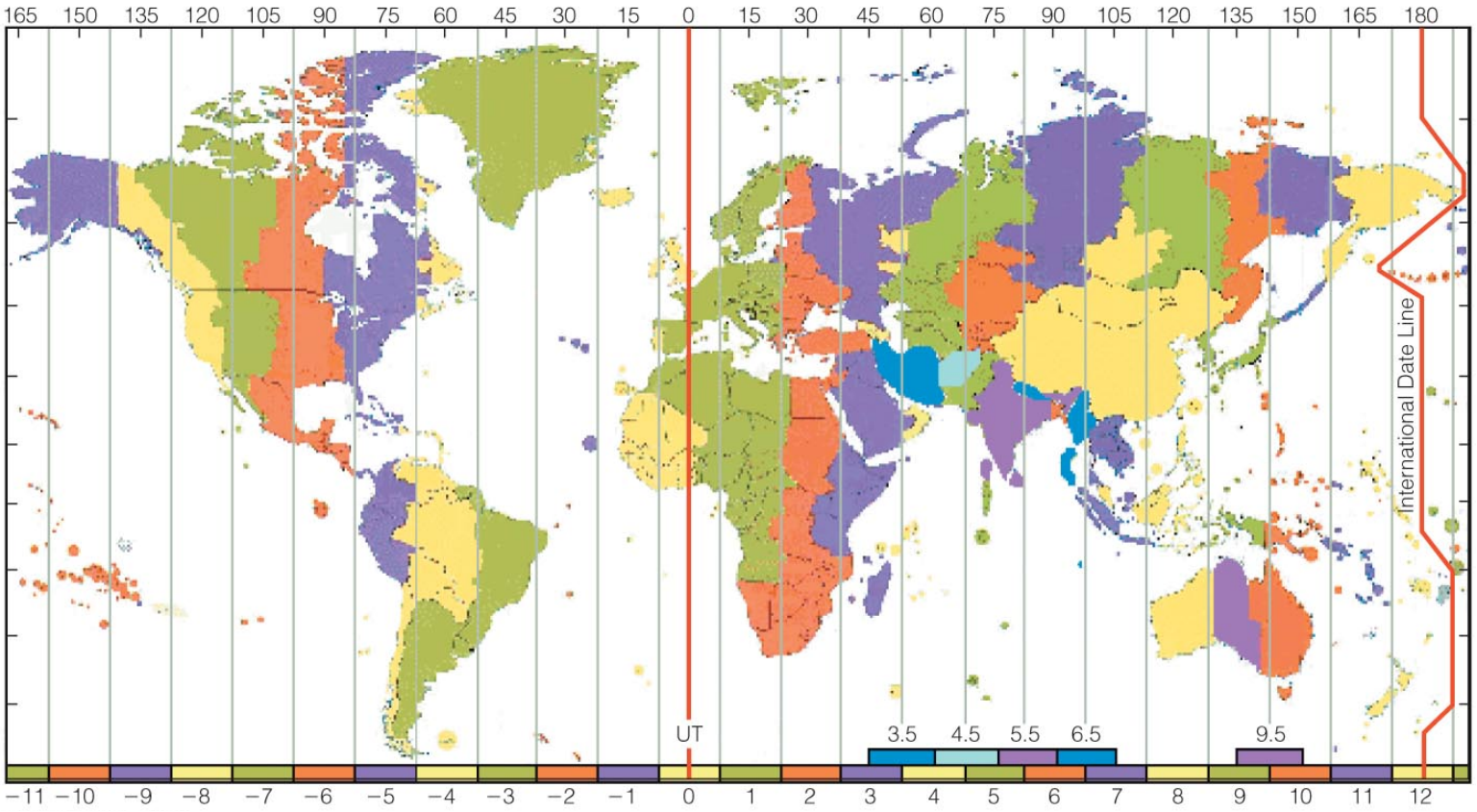
The Analemma





- The **analemma** shows position of Sun with respect to mean solar time – sometimes ahead and sometimes behind

Standard Time and Time Zones



- Since everyone measures a different local (apparent) time, 24 standard time zones using mean time were established.

When and why do we have leap years?

Feb 29?

- The length of a year is about 365.25 days.
- In order to keep the calendar year synchronized with the seasons, we must add one day every 4 years (February 29).
- For precise synchronization, years divisible by 100 (e.g., 1900) are *not* leap years unless they are divisible by 400 (e.g., 2000).

What have we learned?

Begin 3 minute review

S1.1 What have we learned?

How do we define the day, month, year?

Sidereal day (Earth's rotation with respect to stars) is 4 minutes shorter than a **solar day**.

Sidereal month (27.3 day orbit of moon) is shorter then a **synodic month** (29.5 day cycle of phases).

Sidereal year (time to orbit Sun) is 20 minutes longer than a **tropical year** (cycle of seasons)

S1.1 What have we learned?

How do we tell the time of day?

Apparent solar time is based on the Sun's position.

Mean solar time is defined based on the average solar day.

Standard time is defined with respect to time zones.

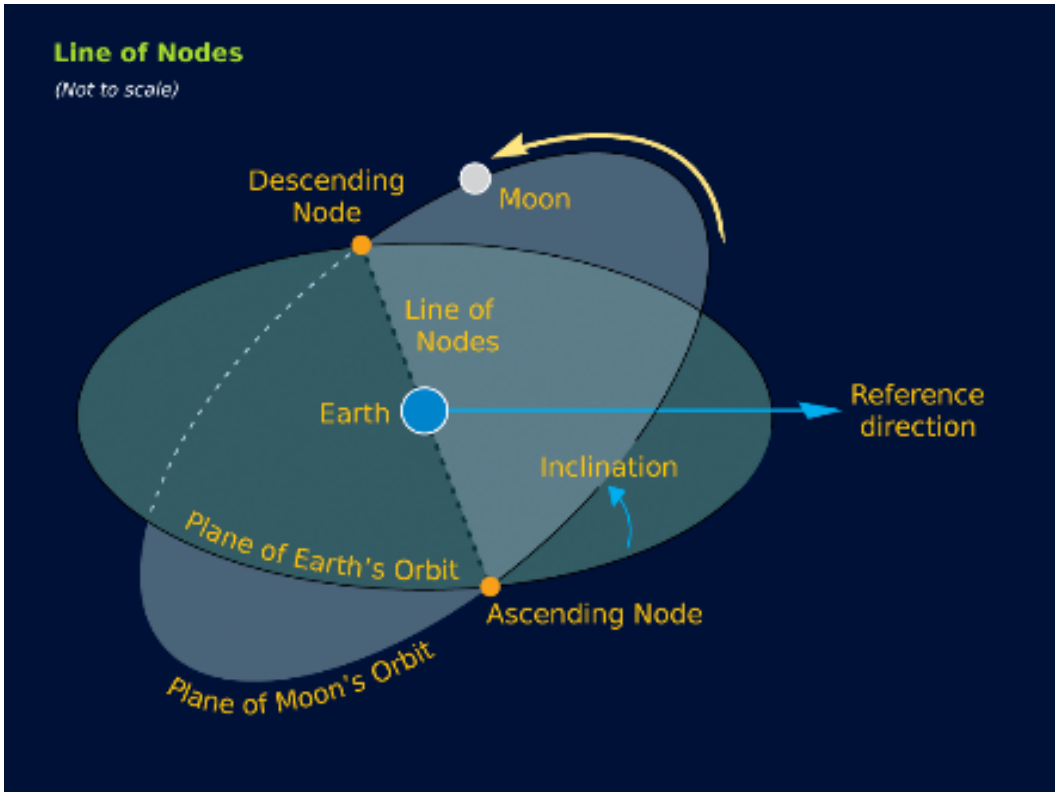
When and why do we have leap years?

Because a year is 365.25 days, we add an extra day every 4 years* so seasons remain synchronized with the calendar.

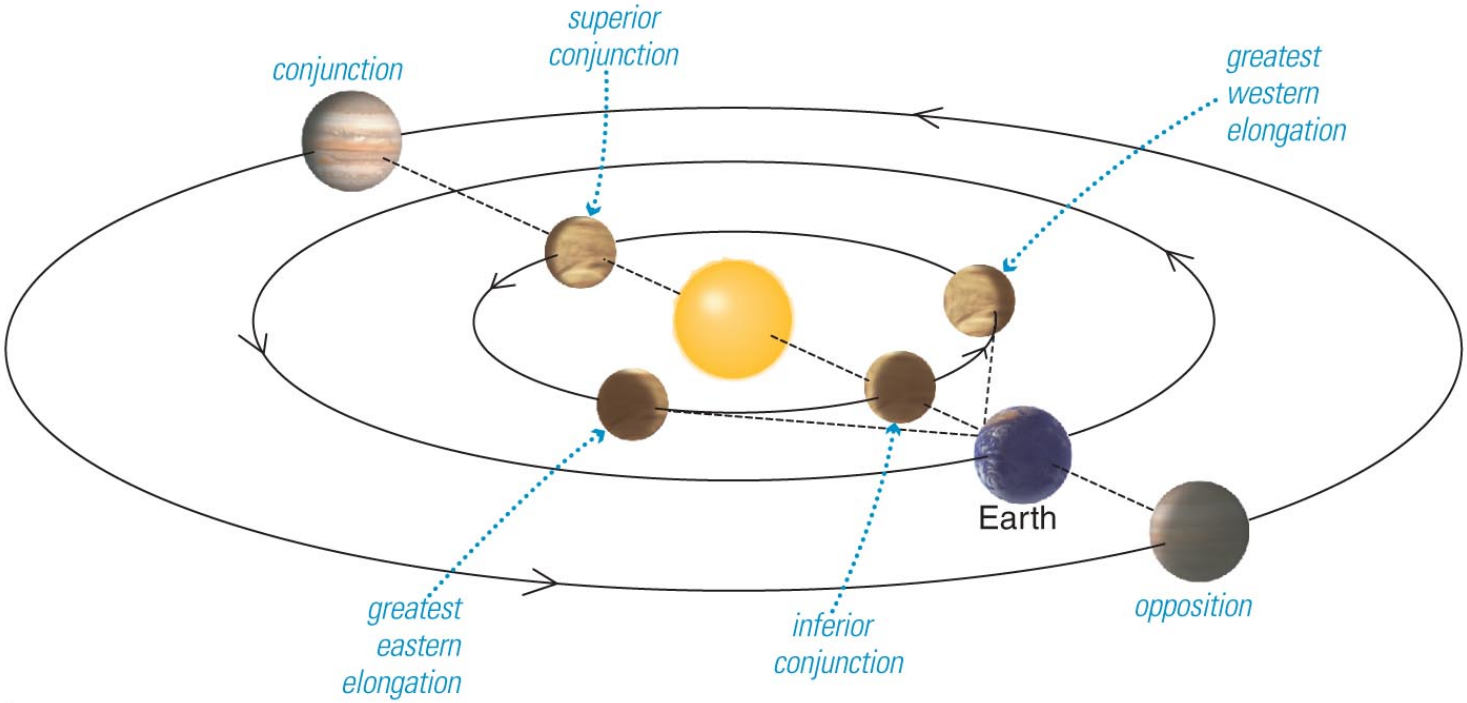
*Except years ending at 00 unless divisible by 400.

The Line of Nodes

- The **Line of Nodes** is the *intersection* of the moon's orbital plane with the Earth orbital plane (ecliptic).
- The moon must be at a node at NM or FM for an eclipse to occur

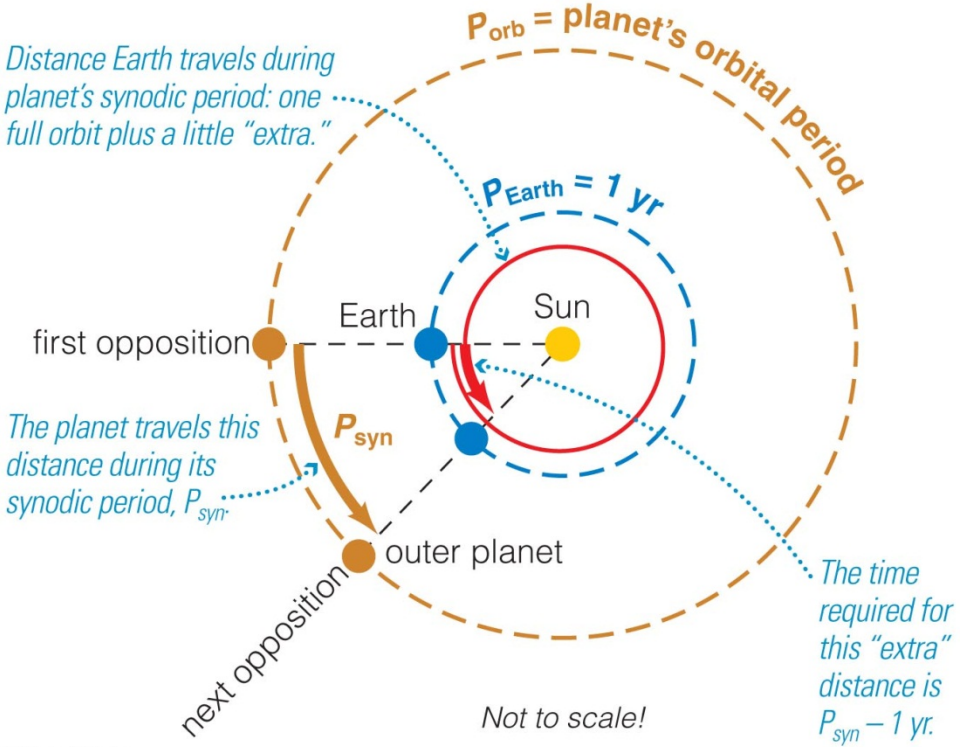


Planetary Periods



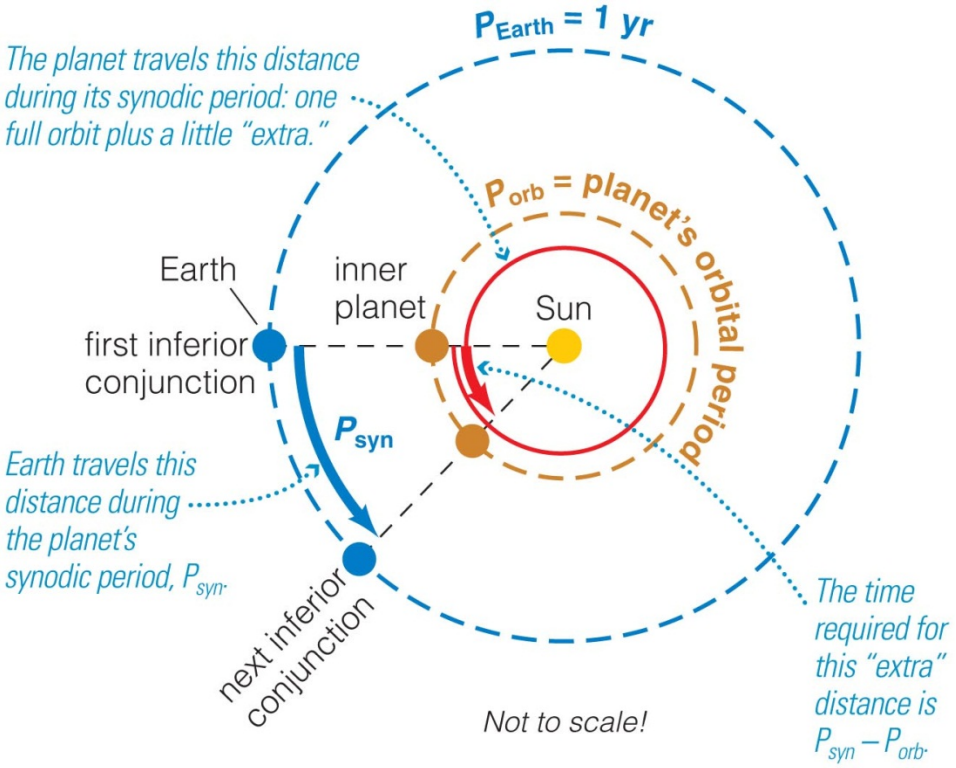
- Planetary periods can be measured with respect to stars (**sidereal**) or to apparent position of Sun (**synodic**).

Planetary Periods



- Difference between a planet's orbital (sidereal) and synodic period depends on how far planet moves in 1 Earth year.

Planetary Periods



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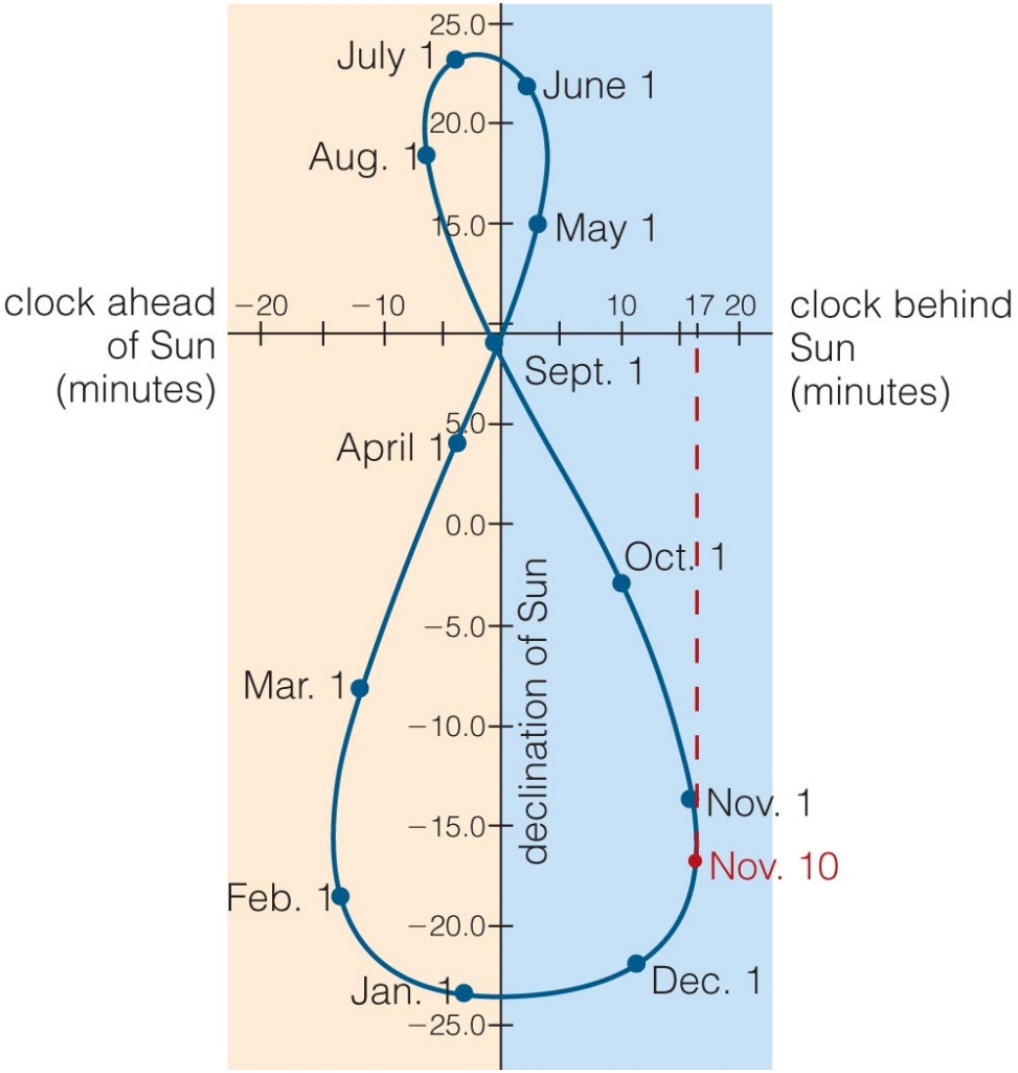
The Analemma



- Seen on the classroom floor is the **analemma.** This is the apparent path of the Sun as it moves north and south in the sky throughout the year
- It also shows the Sun's position with respect to mean solar time at noon – sometimes ahead and sometimes behind