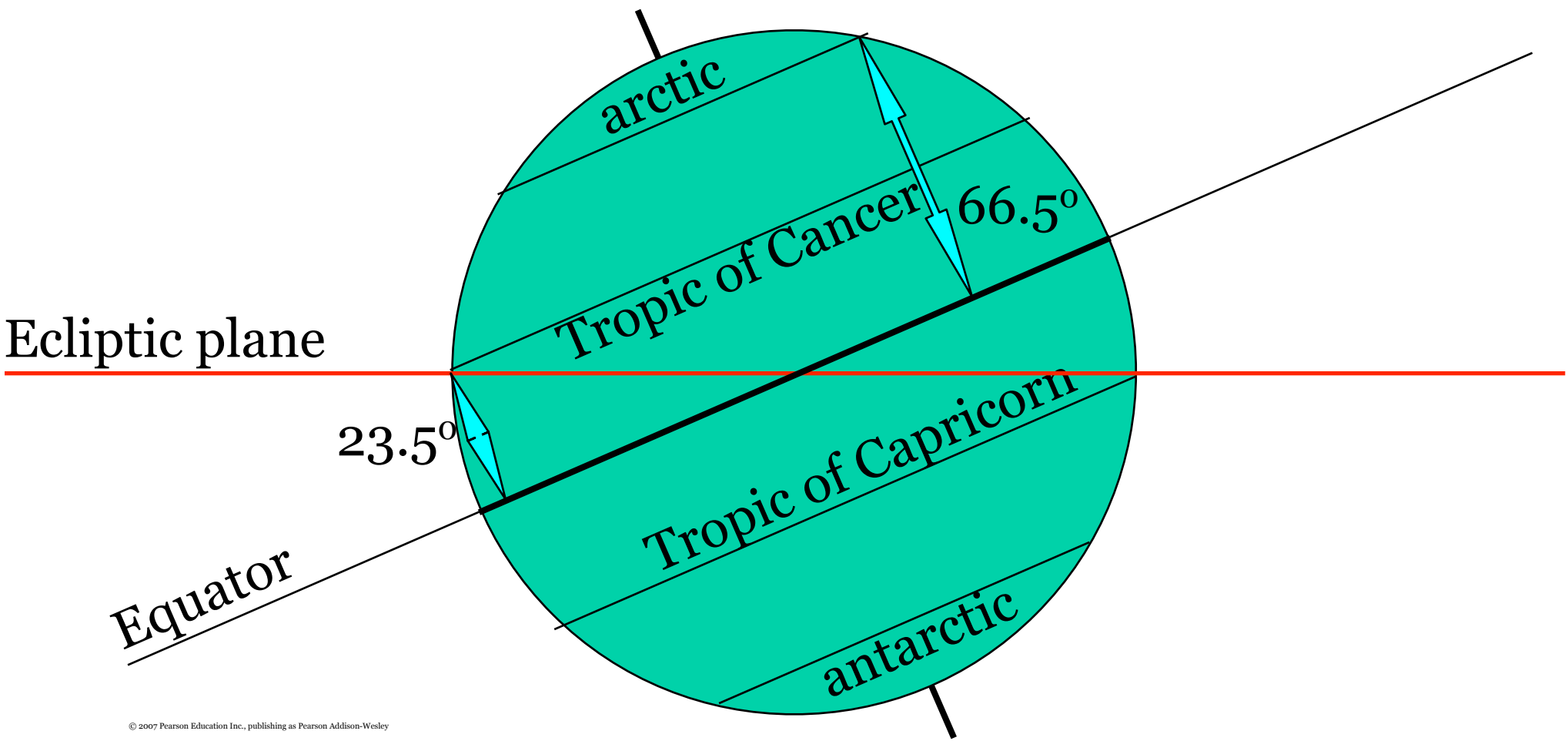
Today

- Solstices & Equinoxes
- Precession
- Phases of the Moon
- Eclipses
  - Lunar, Solar
- Ancient Astronomy

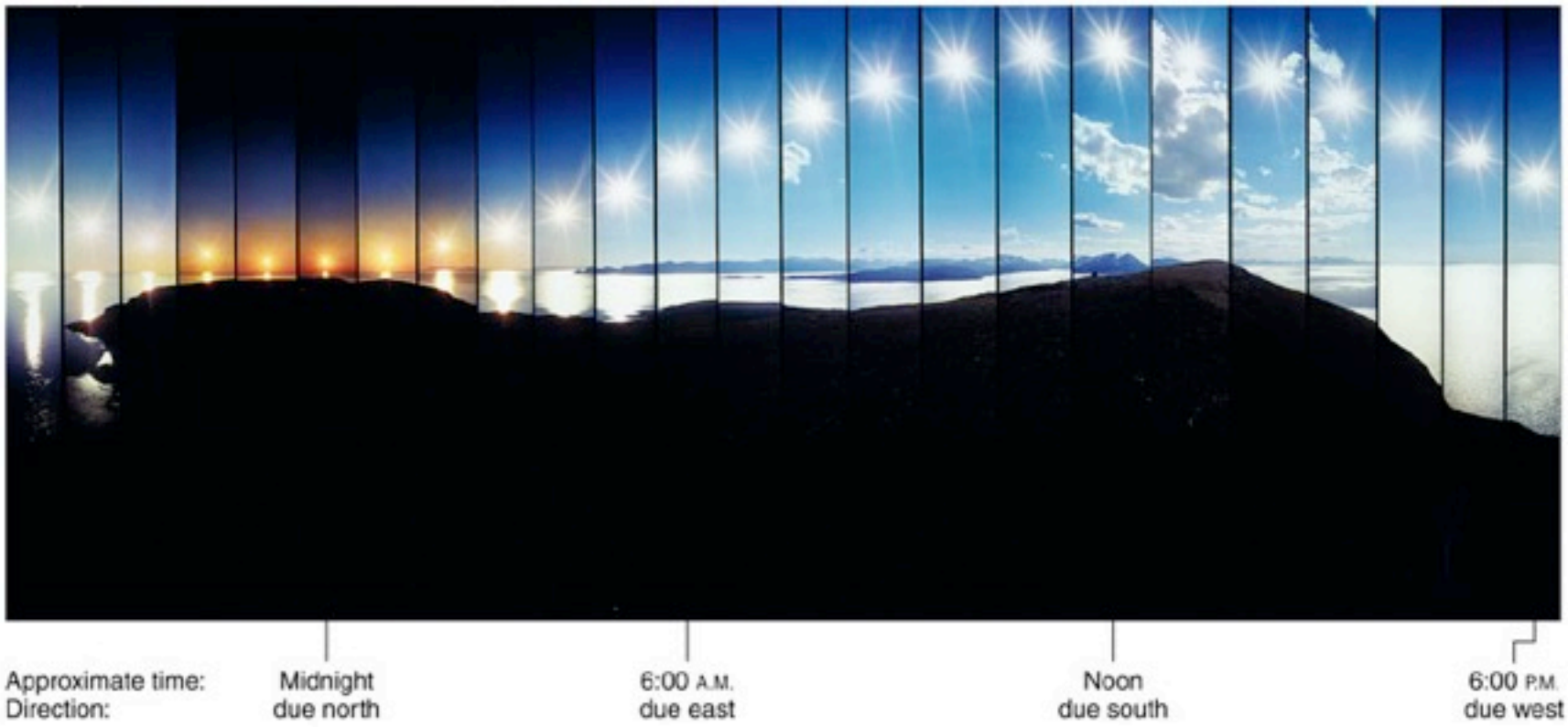
FIRST HOMEWORK DUE NEXT TIME

Tropic: Latitude where the sun [just] reaches the zenith at noon on the summer solstice

Arctic/Antarctic Circle: Latitude where the sun does not set [just barely] on the summer solstice (like a circumpolar star) nor does it rise on the winter solstice



Seasonal changes are more extreme at high latitudes.

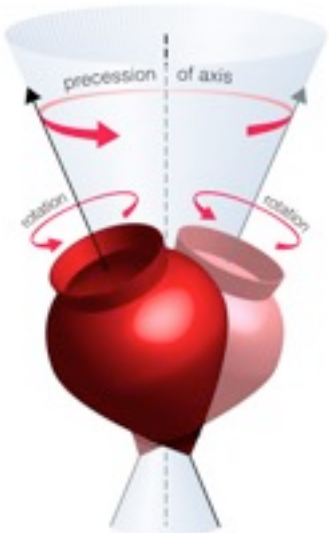


Path of the Sun on the summer solstice at the Arctic Circle

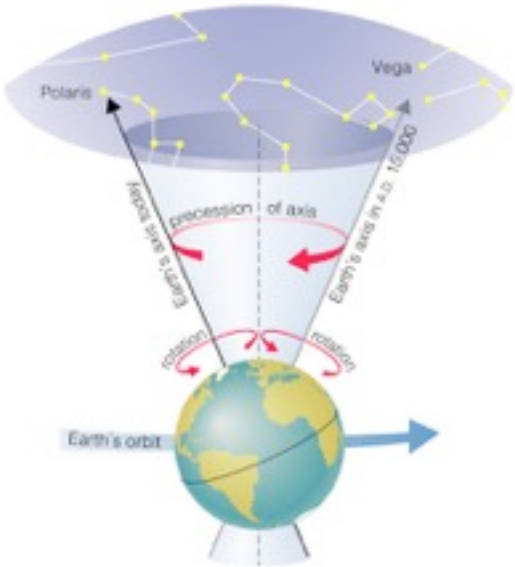
How does the orientation of Earth's axis change with time?

Precession:

- Although the axis seems fixed on human time scales, it actually precesses over about 26,000 years.
  — Polaris won't always be the North Star.



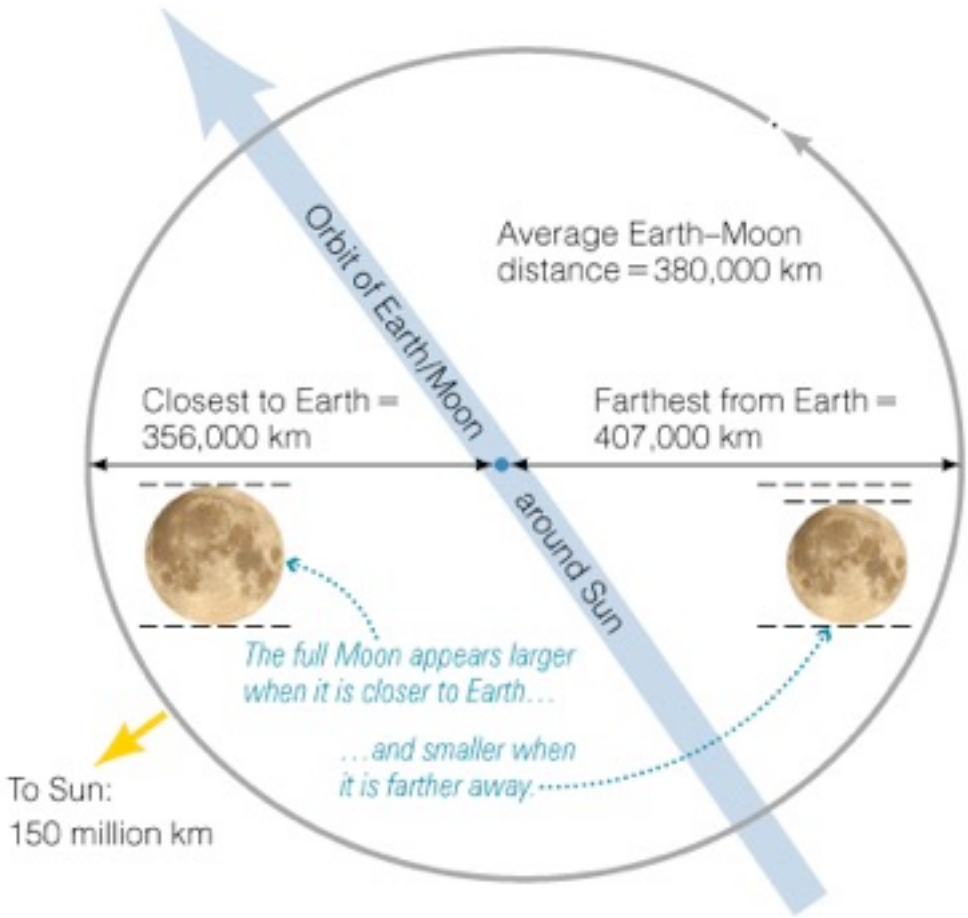
Earth's axis wobbles like the axis of a spinning top.



PLAY 02_05 Precession

- Precession: the orientation of Earth's axis slowly changes with time:
  - The tilt remains about 23.5 degrees (so the season pattern is not affected), but Earth has a 26,000 year **precession** cycle that slowly and subtly changes the orientation of the Earth's axis.
  - The discovery of precession is attributed to the Ancient Greek astronomer **Hipparchus** (c. 280 BC)

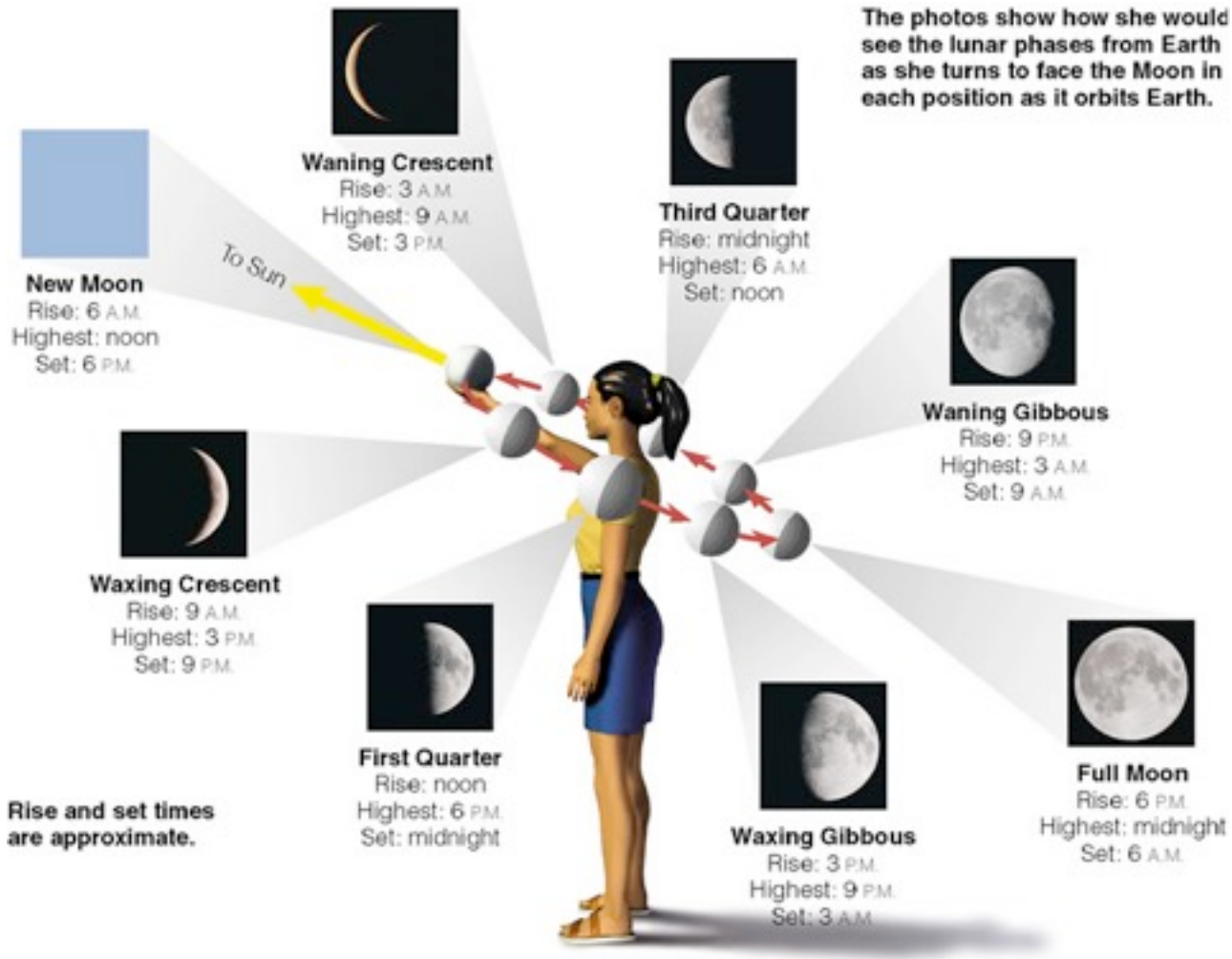
Lunar phases



- Lunar phases are a consequence of the Moon's 27.3-day orbit around Earth.
- This is the *sidereal* period - how long it takes to complete one orbit.
- The *synodic* period - full moon to full moon - is 29.5 days

Phases of Moon

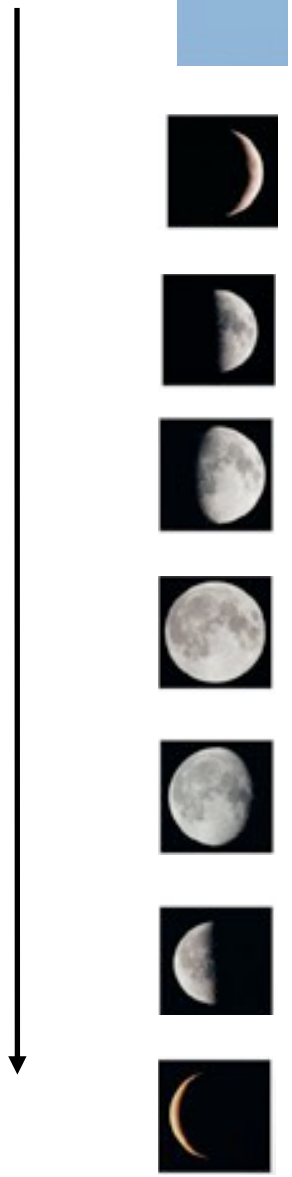
- Half of the Moon is illuminated by the Sun and half is dark.
- We see a changing combination of the bright and dark faces as the Moon orbits Earth.



PLAY Phases of the Moon see also http://astro.unl.edu/naap/lps/animations/

Phases of the Moon: 29.5-day cycle

Synodic (observed) period



new

crescent

first quarter

gibbous

full

gibbous

last quarter

crescent

waxing

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

waning

- Moon visible in late night/morning
- Gets "less" and sets later each day

We see only one side of the Moon

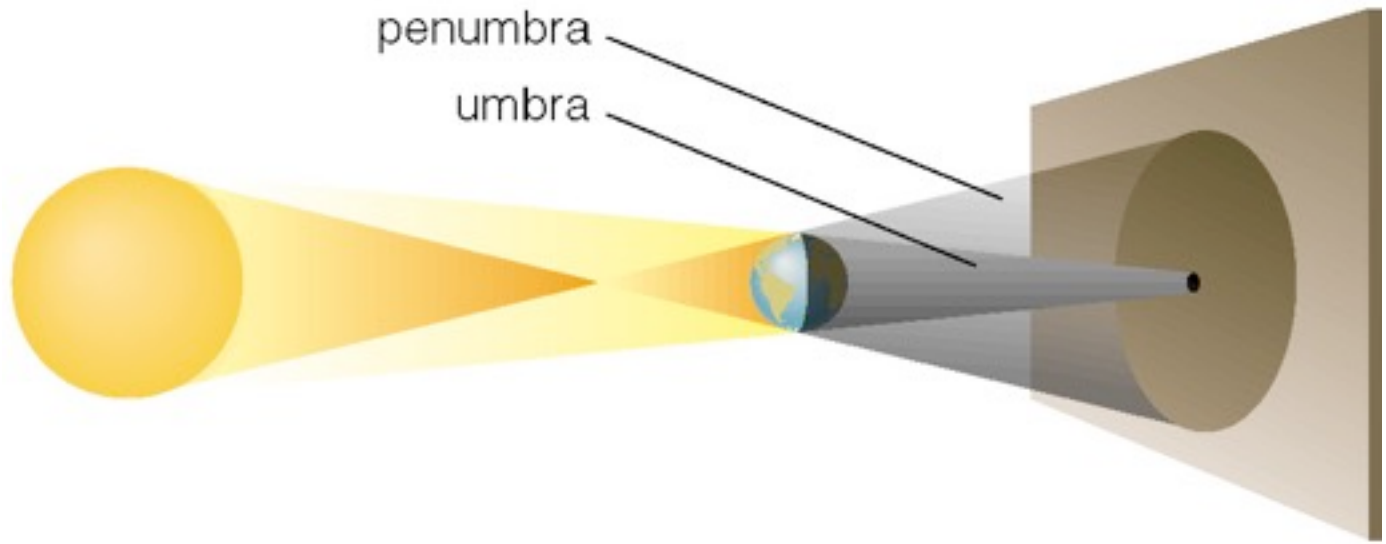
Synchronous rotation:
The Moon rotates exactly once with each orbit.

This is why only one side is visible from Earth.

This is an example of “tidal locking” in which the spin rate of a smaller moon is coupled to its orbital period around a larger planet.

Eclipses

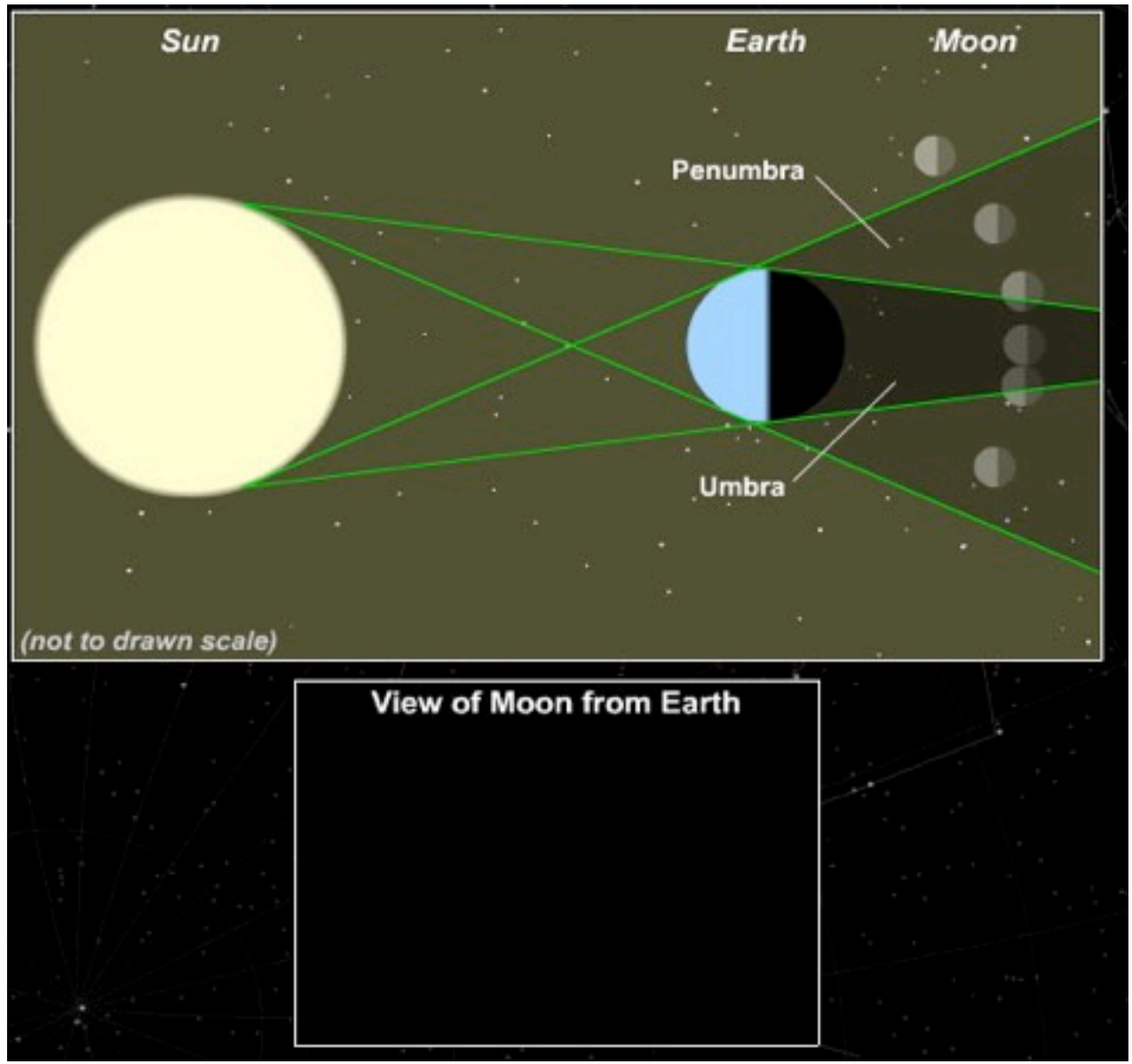
- The Earth and Moon cast shadows.
- When either passes through the other's shadow, we have an **eclipse**.



A **lunar eclipse** is when the Earth shades the Moon.

A **solar eclipse** is when the Moon shades the Earth.

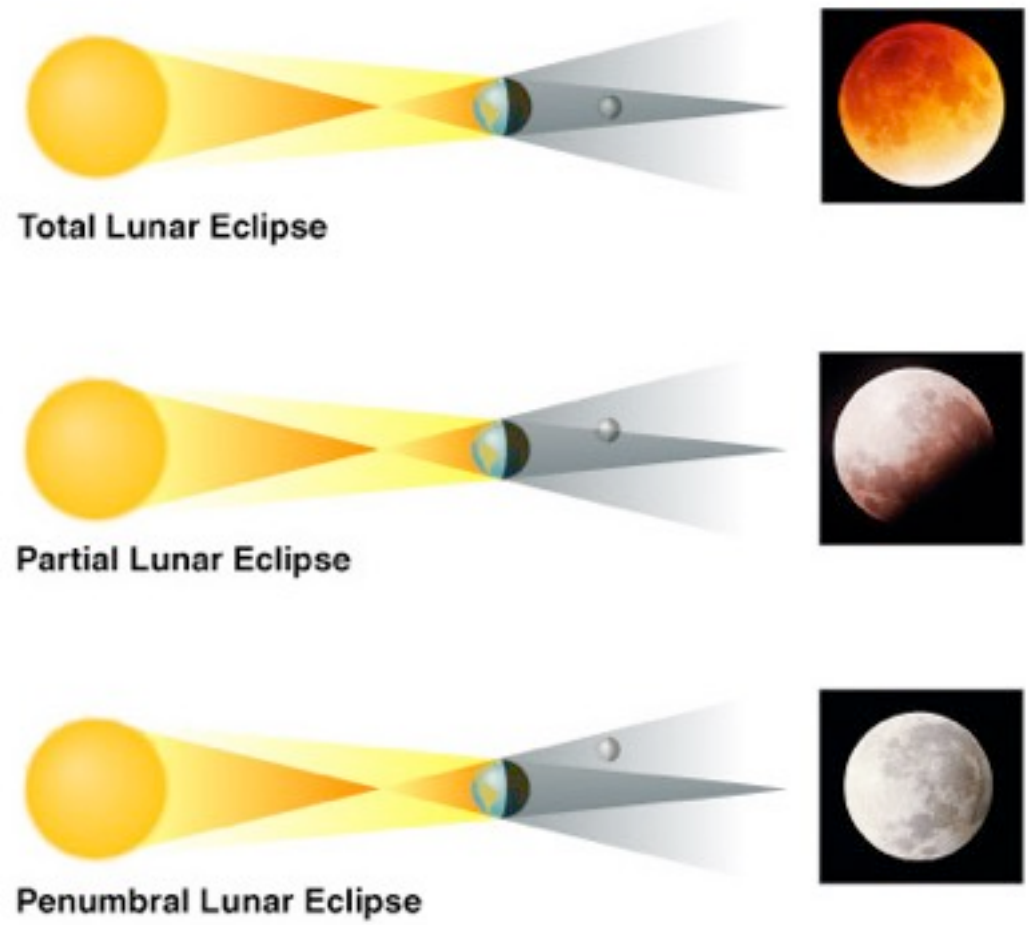
Lunar Eclipse



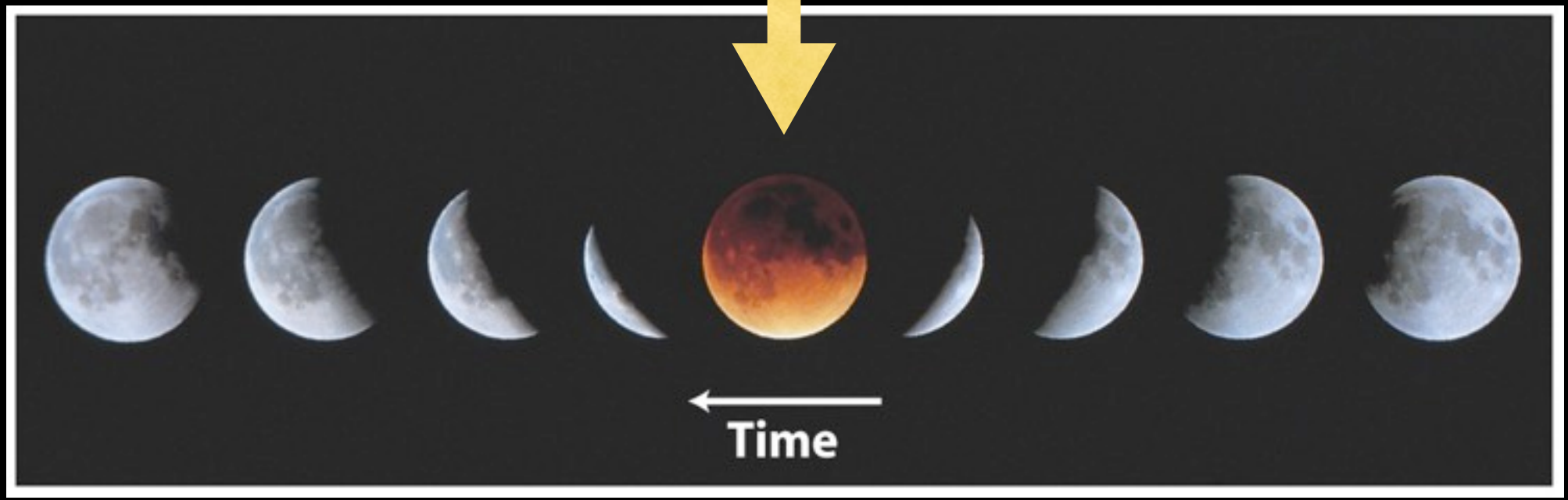
PLAY 02_08 Lunar Eclipse

When can eclipses

- **Lunar eclipses** can occur only at *full moon* when the earth is between the sun and moon.
- Lunar eclipses can be **penumbral**, **partial**, or **total**.



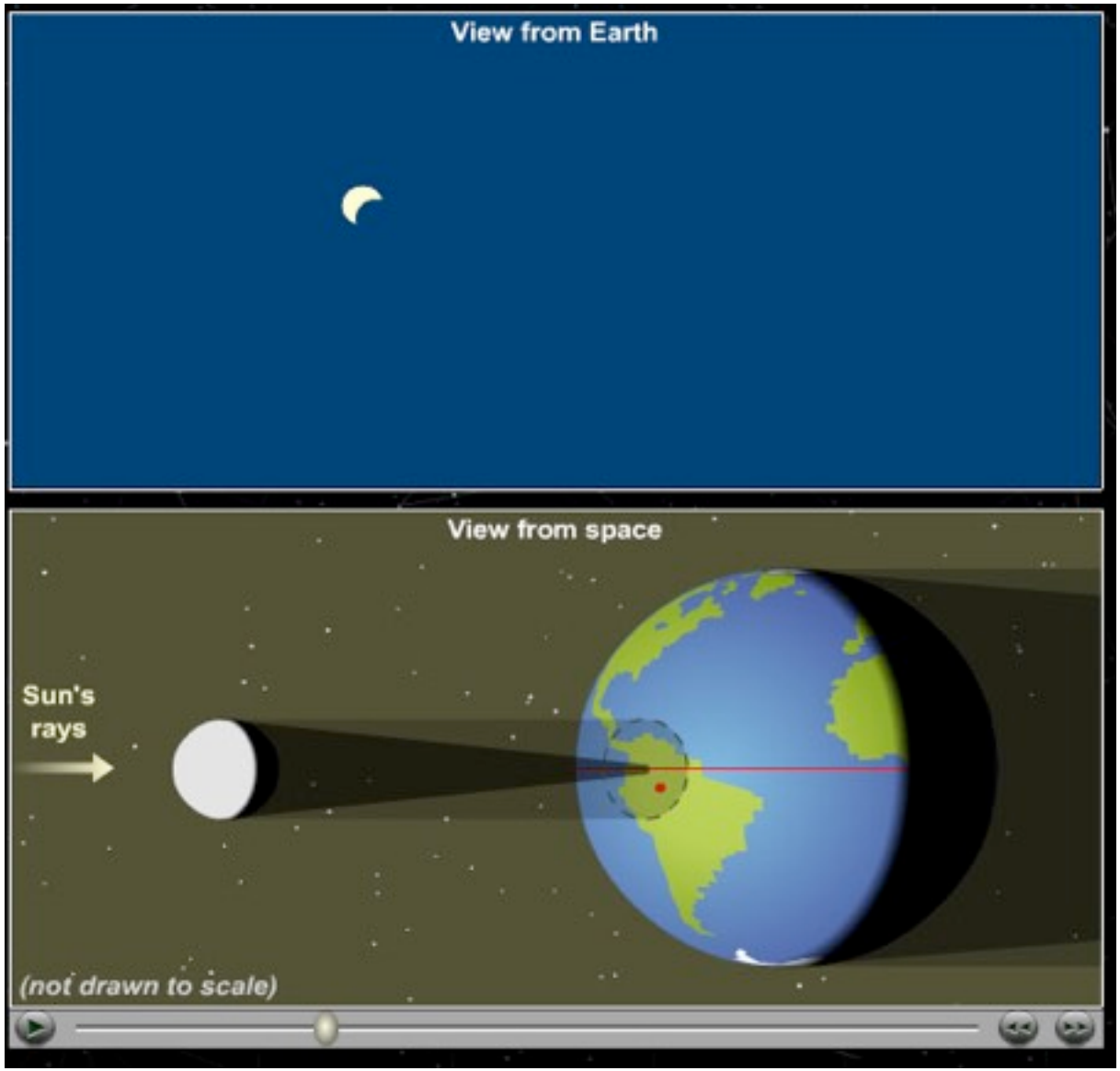
much longer exposure



Total Lunar Eclipse, March 3rd 2007

Newtonhill, Aberdeenshire

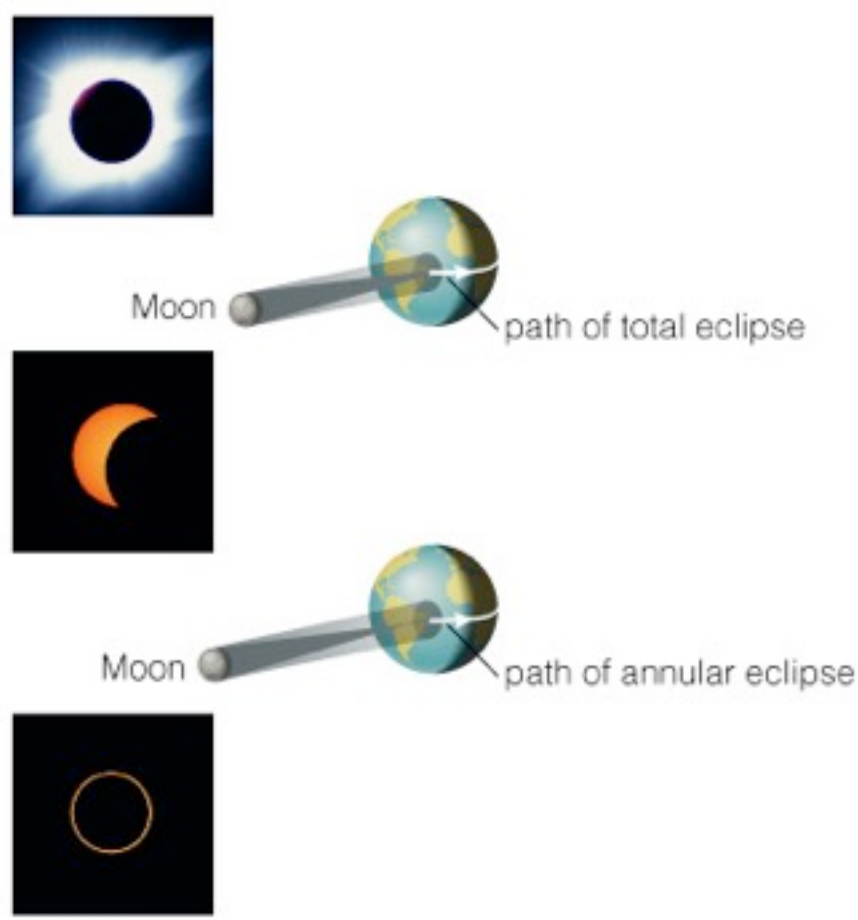
Solar Eclipse



PLAY 02_09 Evolution of a Total Solar Eclipse

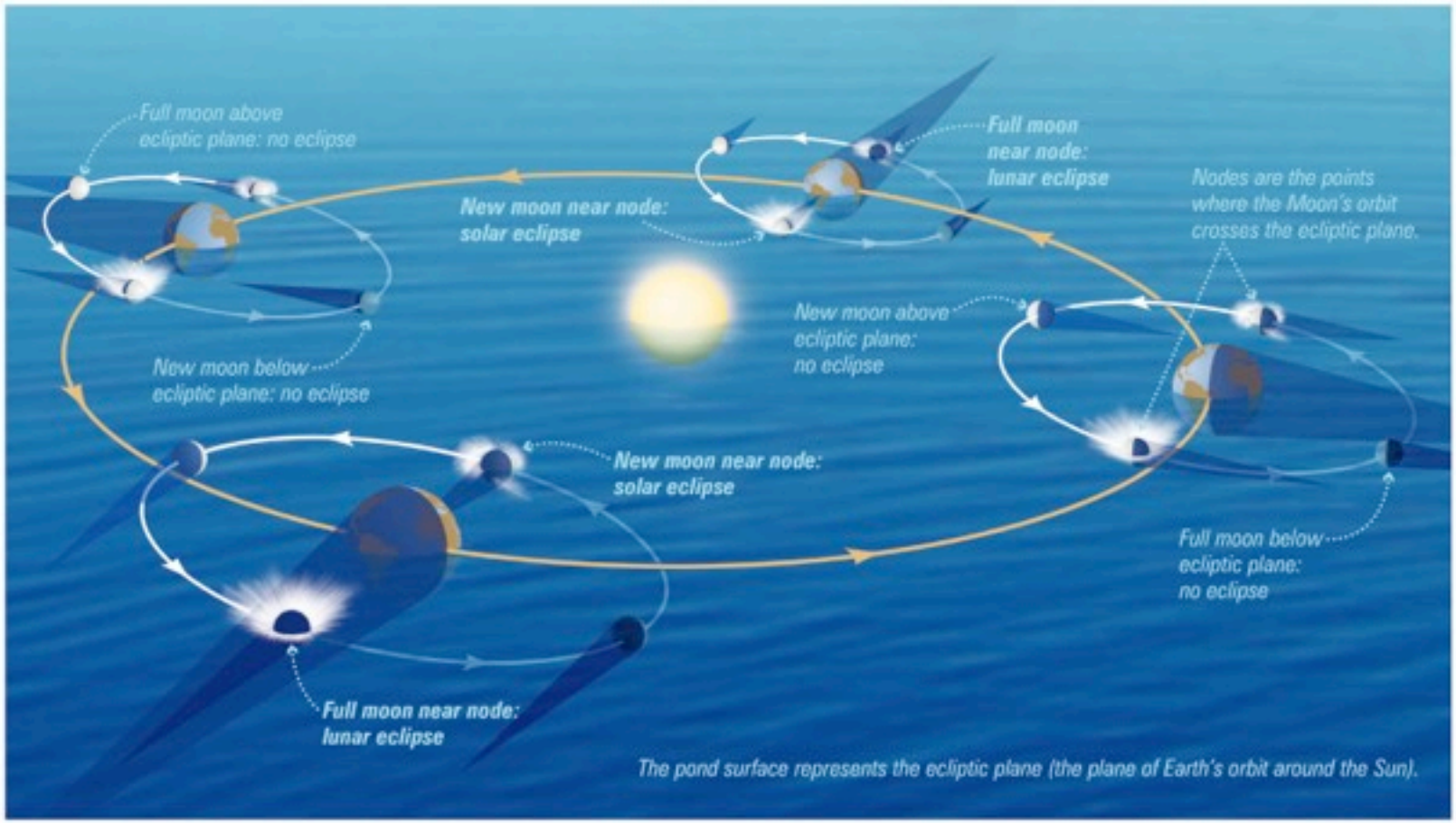
When can eclipses

- **Solar eclipses** can occur only at *new moon* when the moon is between the earth and the sun.
- Solar eclipses can be **partial**, **total,** or **annular**.
- It is a coincidence that the angular size of the sun and moon are approximately equal.



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

- The Moon's orbit is tilted 5° to ecliptic plane.
- So we have about two **eclipse seasons** each year, with a lunar eclipse at new moon and solar eclipse at full moon.



Play Moon's orbit & ecliptic

Summary: Two conditions must be met to have an eclipse:

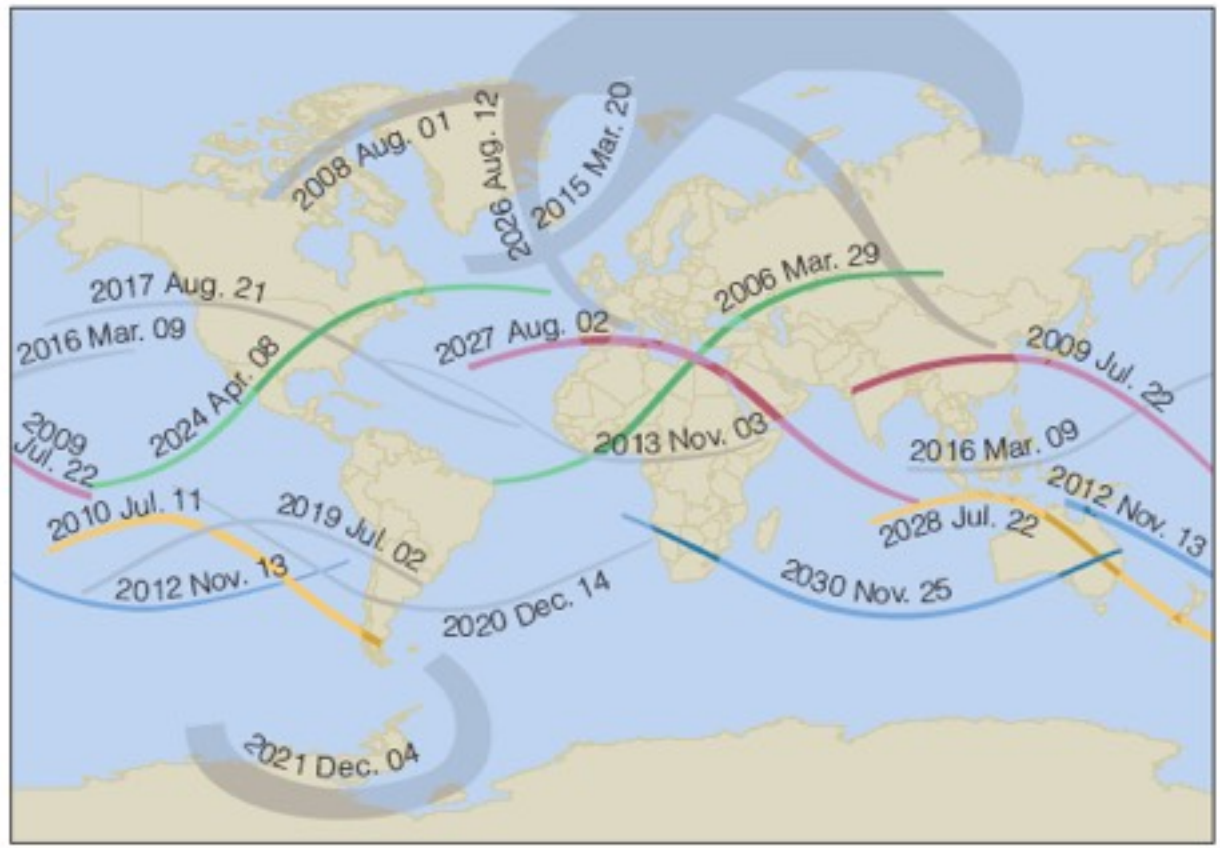
1. It must be a full moon (for a lunar eclipse) or a new moon (for a solar eclipse).

AND

2. The Moon must be at or near one of the two points in its orbit where it crosses the ecliptic plane (its nodes).

Predicting Eclipses

- Solar eclipses recur with the 18 year, 11 1/3 day **saros cycle**, but type (e.g., partial, total) and location may vary.

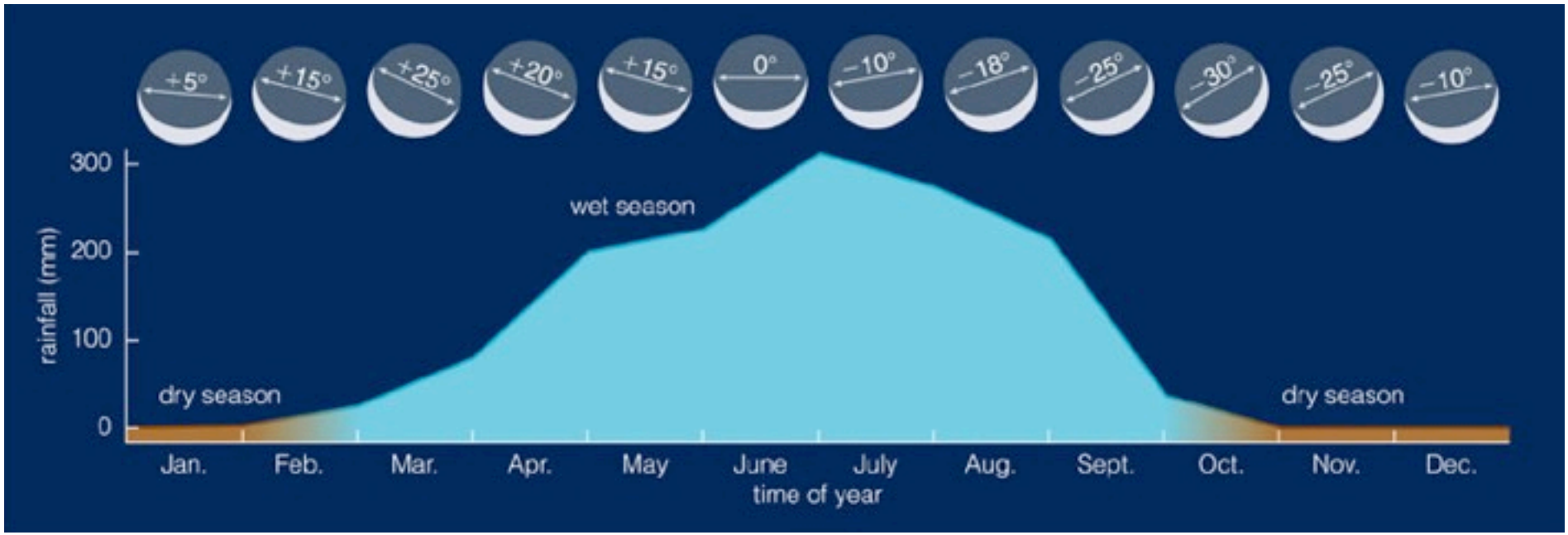


Next up: Aug 21, 2017 a few hundred miles south of Cleveland

Astronomical observations were important to ancient societies

- In keeping track of time and seasons
  - — for practical purposes, including agriculture
  - — for religious and ceremonial purposes

- In aiding navigation



Ancient people of central Africa (6500 B.C.) could predict seasons from the orientation of the crescent moon.

Ancient achievements

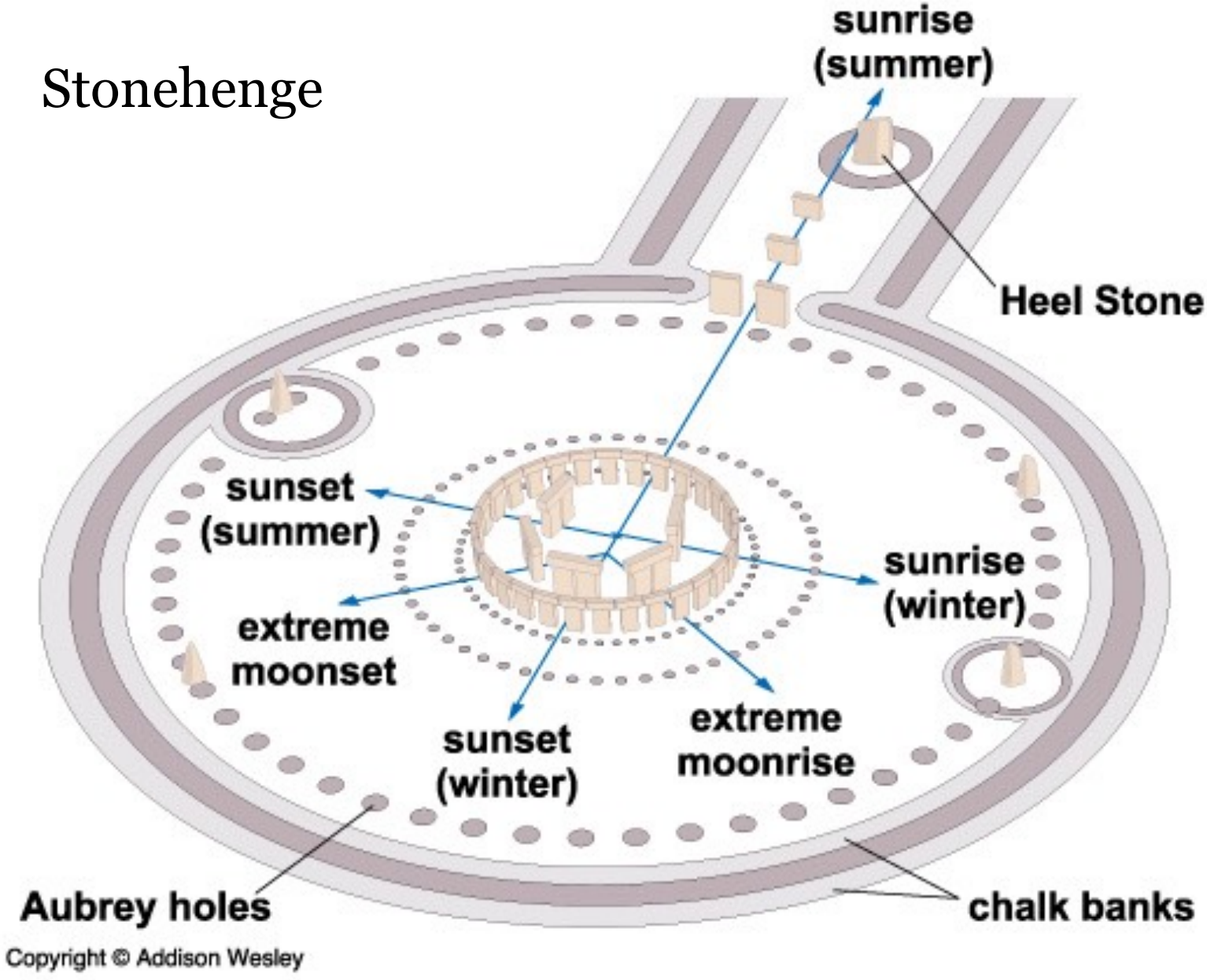
- Daily timekeeping
- Tracking the seasons and calendar
- Monitoring lunar cycles
- Monitoring planets and stars
- Predicting eclipses
- Discovered precession
- And more…

Aztec calendar

- Egyptian obelisk: Shadows tell time of day.

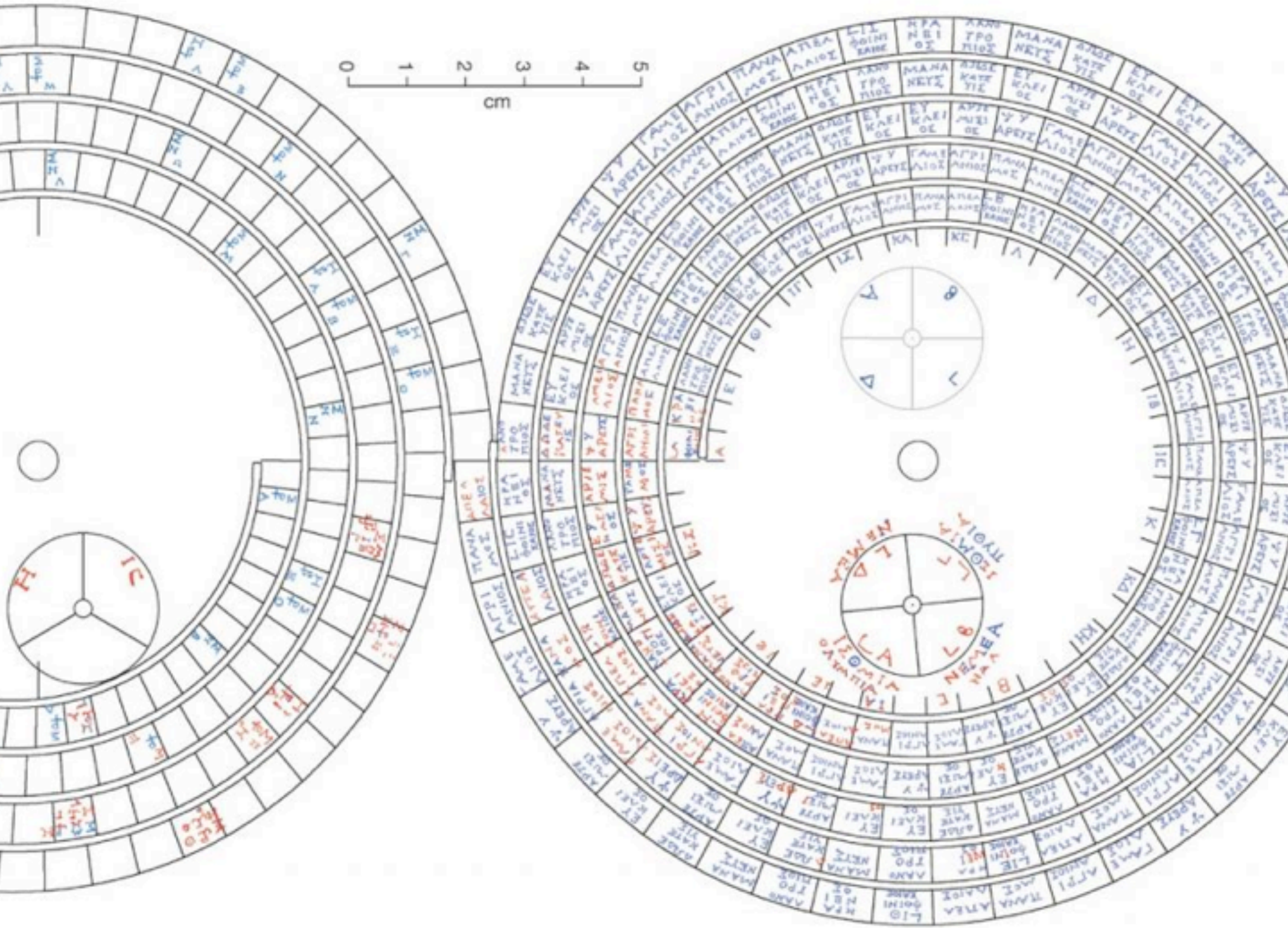
England: Stonehenge (completed around 1550 B.C.)

Stonehenge



Scotland: 4,000-year-old stone circle; Moon rises as shown here every 18.6 years.

Antikythera mechanism (c. 90 BC)


0 1 2 3 4 5
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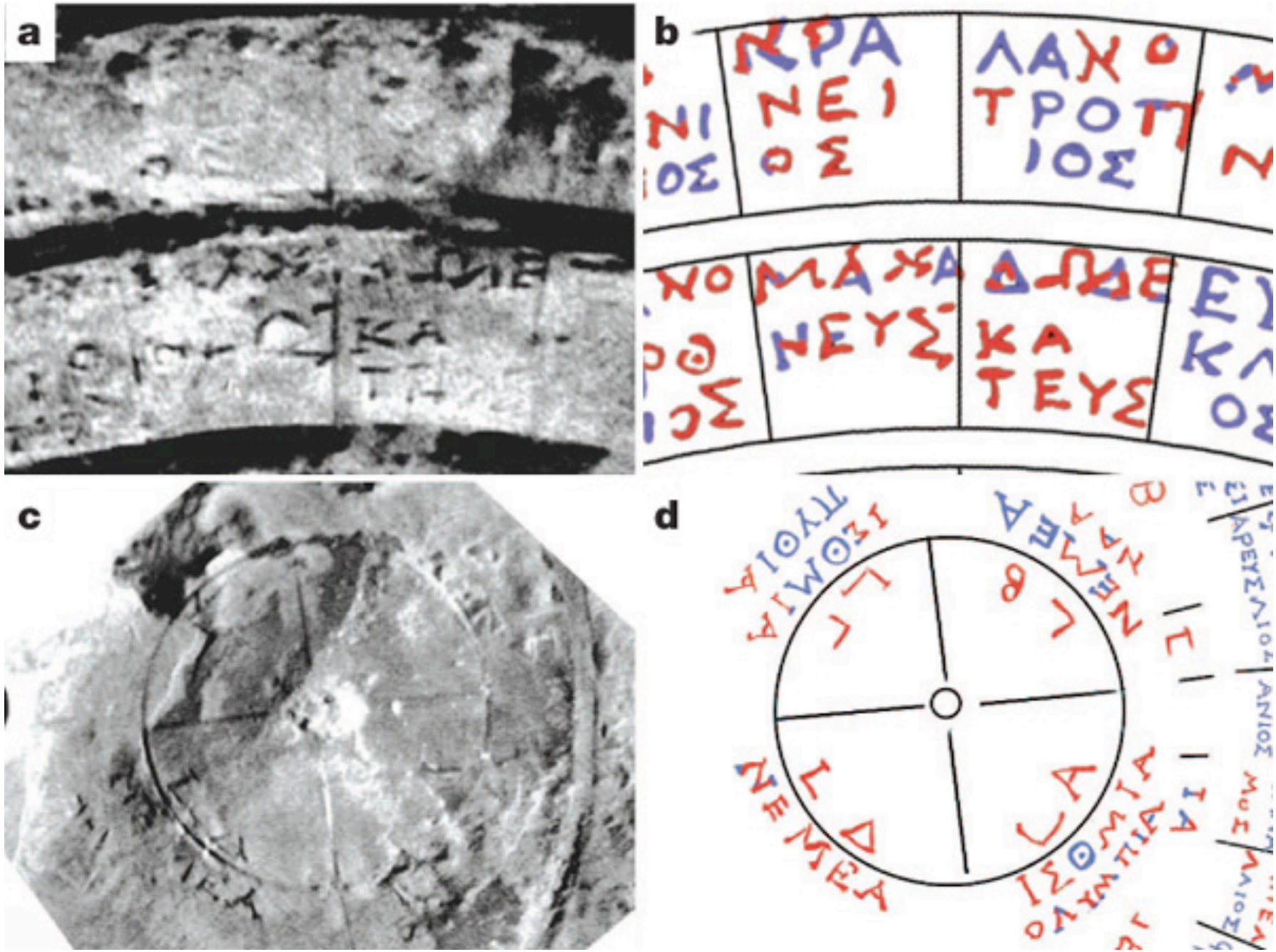
a
b
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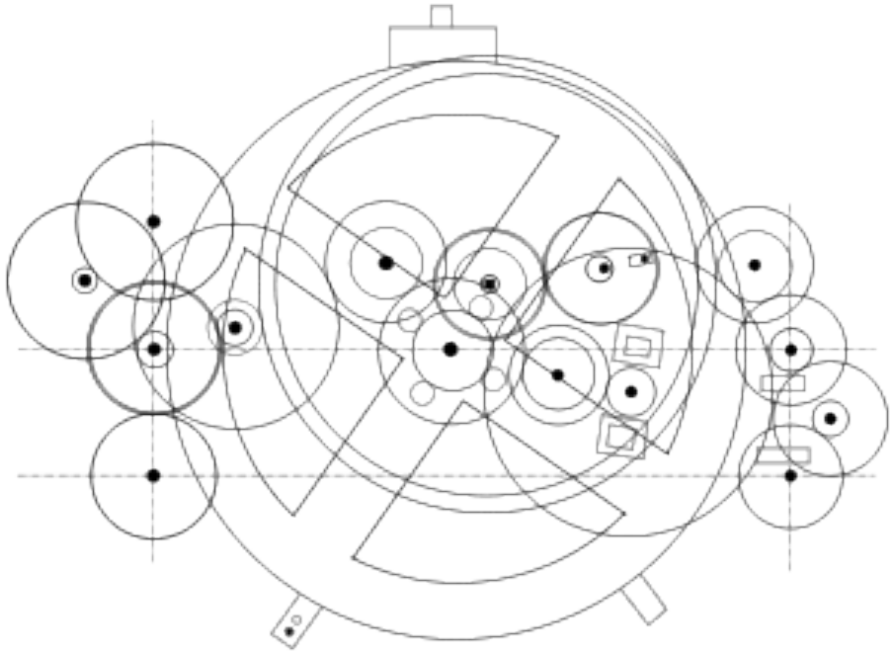
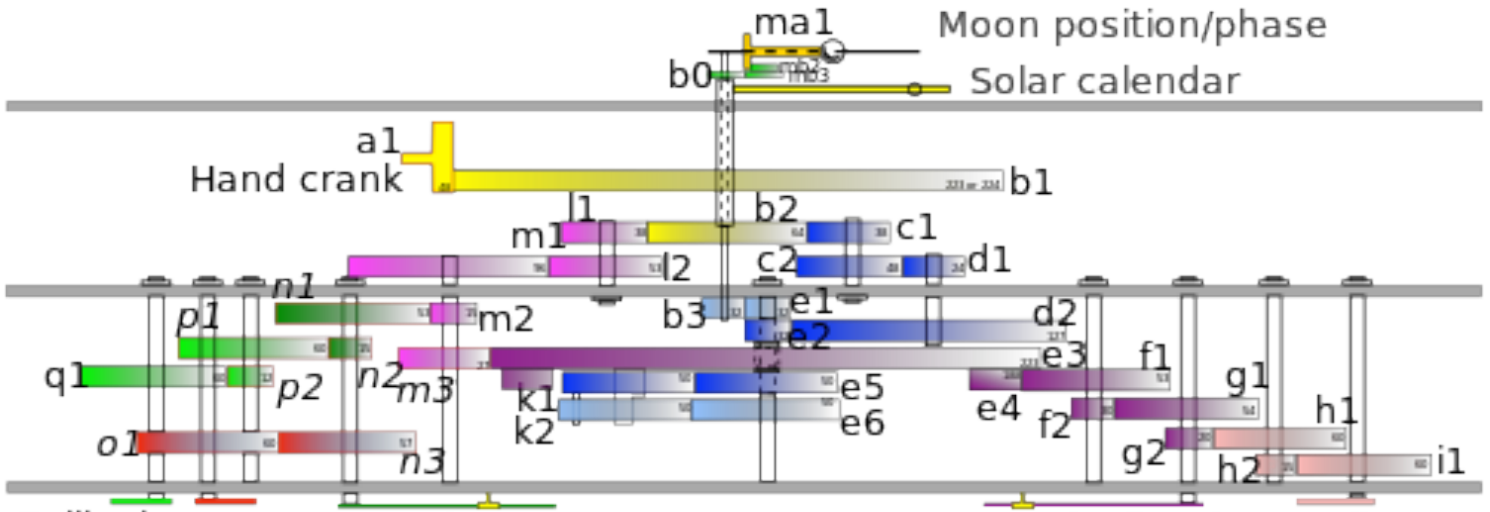
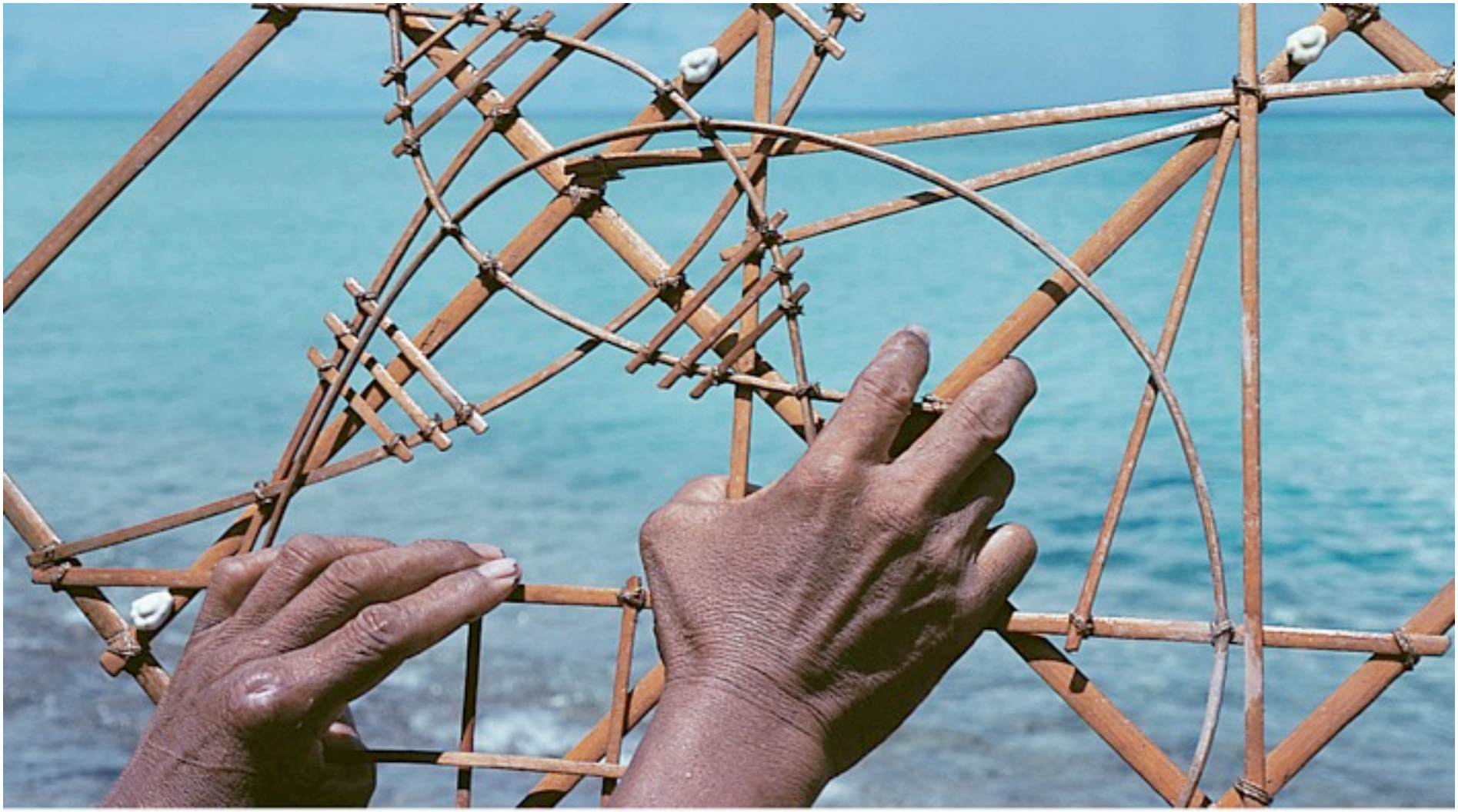
Antikythera mechanism (c. 90 BC)



The Ancients had developed a sophisticated and detailed empirical knowledge of the motions of the sky

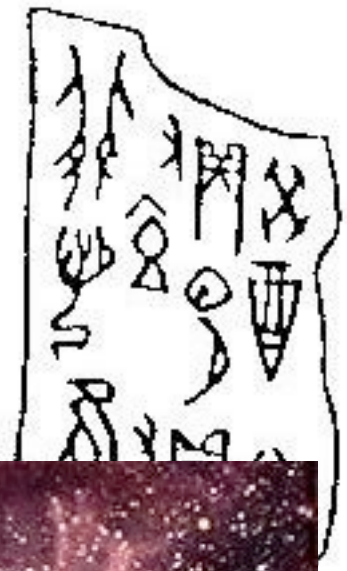


SW United States: "Sun Dagger" marks summer solstice



South Pacific: Polynesians were very skilled in the art of celestial navigation.

"On the Jisi day, the 7th day of the month, a big new star appeared in the company of the Ho



SN 1987A

e new star dwindled."

Bor **B.C.**

China: earliest known records of supernova explosions (1400 B.C.)

- How did astronomical observations benefit ancient societies?
  - Keeping track of time and seasons; navigation = trade
  - This knowledge was essential for trade and agriculture = survival