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ASTRONOMY

Chapter 4 EARTH, MOON, AND SKY

PowerPoint Image Slideshow

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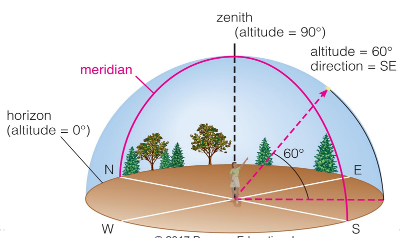
How to locate an object

- **altitude** is position above horizon
- **direction** (azimuth) degrees clockwise from due N along horizon



4.2 THE SEASONS

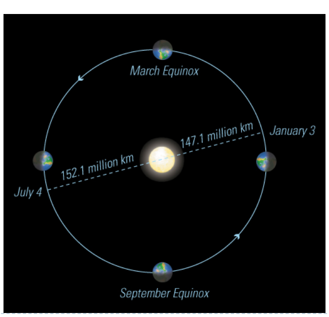
Thought Question

Here in Long Beach CA, In what session is the Earth closer to the Sun?

Hint: When it is summer in America, it is winter in Australia.

- Seasons are opposite in the N and S hemispheres, so distance cannot be the reason for sessions.
- The real reason for seasons involves Earth's axis tilt.

Why *doesn't* distance matter?



- Variation of Earth–Sun distance is small only about 3%;

The Seasons and Sunshine

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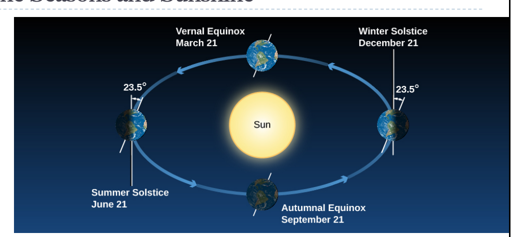

- Seasons depend on how Earth's axis tilt of 23 ½ degrees affects the directness of sunlight.

Directness of Sun light changes

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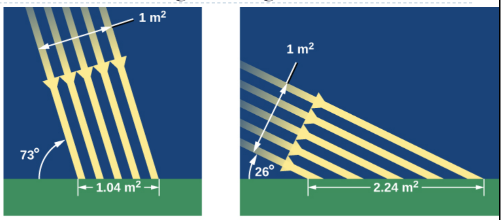

- **The Sun's Rays in Summer and Winter (Fig 4.6).**
  (a) In summer, the Sun appears high in the sky and its rays hit Earth more directly, spreading out less.
  (b) In winter, the Sun is low in the sky and its rays spread out over a much wider area, becoming less effective at heating the ground.

The Sun's altitude also changes

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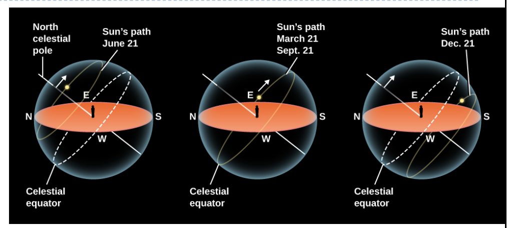
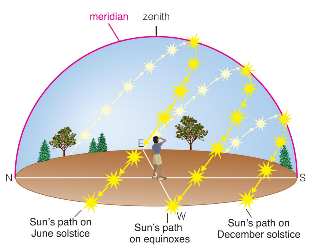


- **The Sun's Path in the Sky for Different Seasons (Fig 4.7).** On June 21, the Sun rises north of east and sets north of west. For observers in the Northern Hemisphere of Earth, the Sun spends about 15 hours above the horizon in the United States, meaning more hours of daylight. On December 21, the Sun rises south of east and sets south of west. It spends 9 hours above the horizon in the United States, which means fewer hours of daylight and more hours of night in northern lands (and a strong need for people to hold celebrations to cheer themselves up). On March 21 and September 21, the Sun spends equal amounts of time above and below the horizon in both hemispheres.

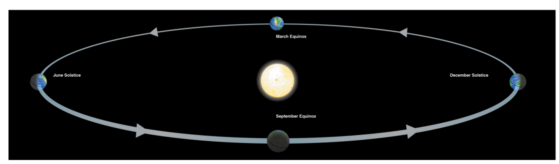
Solstices and equinoxes

- Summer (June) solstice: highest path;
- Winter (December) solstice: lowest path
- Equinoxes: Sun rises precisely due east and sets precisely due west.



First day of sessions

- We define four special points:
  - summer (June 21) solstice
  - winter (December 21) solstice
  - spring (March 21) equinox
  - fall (September 21) equinox



Tropic of Cancer (1st day of summer)

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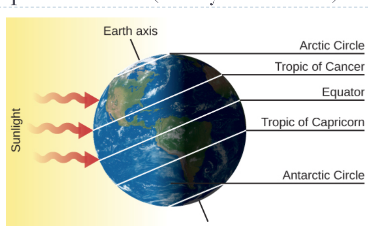

- **Earth on June 21 (Fig 4.8).** This is the date of the summer solstice in the Northern Hemisphere. Note that as Earth turns on its axis (the line connecting the North and South Poles), the North Pole is in constant sunlight while the South Pole is veiled in 24 hours of darkness. The Sun is at the zenith for observers on the Tropic of Cancer.

Tropic of Capricorn (1st day of winter)

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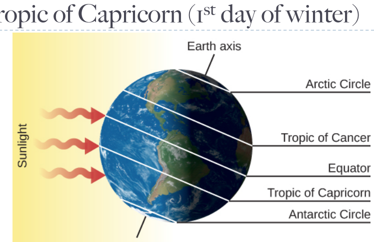
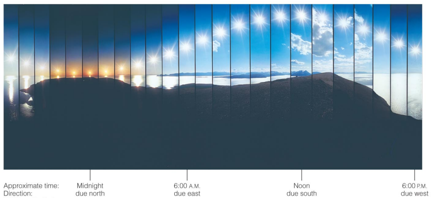


- **Earth on December 21(Fig 4.9).** This is the date of the winter solstice in the Northern Hemisphere. Now the North Pole is in darkness for 24 hours and the South Pole is illuminated. The Sun is at the zenith for observers on the Tropic of Capricorn and thus is low in the sky for the residents of the Northern Hemisphere.

The Seasons at Different Latitudes



- Season changes are more extreme at higher latitudes
  - Vermont has longer summer days than Florida
- Arctic Circle (latitude 66 ½)
  - During summer solstice the sun remains above the horizon
- At the North and South pole during summer and winter
  - the sun never sets or rises for 6 months at a time

4.4 THE CALENDAR

- Astronomy is the oldest of the sciences.

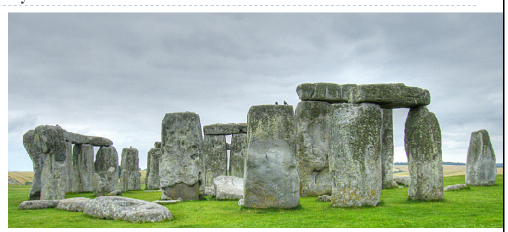
Why study it?

- Inherent curiosity
- Keeping track of time and seasons
  - for practical purposes, including agriculture
  - for religious and ceremonial purposes
- In aiding navigation

What did ancient civilizations achieve in astronomy?

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

Early Calendars



- Stonehenge (Fig 4.12) The ancient monument known as Stonehenge was used to keep track of the motions of the Sun and Moon.(1550 BC)

- El Caracol (Fig 4.13). This Mayan observatory at Chichen Itza in the Yucatan, Mexico, (c. 1000 AD)

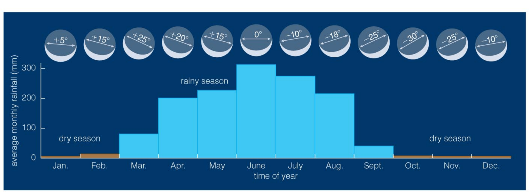
- Egyptian obelisk: Shadows tells time of day.
- am (ante meridiem) pm (post meridiem)

Aztec city of Tenochtitlan Templo Mayor (15th century)

New Mexico: Pueblo Bonito.
Anasazi kiva aligned north–south (1050 A.D.)

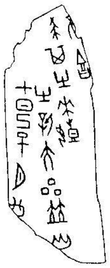
Machu Picchu, Peru: Inca citadel Structures aligned with solstices on a mountain ridge 8000ft above sea level (15th century)

Scotland: 4000-year-old stone circle; Moon rises as shown here every 18.6 years.

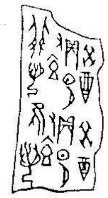


Ancient people of central Africa (6500 B.C.) could predict seasons from the orientation of the crescent moon.

France: Cave paintings from 18,000 B.C. may suggest knowledge of lunar phases (29 dots).



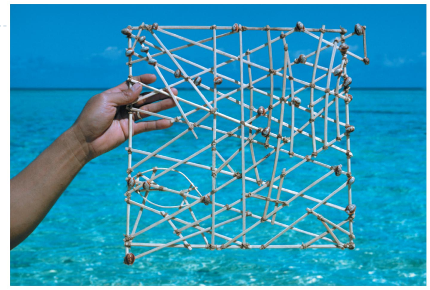
"On the Jisi day, the 7th day of the month, a big new star appeared in the company of the Ho star."



"On the Xinwei day the new star dwindled."

Bone or tortoiseshell inscription from the 14th century B.C.

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



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

Planets Known in Ancient Times

- Mercury (bottom)
  - Difficult to see; always close to Sun in sky
- Venus (above Mercury)
  - Very bright when visible; morning or evening "star"
- Mars (middle)
  - Noticeably red
- Jupiter (top)
  - Very bright
- Saturn (above Mars)
  - Moderately bright

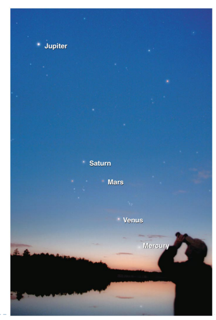


TABLE 3.1 The Seven Days of the Week and the Astronomical Objects They Honor

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; in English the correspondence is obvious for Sunday, "Moonday," and "Saturnday," while other day names come from Germanic gods.

Object	English	French	Spanish
Sun	Sunday	dimanche	domingo
Moon	Monday	lundi	lunes
Mars	Tuesday	mardi	martes
Mercury	Wednesday	mercredi	miércoles
Jupiter	Thursday	jeudi	jueves
Venus	Friday	vendredi	viernes
Saturn	Saturday	samedi	sábado

Days of the week were named for the Sun, Moon, and *visible* planets (*wandering star*).

The Gregorian Calendar

Julian Calendar

- Adopted by early Christian Church was off by about 11 minutes per year.
- By 1582 11 minutes added up and calendar was off by 10 days

Pope Gregory XIII

- 10 days were dropped from calendar bringing vernal equinox back to March 21 and leap years were added.
- Europe 10 days lost
Oct 4 to Oct 15 (1582)
- England & America 12 days lost
Sept 2 to Sept 14 (1752)
- Russia 1917 omitted 13 days

4.5 PHASES OF THE MOON

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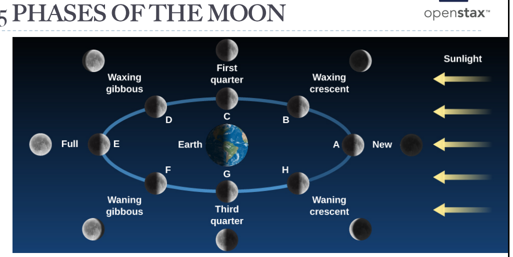
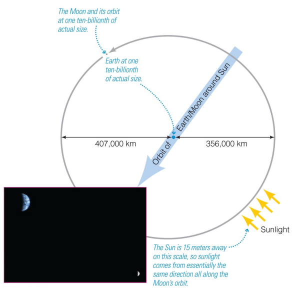


- **Phases of the Moon (Fig 4.14).** The appearance of the Moon changes over the course of a complete monthly cycle. The pictures of the Moon on the white circle show the perspective from space, with the Sun off to the right in a fixed position. The outer images show how the Moon appears to you in the sky from each point in the orbit. Imagine yourself standing on Earth, facing the Moon at each stage. In the position "New," for example, you are facing the Moon from the right side of Earth in the middle of the day. (Note that the distance of the Moon from Earth is not to scale in this diagram: the Moon is roughly 30 Earth-diameters away from us.) (credit: modification of work by NASA)

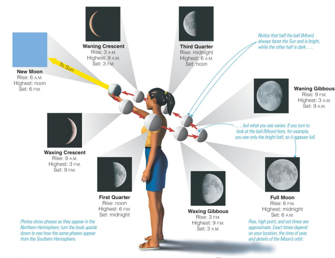
Why do we see phases of the Moon?



- Lunar phases are a consequence of the Moon's orbit around Earth
- The Moon does not shine. It reflects sun light.
- The orbital period is about 27 1/3 days **sidereal month**

Understanding Phases

- Half of the Moon is illuminated by the Sun and half is dark.
- During it's orbit we see different portions illuminated



Phases of the Moon: 29.5-day cycle

- new
- crescent
- first quarter
- gibbous
- full
- gibbous
- last quarter
- crescent

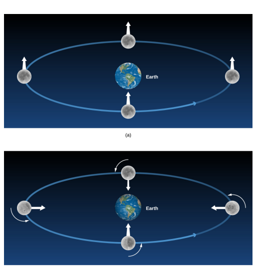
"Think Moonth"
solar month

waxing
- Right side is illuminated
- Moon visible in afternoon/evening
- Gets "fuller" and rises later each day

waning
- Left side is illuminated
- Moon visible in late night/morning
- Gets "less" and sets later each day

Is There a Dark Side of the moon?

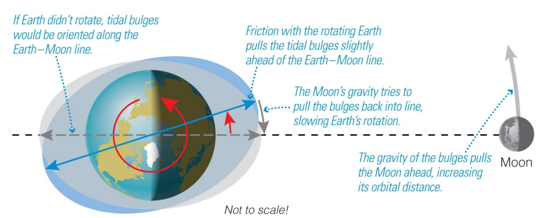
Synchronous rotation



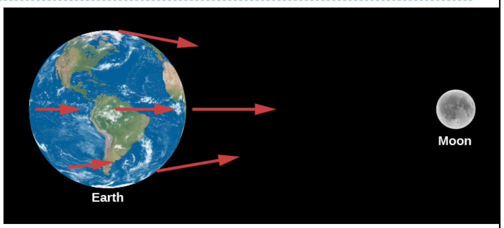
- **The Moon without and with Rotation (Fig 4.15).** In this figure, we stuck a white arrow into a fixed point on the Moon to keep track of its sides.
- The Moon rotates exactly once with each orbit
- The same side is always visible from Earth

Why does the moon always show us the same face?

- Moon once orbited faster; tidal friction caused it to "lock" in synchronous rotation.

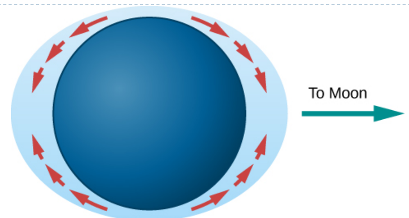


4.6 OCEAN TIDES AND THE MOON



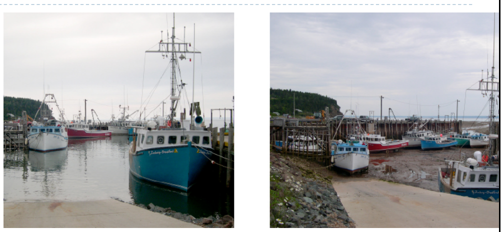
- Pull of the Moon (Fig 4.16) The Moon's differential attraction is shown on different parts of Earth. (Note that the differences have been exaggerated for educational purposes.)

The Formation of Tides



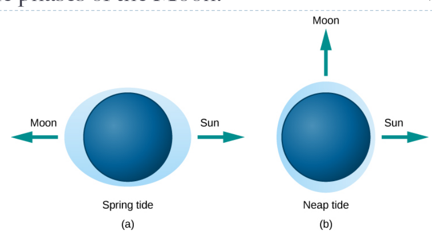
- Tidal Bulges in an "Ideal" Ocean (Fig 4.17). Differences in gravity cause tidal forces that push water in the direction of tidal bulges on Earth.

- The Moon's gravity pulls harder on near side of Earth than on far side.
- The difference in the Moon's gravitational pull stretches Earth (**Tidal Force**).



- High and Low Tides (fig 4.18). This is a side-by-side comparison of the Bay of Fundy in Canada at high and low tides.

The size of tides are connected to the phases of the Moon.



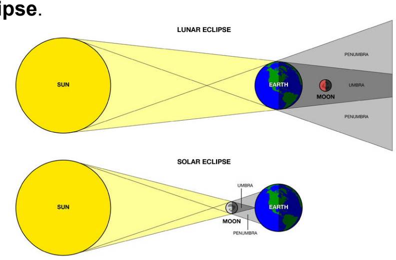
- Tides Caused by Different Alignments of the Sun and Moon (Fig 4.19).

(a) In spring tides, the Sun's and Moon's pulls reinforce each other (full & new moons).

(b) In neap tides, the Sun and the Moon pull at right angles to each other and the resulting tides are lower than usual (1st & 3rd quarter moons).

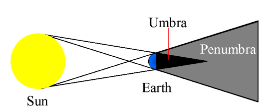
4.7 ECLIPSES OF THE SUN AND MOON

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



Areas of Eclipses

The Earth's Shadow



- **Umbra** *(shadow)*

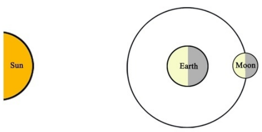
  a conical shadow excluding all light from a given source

- **Penumbra** *(almost, nearly)*

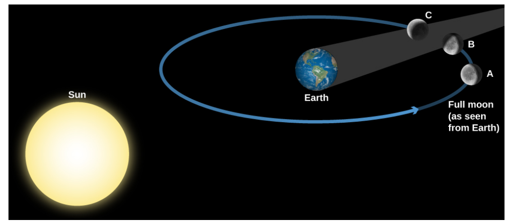
  a space of partial illumination

Lunar Eclipse Occurs at Full Moon

Alignment for a full moon.



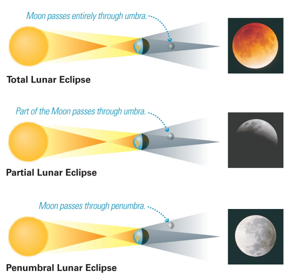
- A full moon occurs when the Sun and Moon align on opposite sides of the Earth.



- Geometry of a Lunar Eclipse (Fig 4.24). The Moon is shown moving through the different parts of Earth's shadow during a total lunar eclipse. Note that the distance the Moon moves in its orbit during the eclipse has been exaggerated here for clarity.

Types of Lunar Eclipses

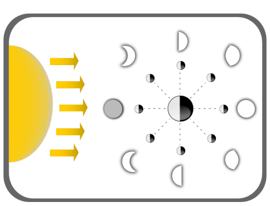
- Lunar eclipses can occur only at *full moon*.
- Lunar eclipses can be
  - Total
  - Partial
  - Penumbral



Total Eclipse

Phases of the Moon: 29.5-day cycle

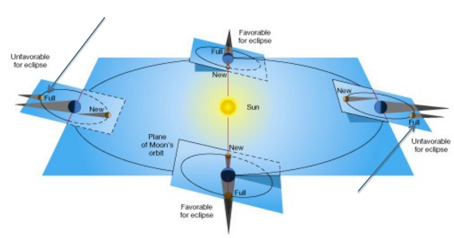
"Think Moonth"



- Why doesn't a lunar eclipse occur each month at every full moon?

The Moon's Orbital Tilt_

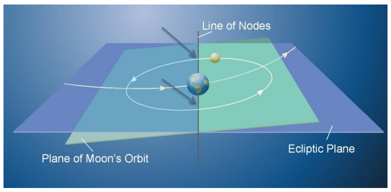
- The Moon's orbit is tilted 5° to the ecliptic plane.
- Thus, we have about two eclipse seasons each year.



Nodes_

A point of intersection.

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



Solar Eclipse

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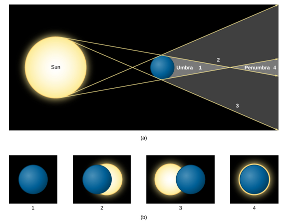

- **Solar Eclipse.** (a) The shadow cast by a spherical body (the Moon, for example) is shown. Notice the dark umbra and the lighter penumbra. Four points in the shadow are labeled with numbers. In (b) you see what the Sun and Moon would look like in the sky at the four labeled points. At position 1, you see a total eclipse. At positions 2 and 3, the eclipse is partial. At position 4, the Moon is farther away and thus cannot cover the Sun completely; a ring of light thus shows around the Sun, creating what is called an "annular" eclipse.

Solar Eclipses Occur at New Moon

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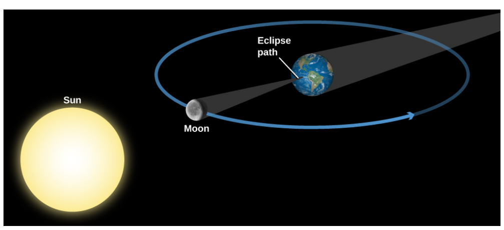
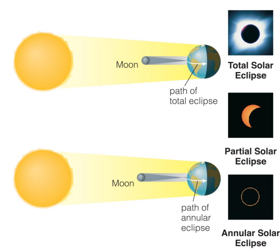


- **Geometry of a Total Solar Eclipse (fig 4.22).** Note that our diagram is not to scale. The Moon blocks the Sun during new moon phase as seen from some parts of Earth and casts a shadow on our planet.

Types of Solar Eclipses

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



a The three types of solar eclipse. The diagrams show the Moon's shadow falling on Earth; note the dark central umbra surrounded by the much lighter penumbra.

WARNING: Never look at the Sun

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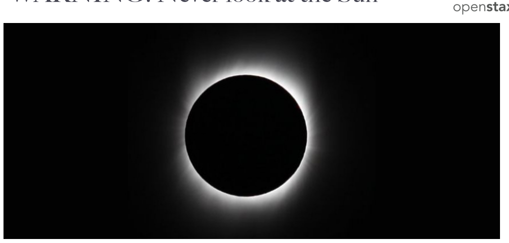
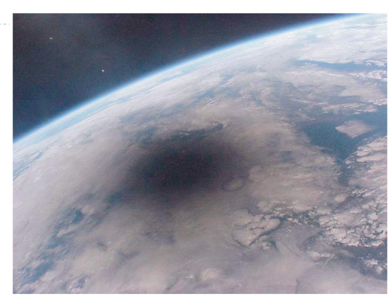


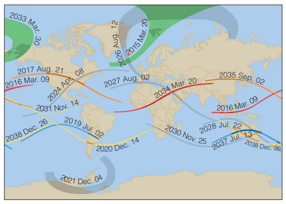
- **The Sun's Corona (Fig 4.23).** The corona (thin outer atmosphere) of the Sun is visible during a total solar eclipse. (It looks more extensive in photographs than it would to the unaided eye.) (credit: modification of work by Lutfar Rahman Nirjhar)



b This photo from Earth orbit shows the Moon's shadow (umbra) on Earth during a total solar eclipse. Notice that only a small region of Earth experiences totality at any one time.

Predicting Eclipses

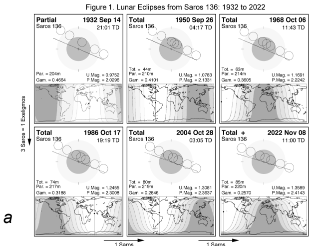
- Eclipses recur with the 18-year, 11 1/3-day **saros cycle**, but type (e.g., partial, total) and location may vary.



Predicting Eclipses

- **Saros cycle** 6585.3 days or 18yrs 11 1/3 days.
  - Synodic Month
    223 New Moons
  - Anomalistic Month
    239 Perigees
  - Draconic Month
    242 Nodes

Figure 1. Lunar Eclipses from Saros 136: 1932 to 2022



from Five Millennium Canon of Lunar Eclipses, Espenak & Meeus (2009)

Two eclipses separated by a Saros cycle share very similar geometries

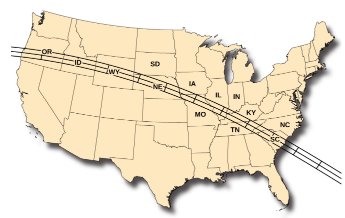
Predicting Eclipses_

Eclipses of the Moon: 2014 - 2020				
Date	Eclipse Type	Umbral Magnitude	Eclipse Duration	Geographic Region of Eclipse Visibility
2014 Apr 15	Total	1.291	03h35m **01h18m**	Aus., Pacific, Americas
2014 Oct 08	Total	1.166	03h20m **00h59m**	Asia, Aus., Pacific, Americas
2015 Apr 04	Total	1.001	03h29m **00h05m**	Asia, Aus., Pacific, Americas
2015 Sep 28	Total	1.276	03h20m **01h12m**	e Pacific, Americas, Europe, Africa, w Asia
2016 Mar 23	Penumbral	-0.312	-	Asia, Aus., Pacific, w Americas
2016 Sep 16	Penumbral	-0.064	-	Europe, Africa, Asia, Aus., w Pacific
2017 Feb 11	Penumbral	-0.035	-	Americas, Europe, Africa, Asia
2017 Aug 07	Partial	0.246	01h55m	Europe, Africa, Asia, Aus.
2018 Jan 31	Total	1.315	03h23m **01h16m**	Asia, Aus., Pacific, w N.America
2018 Jul 27	Total	1.609	03h55m **01h43m**	S.America, Europe, Africa, Asia, Aus.
2019 Jan 21	Total	1.195	03h17m **01h02m**	c Pacific, Americas, Europe, Africa
2019 Jul 16	Partial	0.653	02h58m	S.America, Europe, Africa, Asia, Aus.
2020 Jan 10	Penumbral	-0.116	-	Europe, Africa, Asia, Aus.
2020 Jun 05	Penumbral	-0.405	-	Europe, Africa, Asia, Aus.
2020 Jul 05	Penumbral	-0.644	-	Americas, sw Europe, Africa
2020 Nov 30	Penumbral	-0.262	-	Asia, Aus., Pacific, Americas

- Eclipse Chart

The Great American Eclipse

openstax



- **2017 Total Solar Eclipse (Fig 4.25).** This map of the United States shows the path of the total solar eclipse of 2017. On August 21, 2017, the shadow will first cross onto the West Coast near Portland, Oregon, traversing the United States and exiting the East Coast in South Carolina approximately 90 minutes later, covering about 3000 miles in the process. (credit: modification of work by NASA)