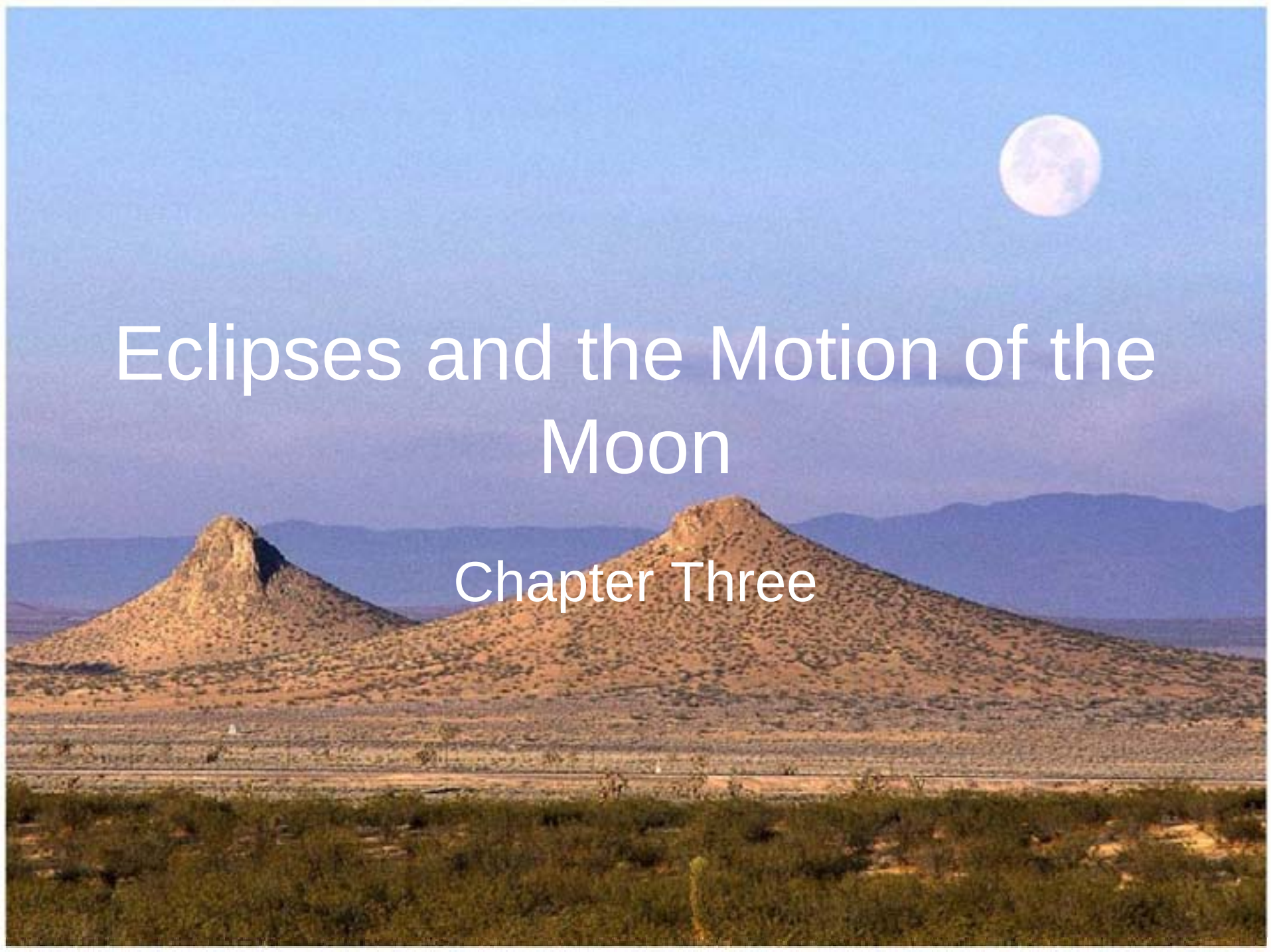


Eclipses and the Motion of the Moon

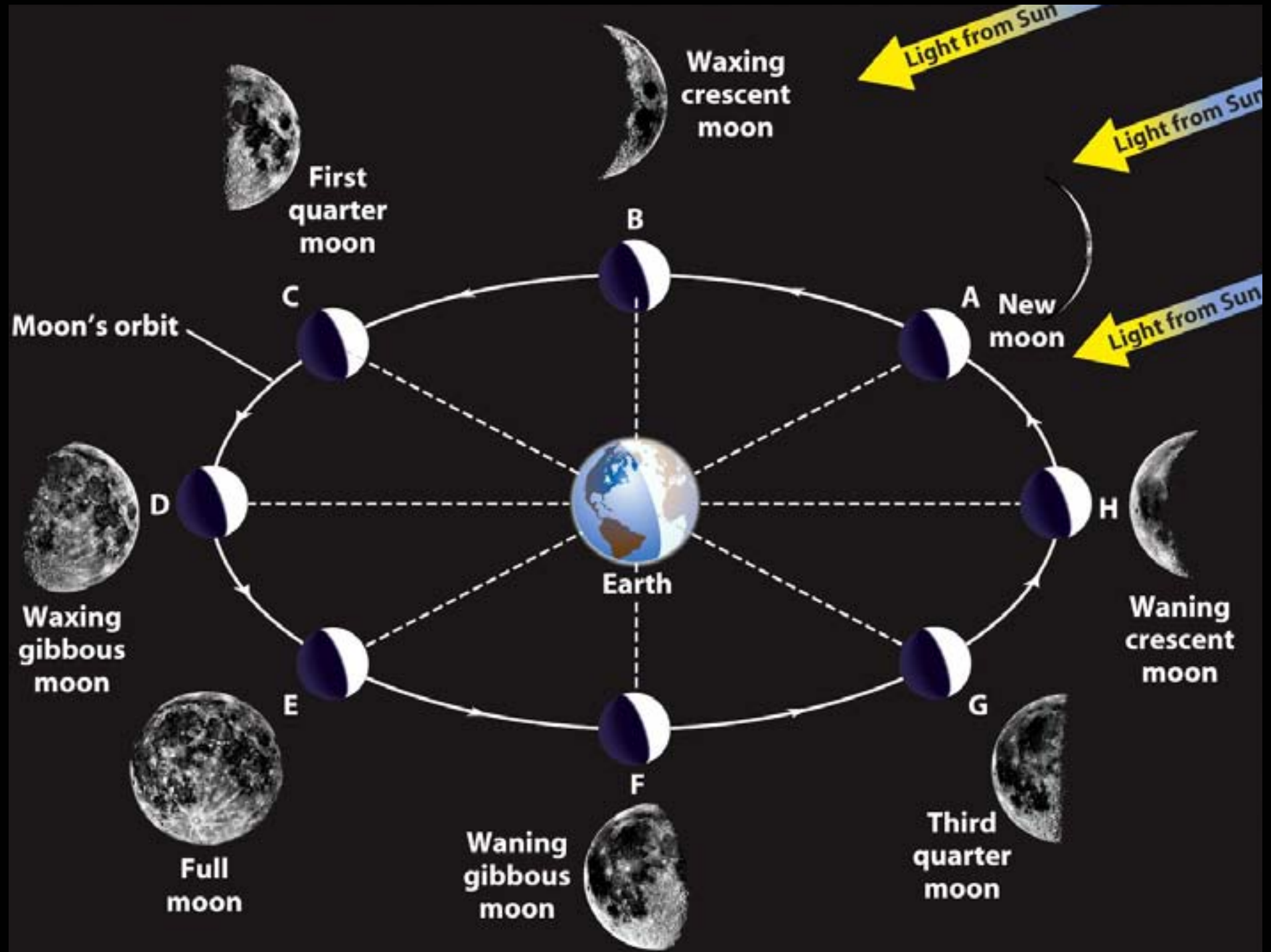
Chapter Three

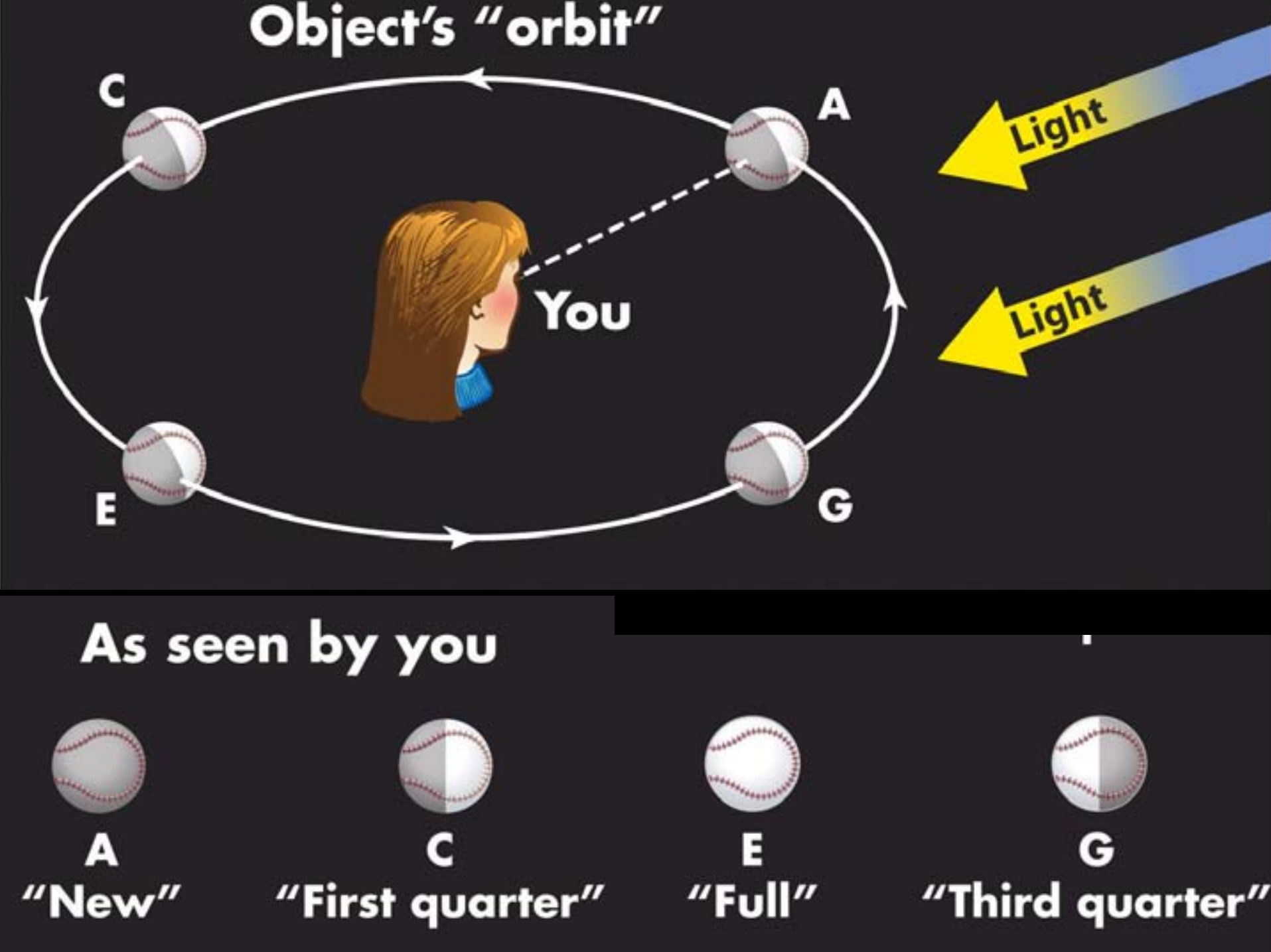
Guiding Questions

1. Why does the Moon go through phases?
2. Is there such a thing as the “dark side of the Moon”?
3. What is the difference between a lunar eclipse and a solar eclipse?
4. How often do lunar eclipses happen? When one is taking place, where do you have to be to see it?
5. How often do solar eclipses happen? Why are they visible only from certain special locations on Earth?
6. How did ancient astronomers deduce the sizes of the Earth, the Moon, and the Sun?

The phases of the Moon are caused by its orbital motion

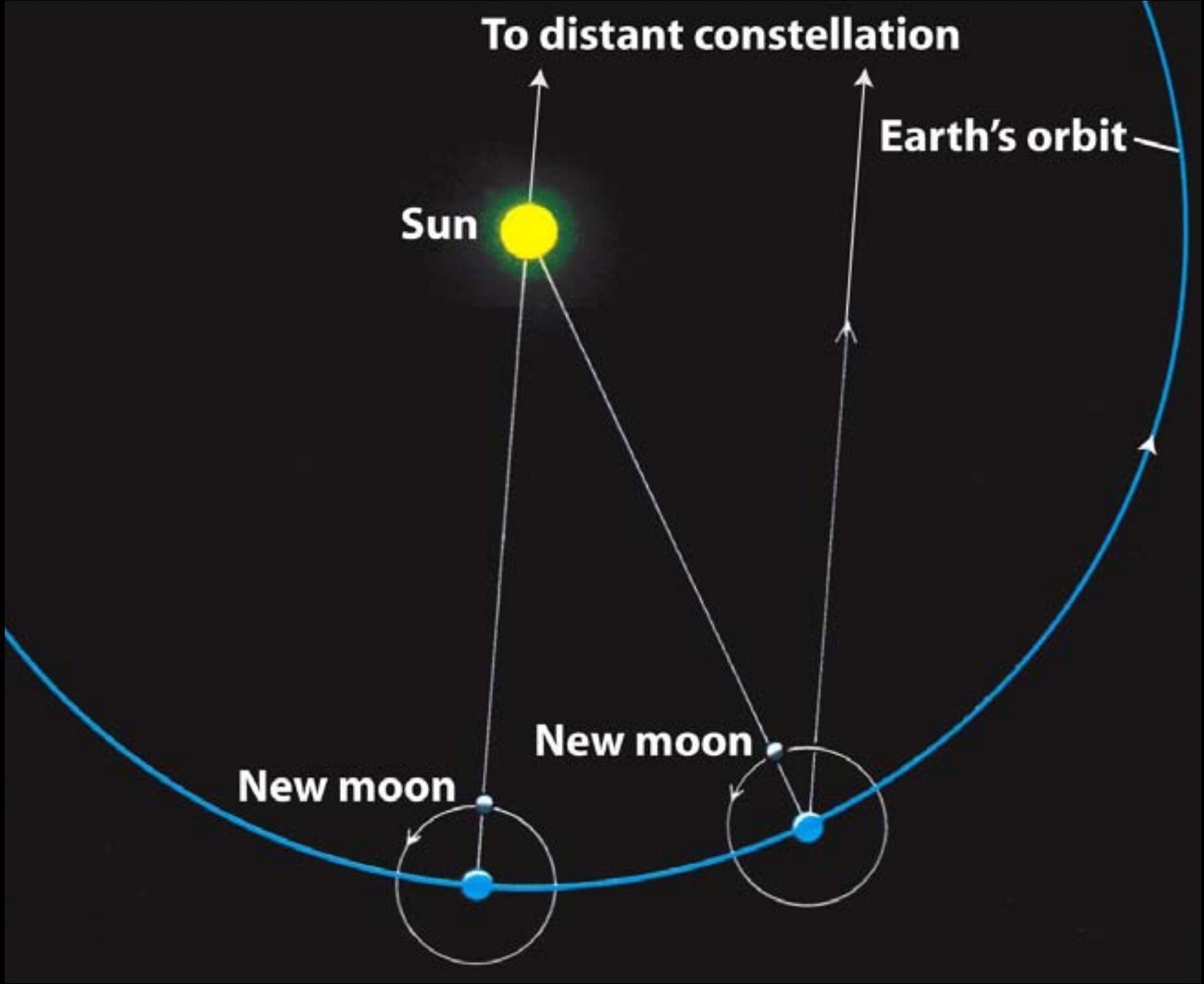
- The phases of the Moon occur because light from the Moon is actually reflected sunlight
- As the relative positions of the Earth, the Moon, and the Sun change, we see more or less of the illuminated half of the Moon.


Light from Sun
Light from Sun
Light from Sun
Waxing crescent moon
First quarter moon
B
C
A
New moon
Moon's orbit
D
H
Earth
Waxing gibbous moon
Waning crescent moon
E
G
F
Full moon
Waning gibbous moon
Third quarter moon

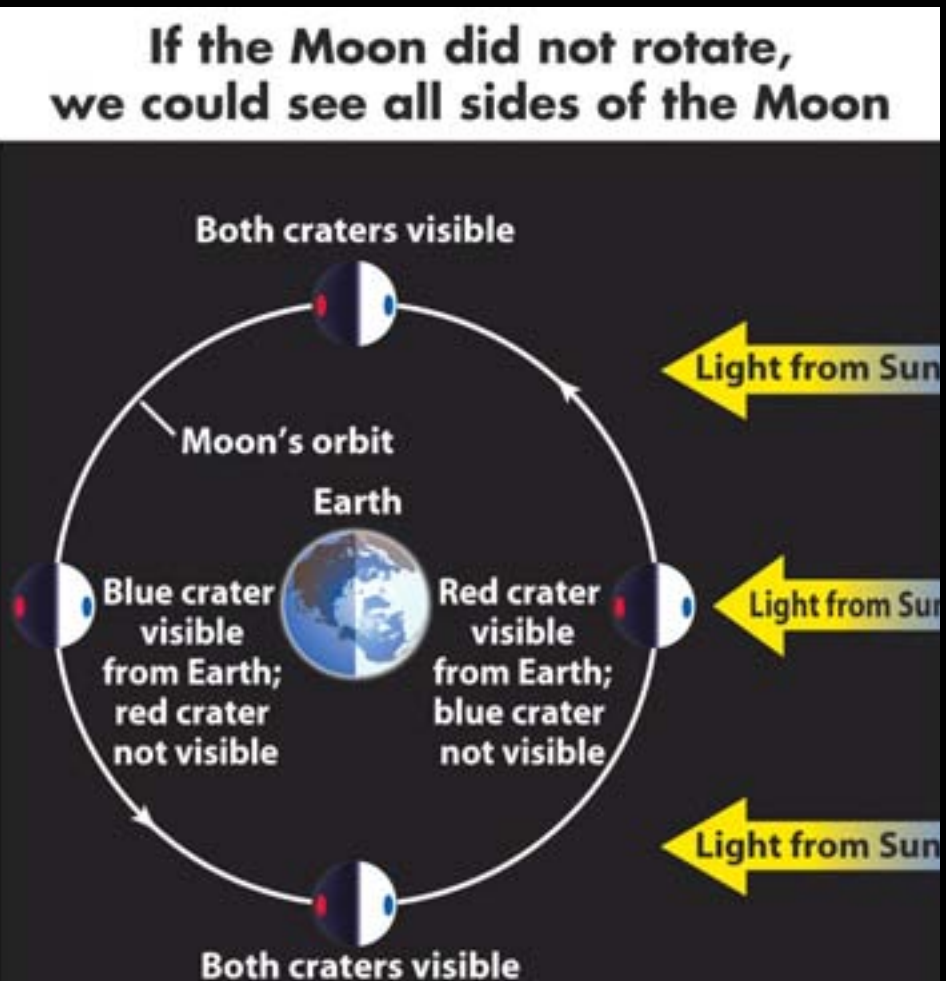

Object's "orbit"
C
A
Light
You
Light
E
G
As seen by you
A
"New"
C
"First quarter"
E
"Full"
G
"Third quarter"

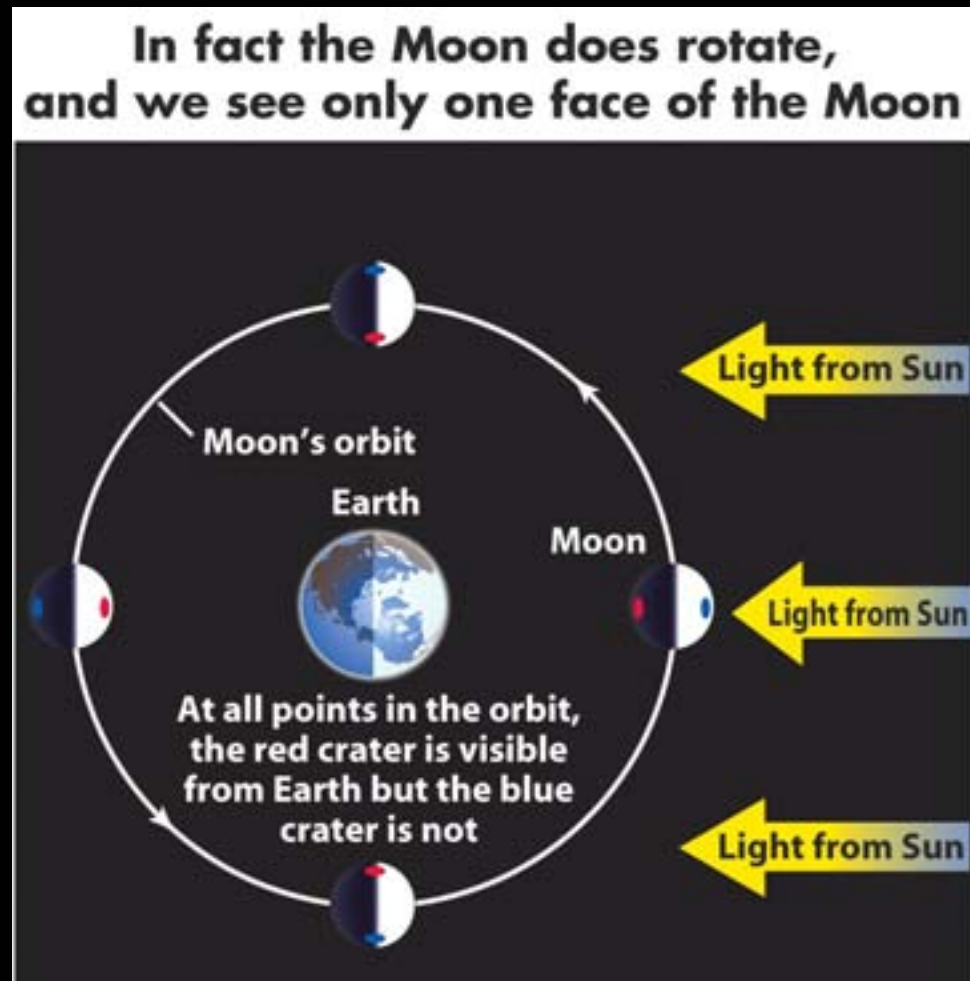
Time and the Moon

- Two types of months are used in describing the motion of the Moon.
- With respect to the stars, the Moon completes one orbit around the Earth in a sidereal month, averaging 27.32 days.
- The Moon completes one cycle of phases (one orbit around the Earth with respect to the Sun) in a synodic month, averaging 29.53 days.

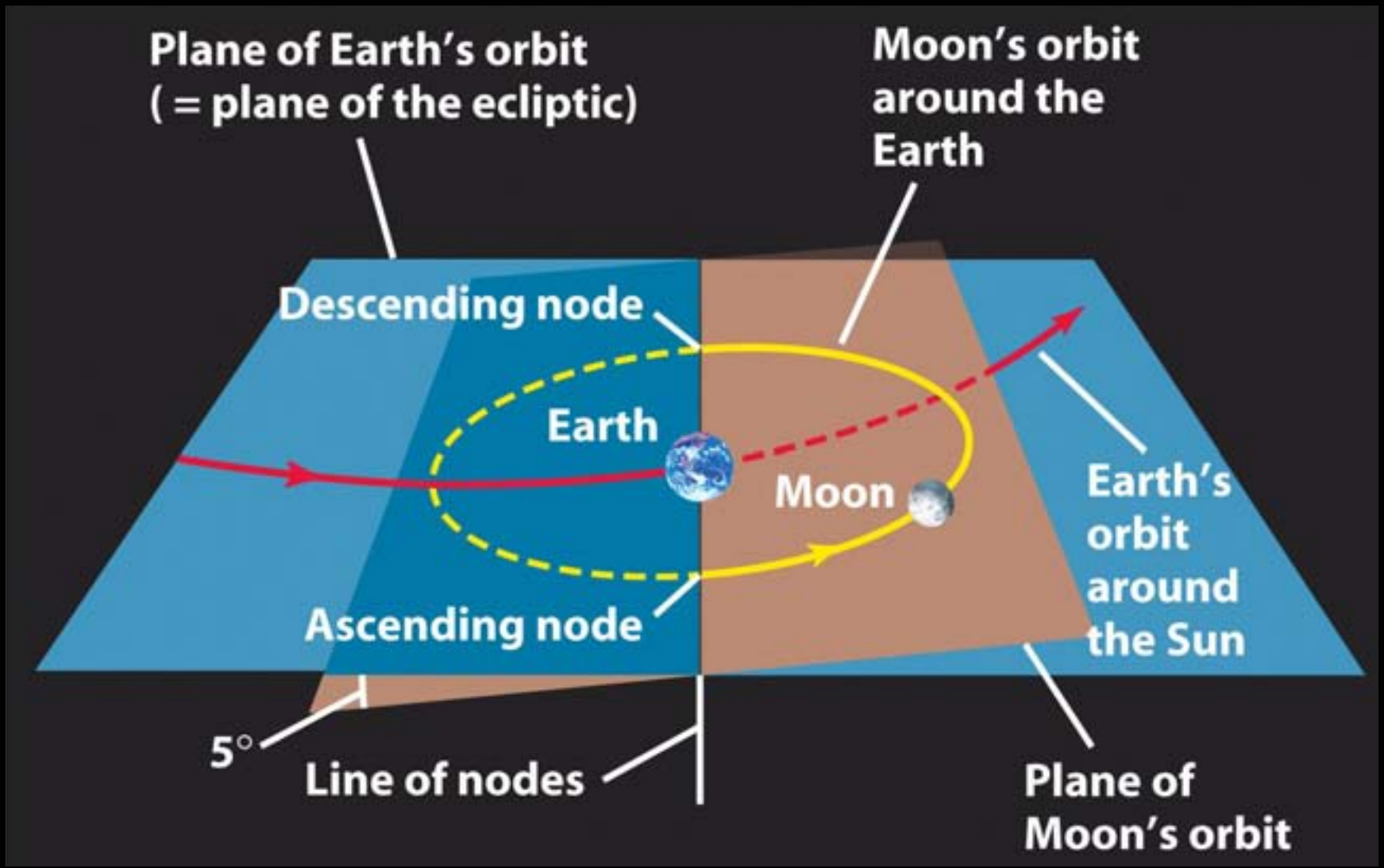

To distant constellation
Earth's orbit
Sun
New moon
New moon

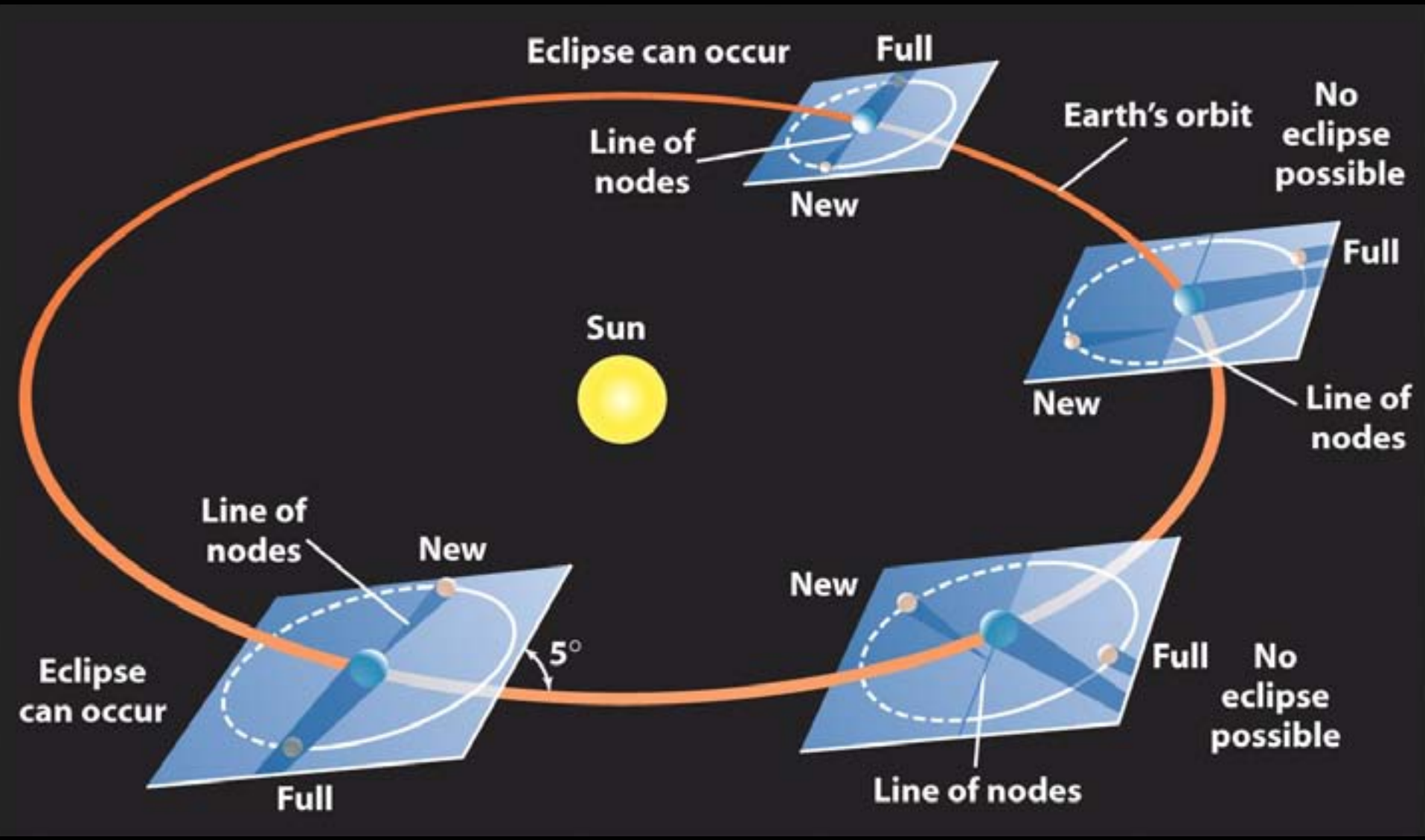
The Moon's rotation always keeps the same face toward the Earth due to synchronous rotation



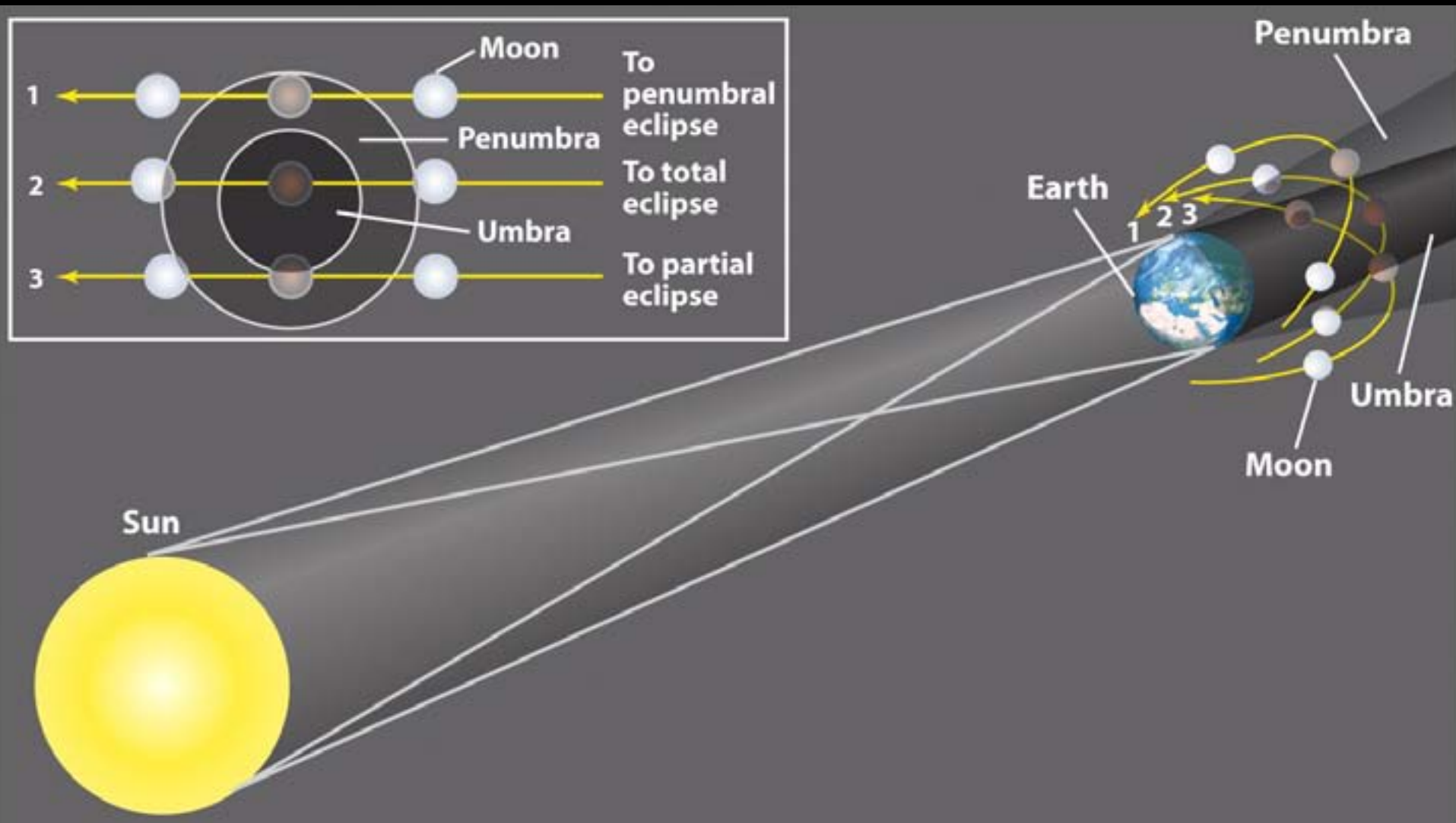


Eclipses occur only when the Sun and Moon are both on the line of nodes




Eclipse can occur
Full
Line of nodes
New
Earth's orbit
No eclipse possible
Full
Sun
New
Line of nodes
Line of nodes
New
New
5°
Full
No eclipse possible
Eclipse can occur
Full
Line of nodes

Lunar eclipses can be either total, partial, or penumbral, depending on the alignment of the Sun, Earth, and Moon



Time Lapse Photographic Sequence of a Lunar Eclipse

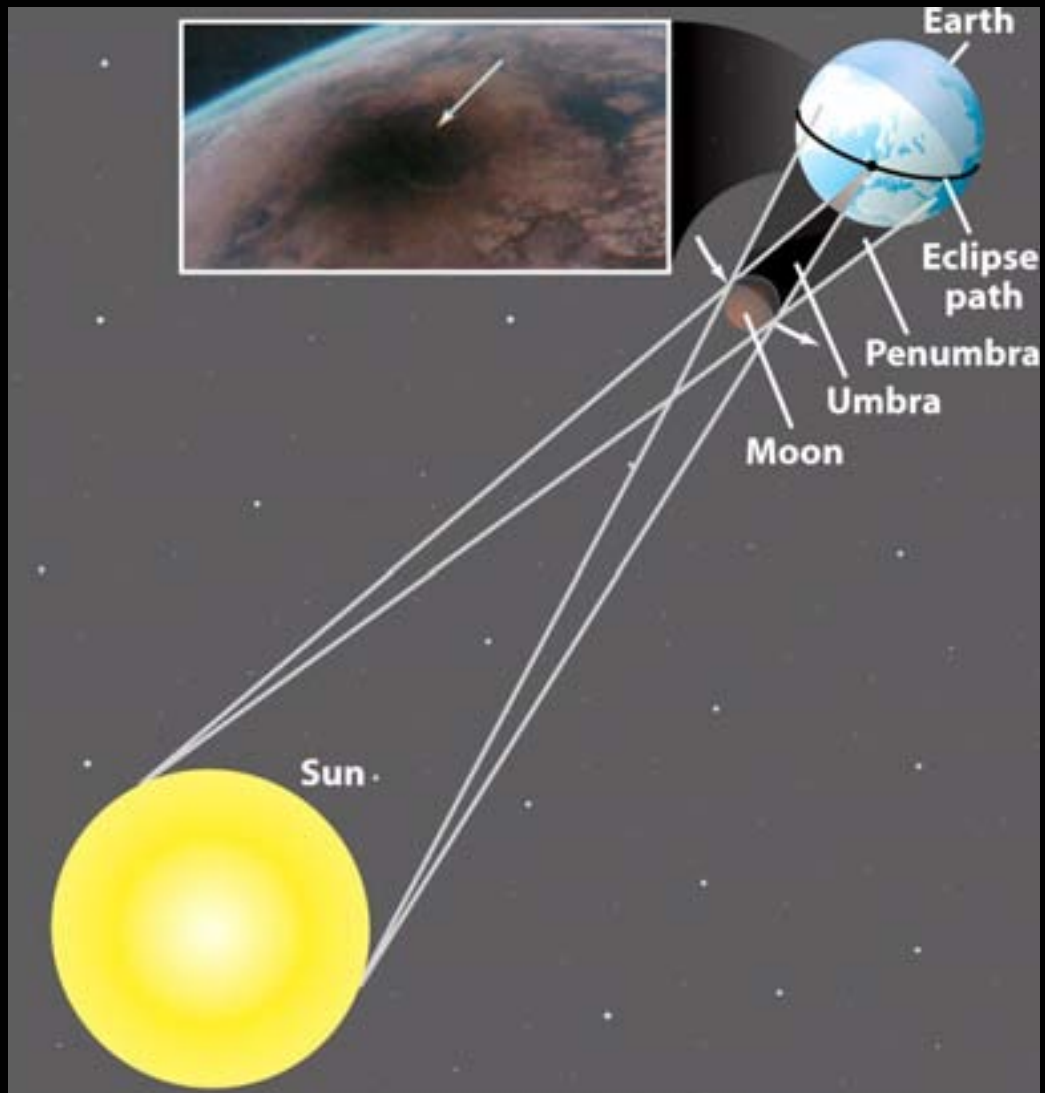
Future Lunar Eclipses

table 3-1 **Lunar Eclipses, 2004-2008**

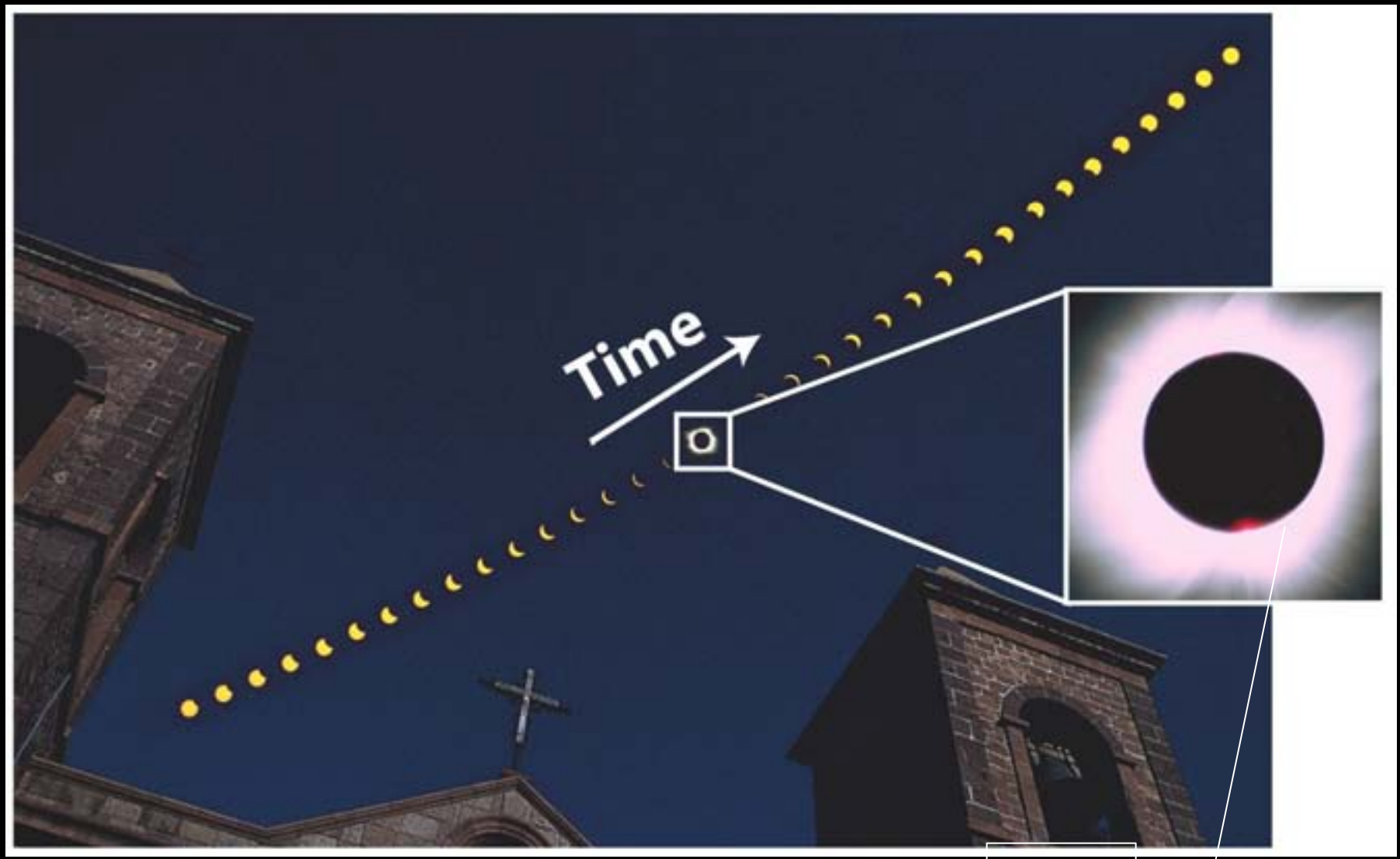
Date	Type	Where visible	Duration of totality (h = hours, m = minutes)
2004 May 4	Total	South America, Europe, Africa, Asia, Australia	1h 16m
2004 October 28	Total	Americas, Europe, Africa, central Asia	1h 21m
2005 April 24	Penumbral	Eastern Asia, Australia, Pacific, Americas	—
2005 October 17	Partial	Asia, Australia, Pacific, North America	—
2006 March 14	Penumbral	Americas, Europe, Africa, Asia	—
2006 September 7	Partial	Europe, Africa, Asia, Australia	—
2007 March 3	Total	Americas, Europe, Africa, Asia	1h 14m
2007 August 28	Total	Eastern Asia, Australia, Pacific, Americas	1h 31m
2008 February 21	Total	Central Pacific, Americas, Europe, Africa	51m
2008 August 16	Partial	South America, Europe, Africa, Asia, Australia	—

**Eclipse predictions by Fred Espenak, NASA/Goddard Space Flight Center. All dates are given in standard astronomical format: year, month, day.*

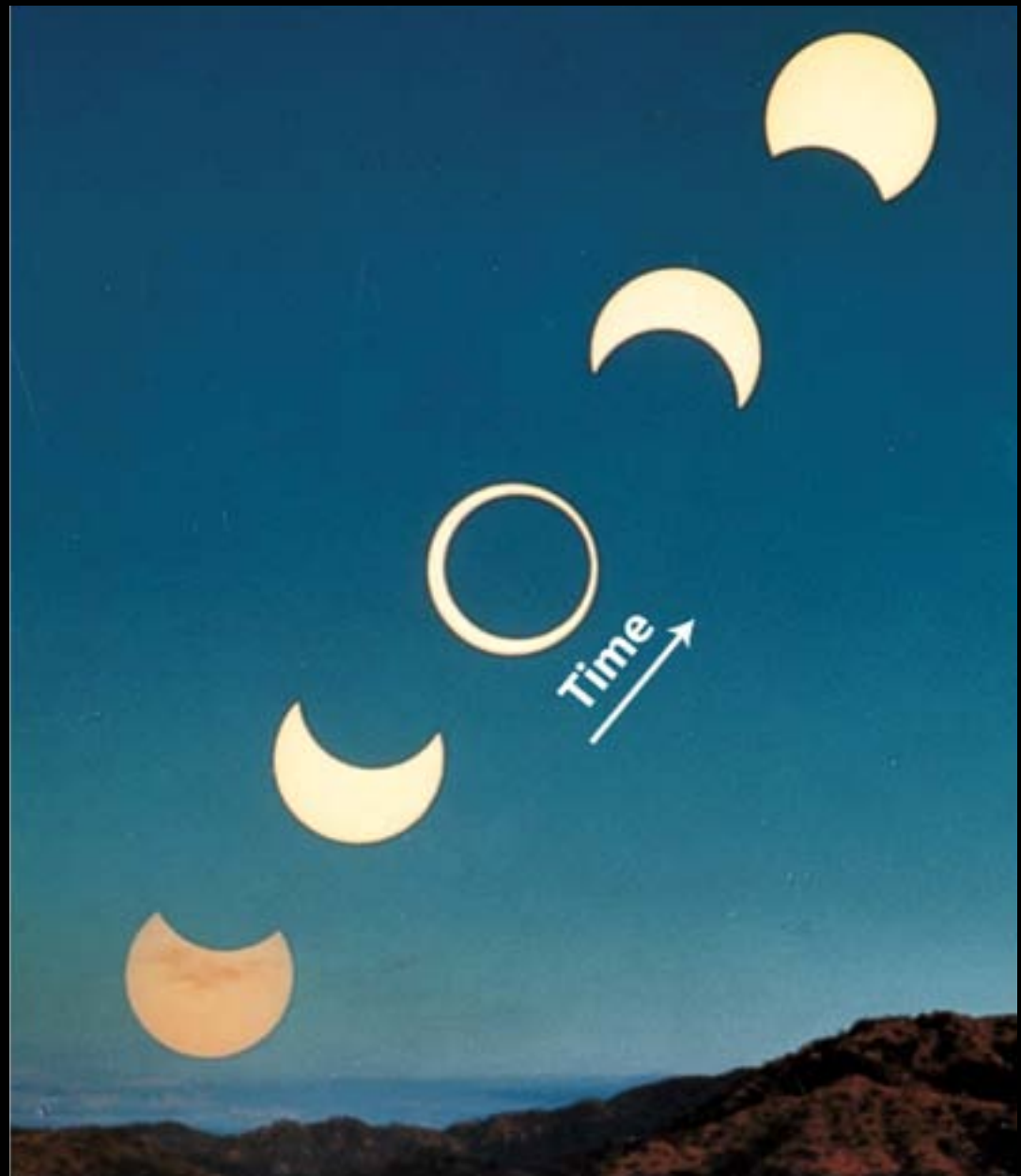
Solar eclipses can be either total, partial, or annular, depending on the alignment of the Sun, Earth, and Moon



Time Lapse Photo-sequence of a Total Eclipse



An Example of an Annular Eclipse



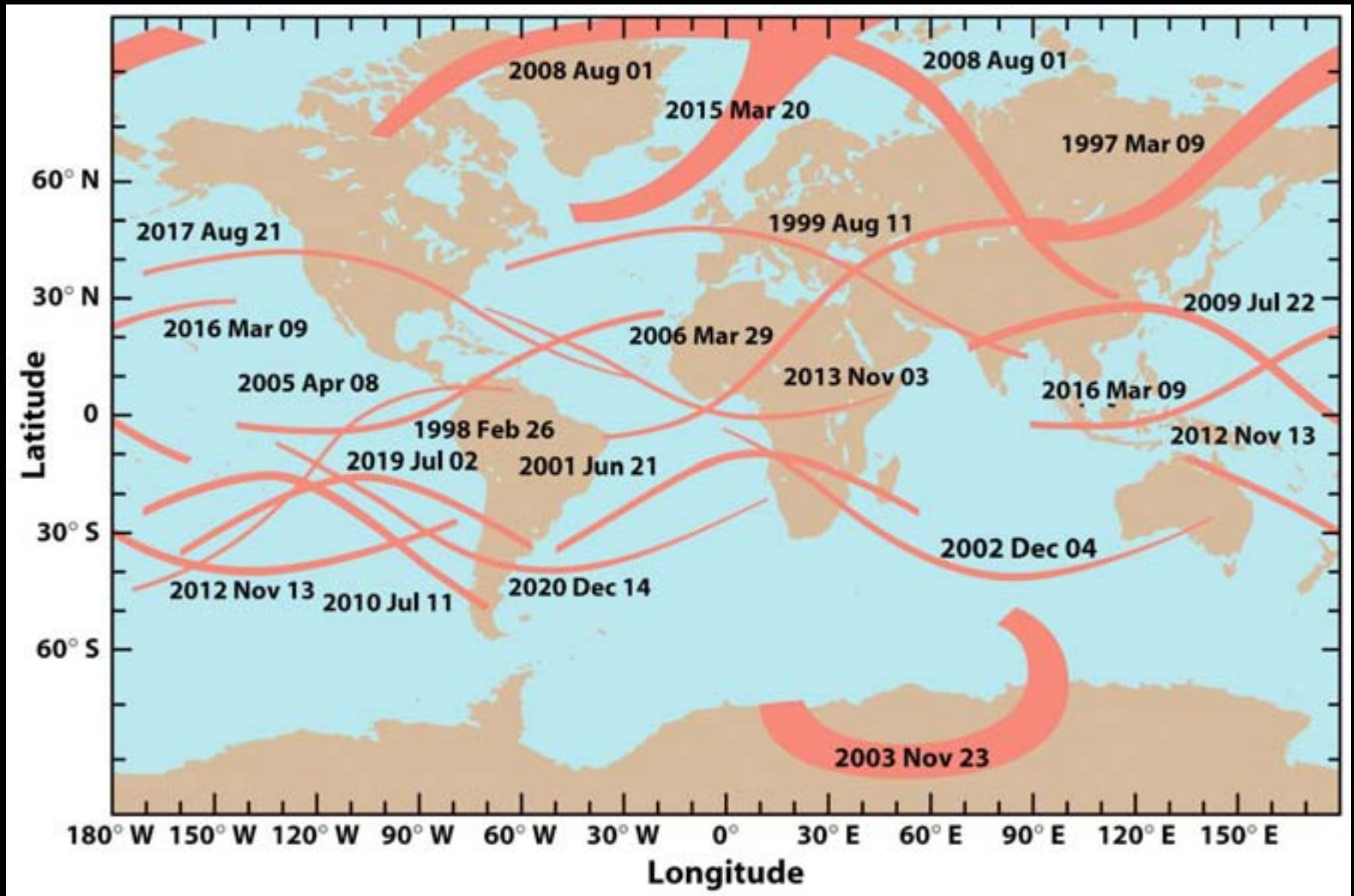
Future Solar Eclipses

table 3-2 **Solar Eclipses, 2004–2008**

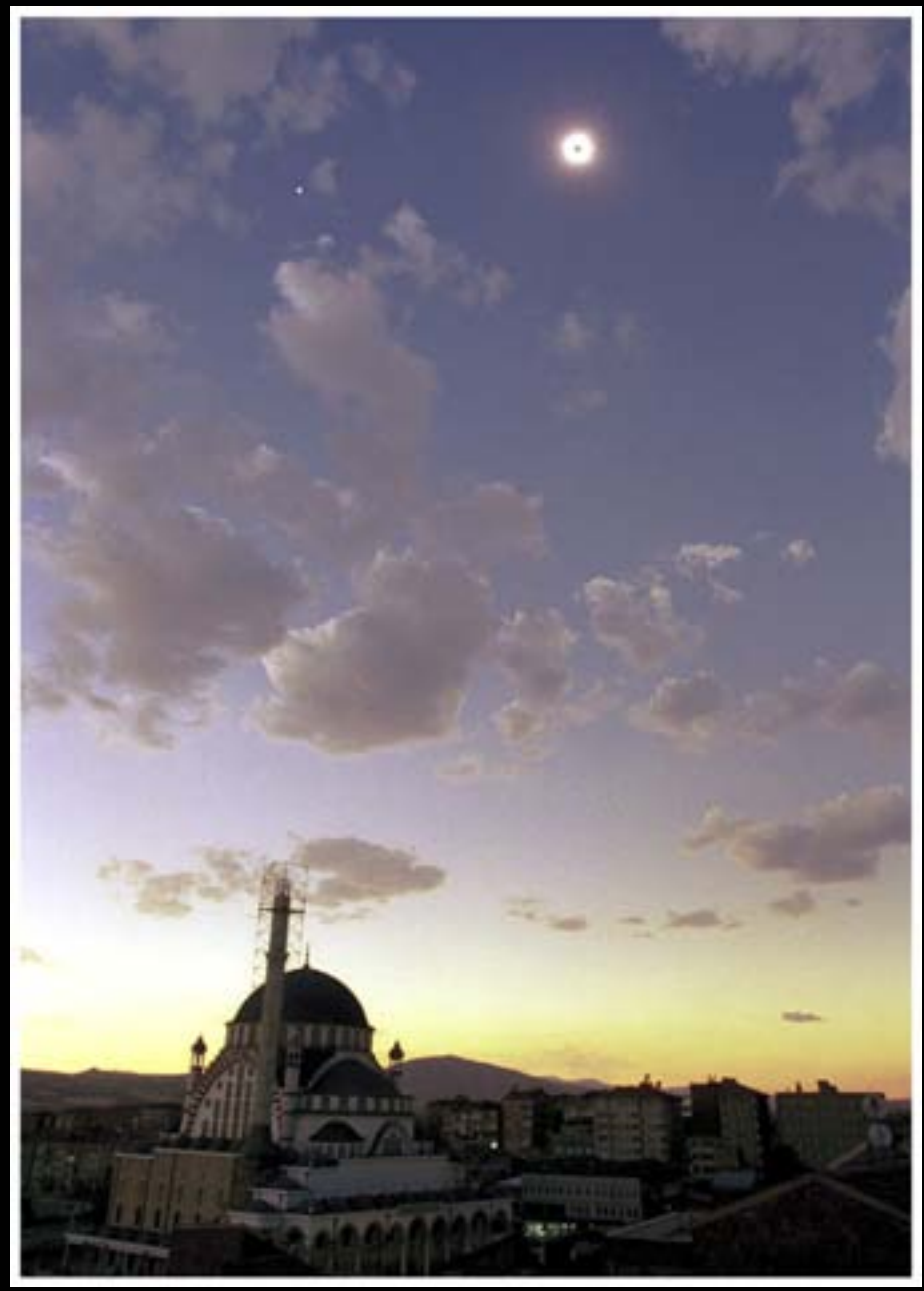
Date	Type	Where visible	Notes
2004 April 19	Partial	Antarctica, southern Africa	74% eclipsed
2004 October 14	Partial	Northeast Asia, Hawaii, Alaska	93% eclipsed
2005 April 8	Annular and Total	New Zealand, North and South America	Annular along part of path; maximum duration of totality 0m 42s
2005 October 3	Annular	Europe, Africa, southern Asia	—
2006 March 29	Total	Africa, Europe, western Asia	Maximum duration of totality 4m 7s
2006 September 22	Annular	South America, western Africa, Antarctica	—
2007 March 19	Partial	Asia, Alaska	87% eclipsed
2007 September 11	Partial	South America, Antarctica	75% eclipsed
2008 February 7	Annular	Antarctica, eastern Australia, New Zealand	—
2008 August 1	Total	Northeast North America, Europe, Asia	Maximum duration of totality 2m 27s

Eclipse predictions by Fred Espenak, NASA/Goddard Space Flight Center. All dates are given in standard astronomical format: year, month, day.

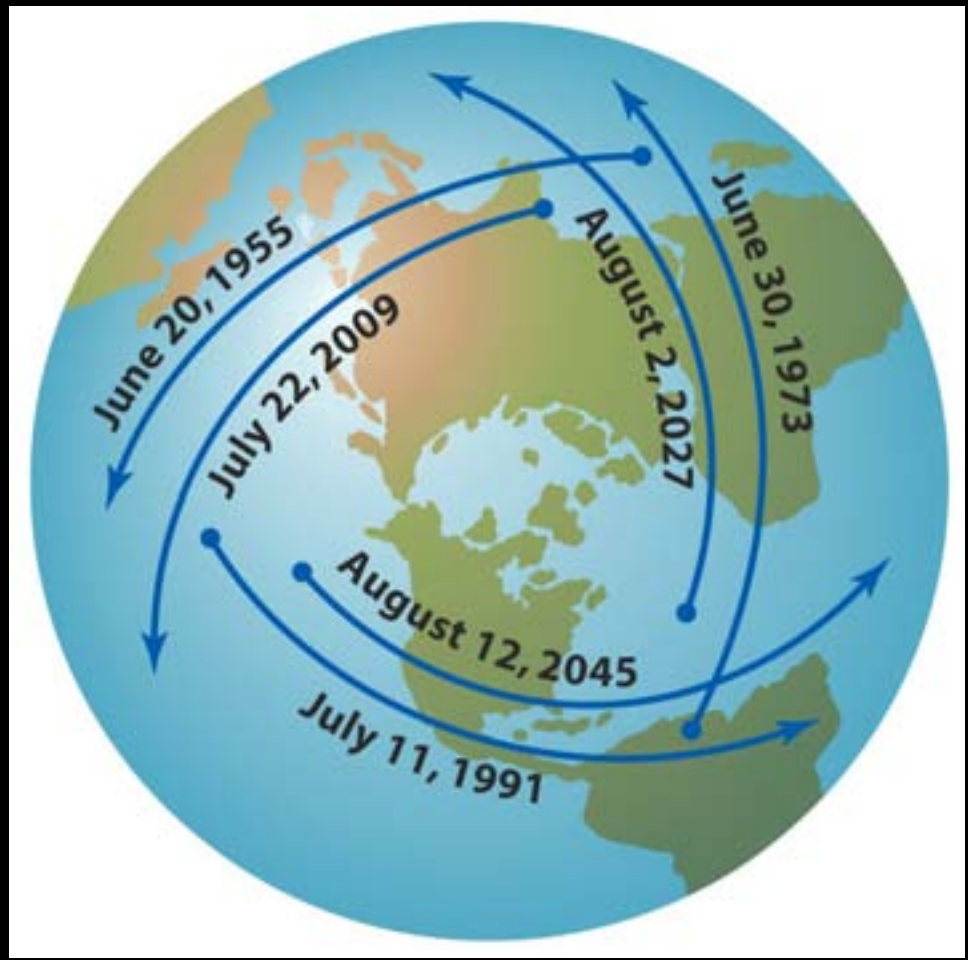
Paths of Future Solar Eclipses



Another Solar Eclipse

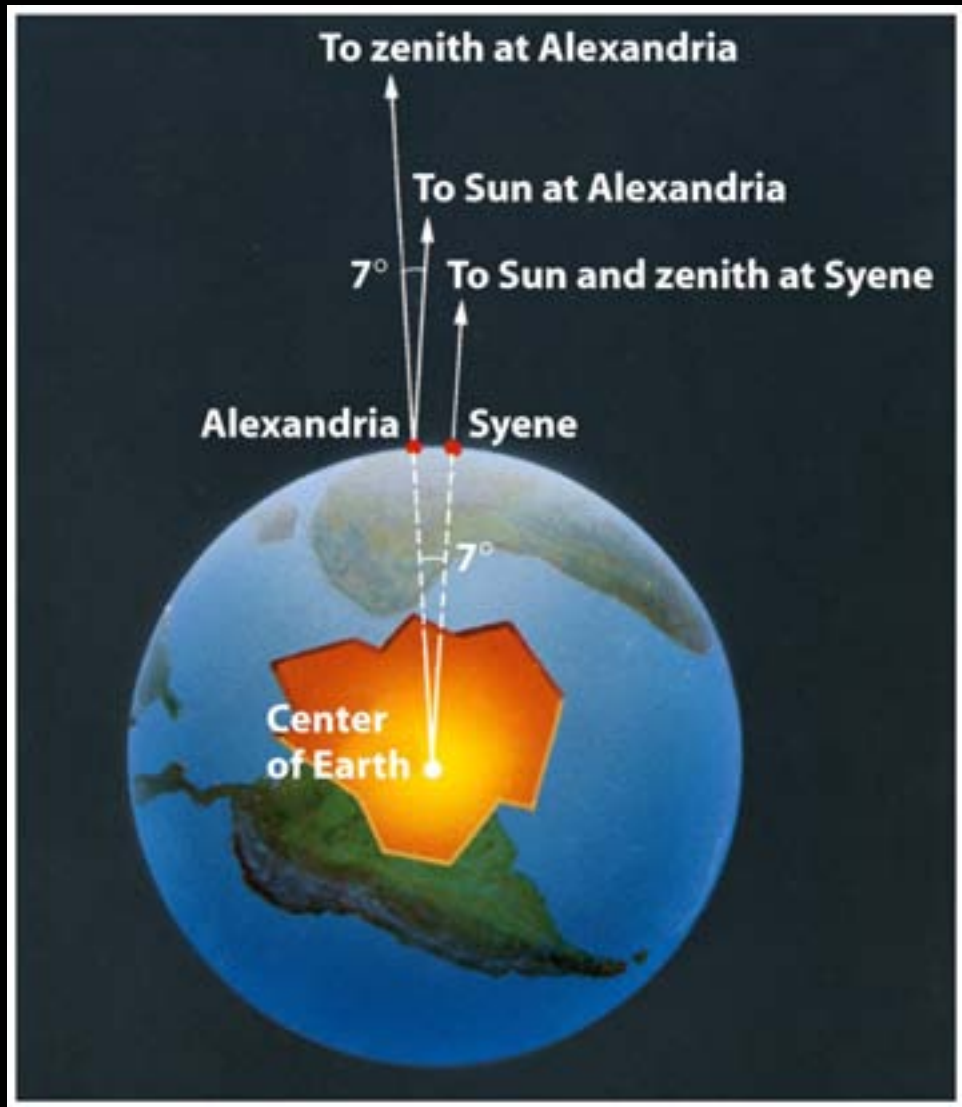


The Saros Cycle



Ancient astronomers measured the size of the Earth and attempted to determine distances to the Sun and Moon

- Observations
  - In the town of Syene, the Sun shone directly down a vertical shafts on the summer solstice
  - In Alexandria, the position of the sun changed by 7° or about one-fiftieth of a complete circle
- Conclusion
  - Around 200 B.C., the Greek astronomer Eratosthenes used 50 x the distance between Alexandria and Syene to get a circumference of the earth of about 42000 km (the actual is about 40000 kilometers)



- Aristarchus knew that the Sun, Moon, and Earth form a right triangle at first and third quarter phases
- Using geometrical arguments, he calculated the relative lengths of the sides of these triangles, thereby obtaining the relative distances to the Sun and Moon

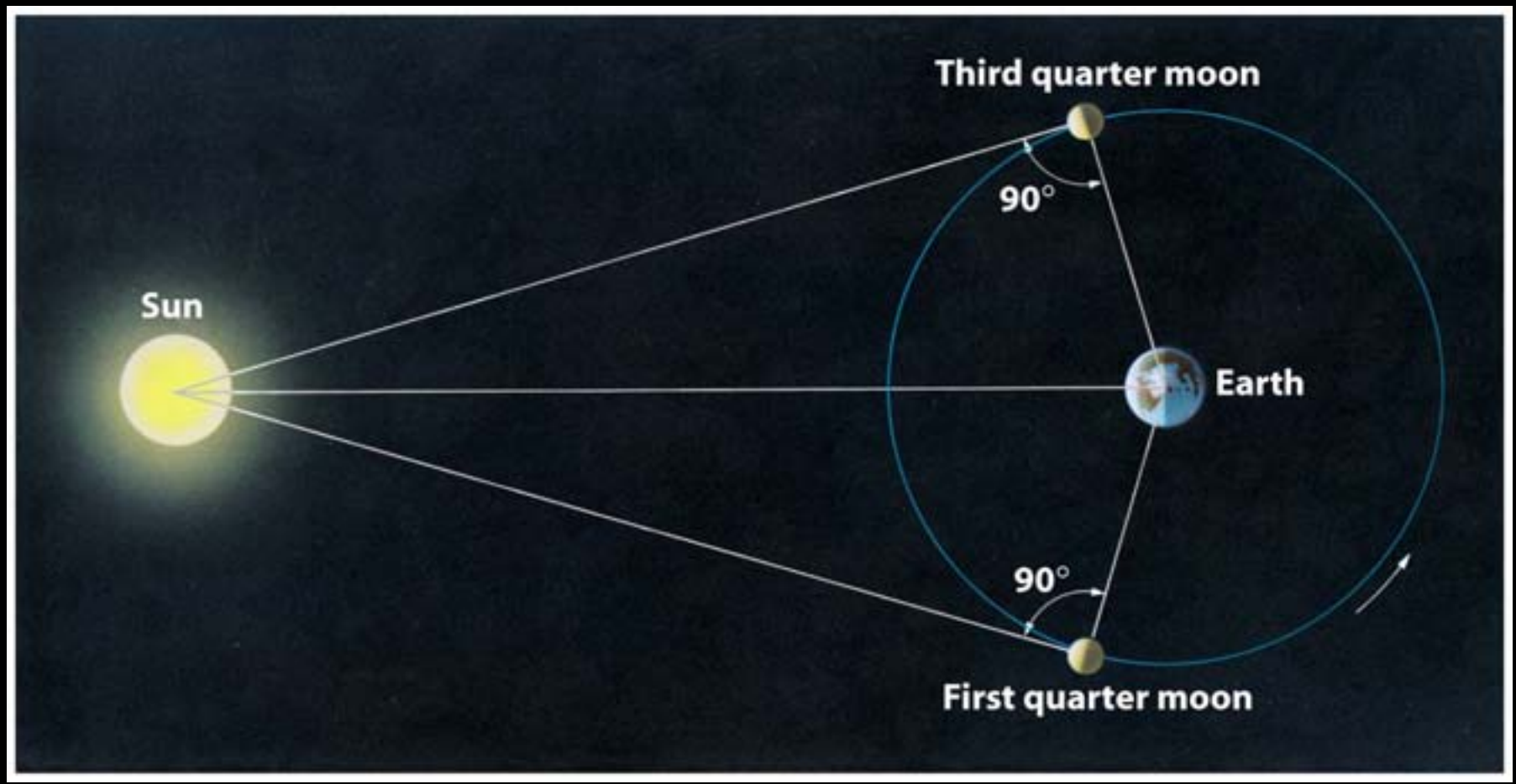


table 3-3 Comparison of Ancient and Modern Astronomical Measurements

	Ancient measure (km)	Modern measure (km)
Earth's diameter	13,000	12,756
Moon's diameter	4,300	3,476
Sun's diameter	9×10^4	1.39×10^6
Earth-Moon distance	4×10^5	3.84×10^5
Earth-Sun distance	10^7	1.50×10^8

Key Words

- annular eclipse
- apogee
- eclipse
- eclipse path
- eclipse year
- first quarter moon
- full moon
- line of nodes
- lunar eclipse
- lunar phases
- new moon
- partial lunar eclipse
- partial solar eclipse
- penumbra
- penumbral eclipse
- perigee
- plane of the ecliptic
- saros
- sidereal month
- solar corona
- solar eclipse
- synchronous rotation
- synodic month
- third quarter moon
- totality
- total lunar eclipse
- total solar eclipse
- umbra
- waning crescent moon
- waning gibbous moon
- waxing crescent moon
- waxing gibbous moon