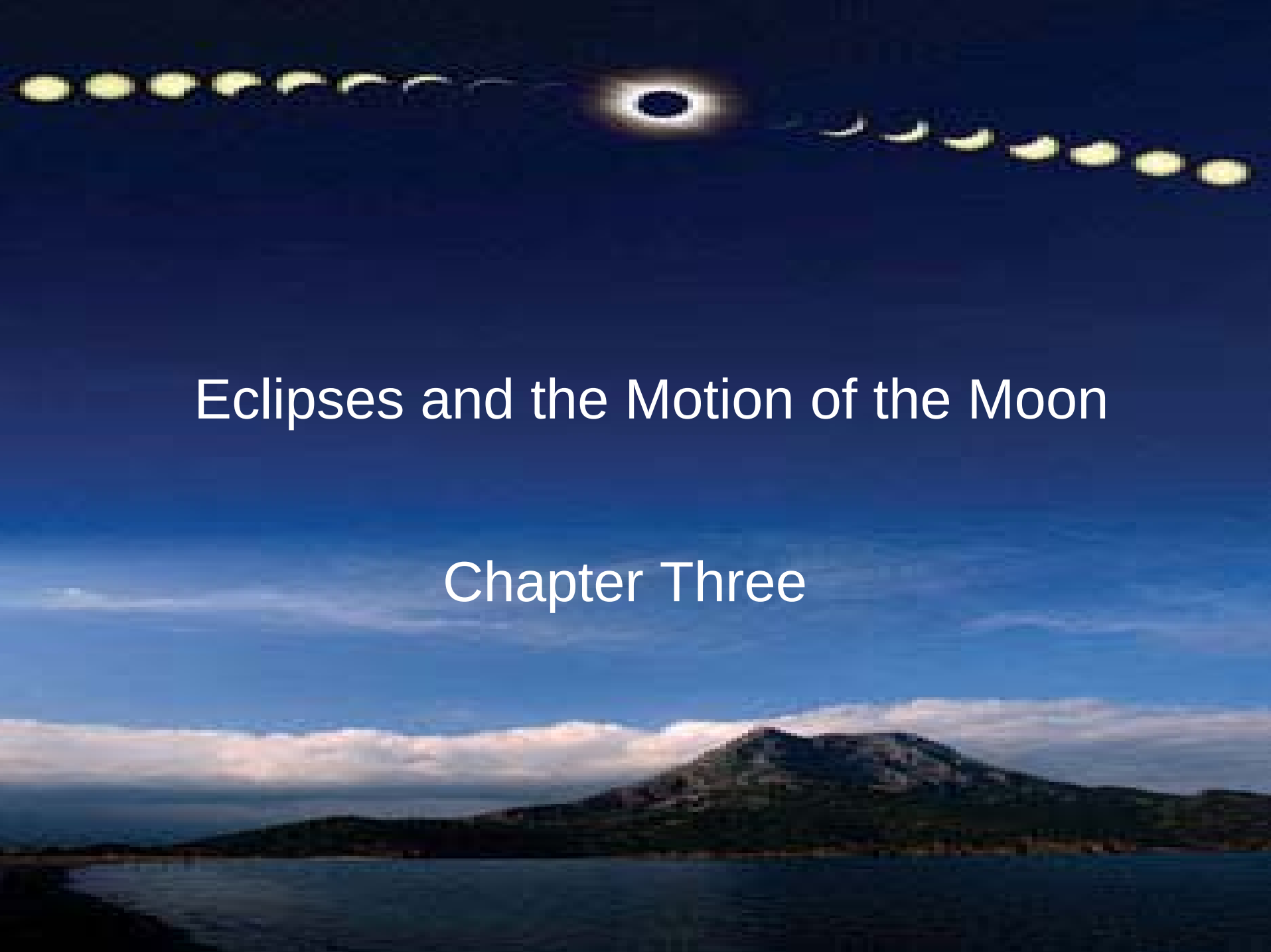


Eclipses and the Motion of the Moon

Chapter Three

ASTR 111 – 003 **Fall 2007**
Lecture 03 Sep. 17, 2007

Introduction To Modern Astronomy I: Solar System

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-15)

Chap. 16: Our Sun
Chap. 28: Search for
Extraterrestrial life

Ch1: Astronomy and the Universe
Ch2: Knowing the Heavens

Ch3: Eclipses and
the Motion of the Moon

Ch4: Gravitation and
the Waltz of the Planets
Ch5: The Nature of Light
Ch6: Optics and Telescope

Phases of the Moon

The cycle of

→New

→ Waxing Crescent

→ First Quarter

→ Waxing Gibbous

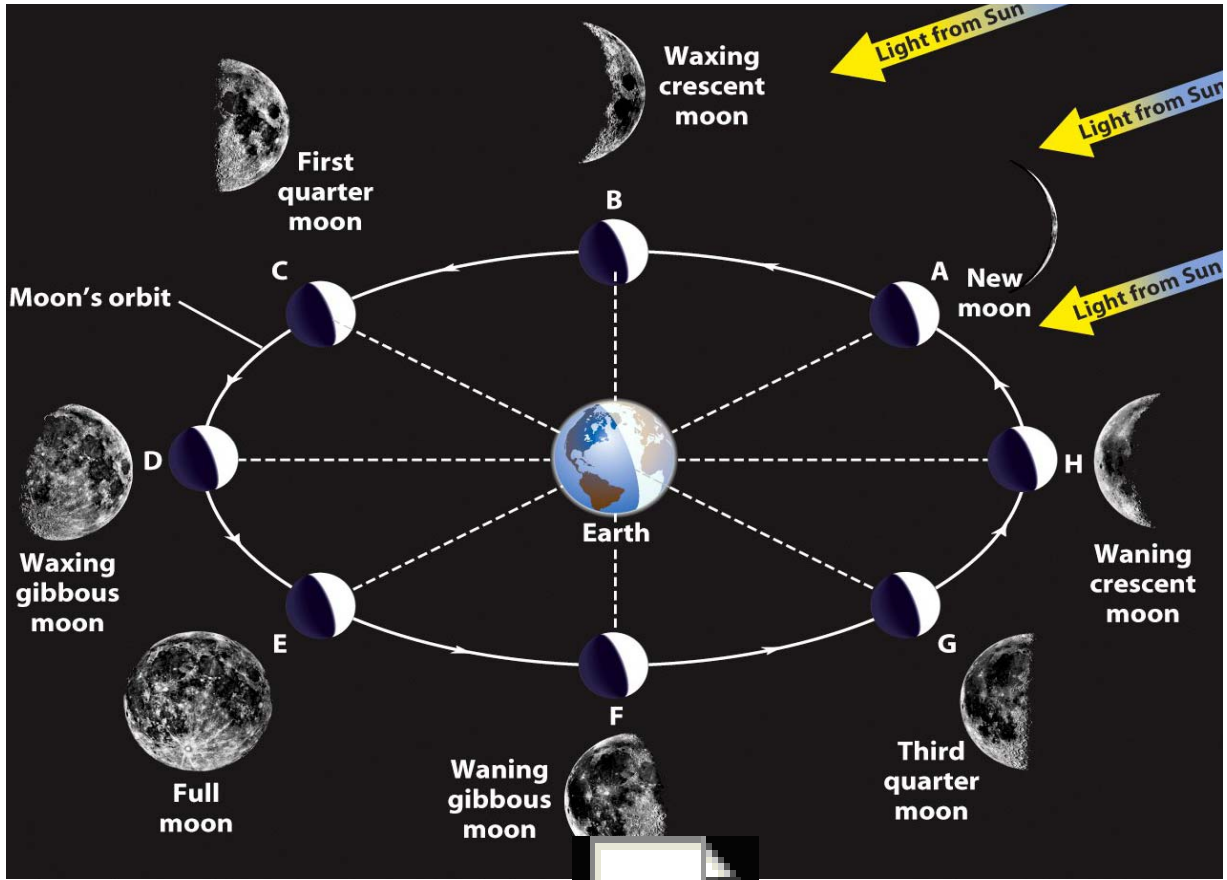
→ Full

→ Waning Gibbous

→ Third Quarter

→ Waning Crescent

→ New



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Phases of the Moon

- The phases of the Moon occur because
  - **we see the varying amount of the illuminated half of the Moon, as the Moon orbits around the Earth**
  - light from the Moon is actually reflected sunlight
  - At any moment, the Sun illuminates one half of the Moon

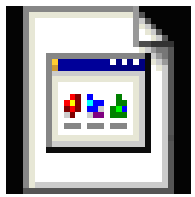
  - At any moment, only the half facing the Earth is visible from the Earth
  - What we see is the **intersection of the illuminated half and the visible half**

Phases of the Moon

- Waxing crescent moon
  - When you see a waxing crescent moon in the evening sky, what time is it? and where is the Moon?
- Full moon
  - What time does it rise? What time does it set? And where?
  - When you see a full Moon overhead, what is the time?
- When the Sun sets, where is the first quarter moon?
- When the Sun sets, where is the third quarter moon?

Synchronous Rotation of Moon

- Observations show that the Moon always keeps the same hemisphere, or face, toward the Earth.
- Synchronous rotation: the Moon makes one rotation in exactly the same time that it makes one orbit around the Earth. Thus we only see the same face.

FLASH 

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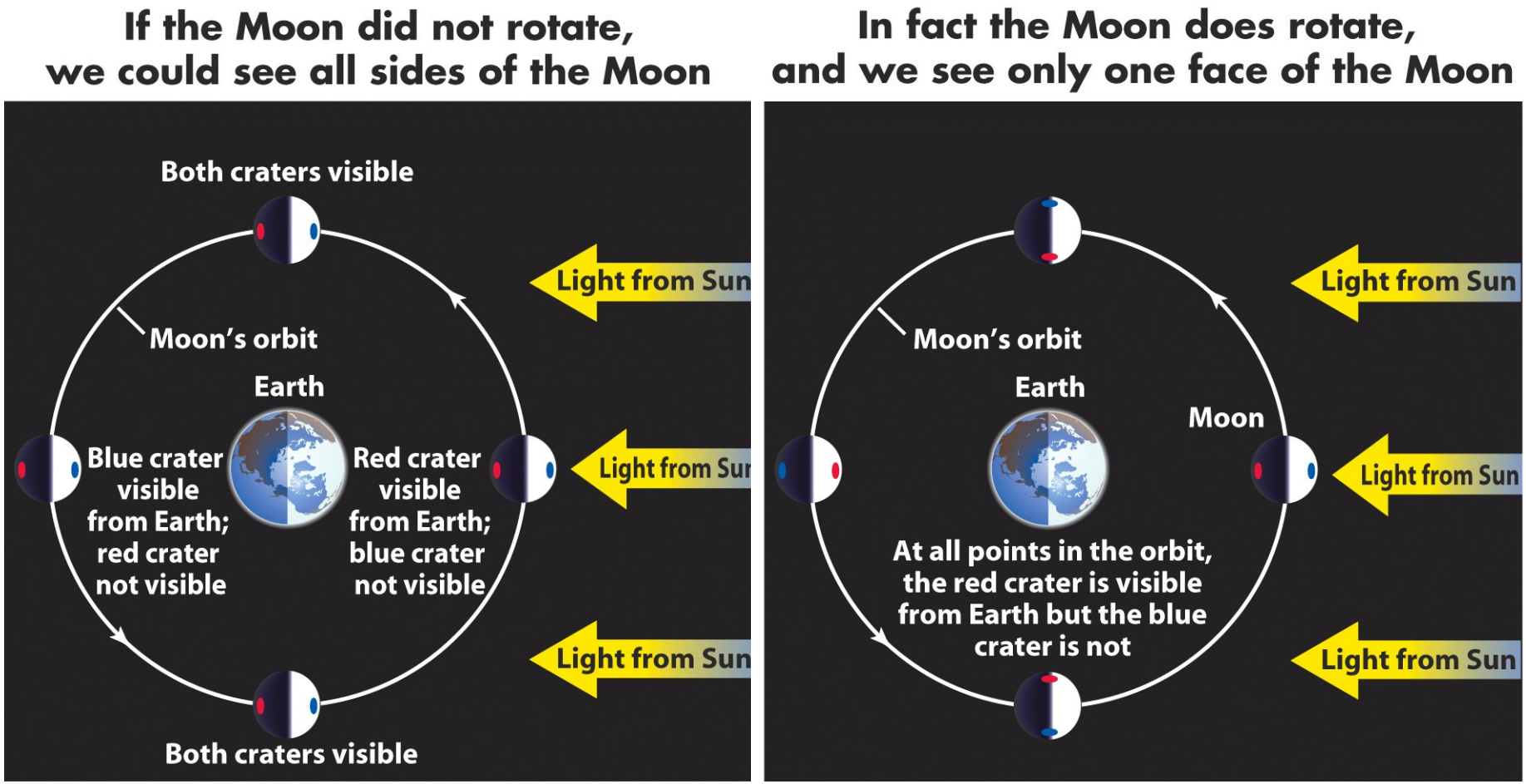
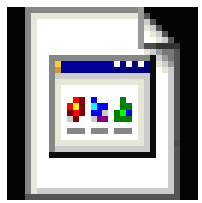
Synchronous Rotation of Moon



Synodic Month and Sidereal Month

- **Synodic month** (or lunar month):
  - The cycle with respect to the Sun
  - the Moon completes one cycle of phases, or one complete orbit around the Earth with respect to the Sun, averaging 29.53 day
- **Sidereal month:**
  - The cycle with respect to the stars
  - the Moon completes one orbit around the Earth with respect to the stars, averaging 27.32 days.

FLASH 

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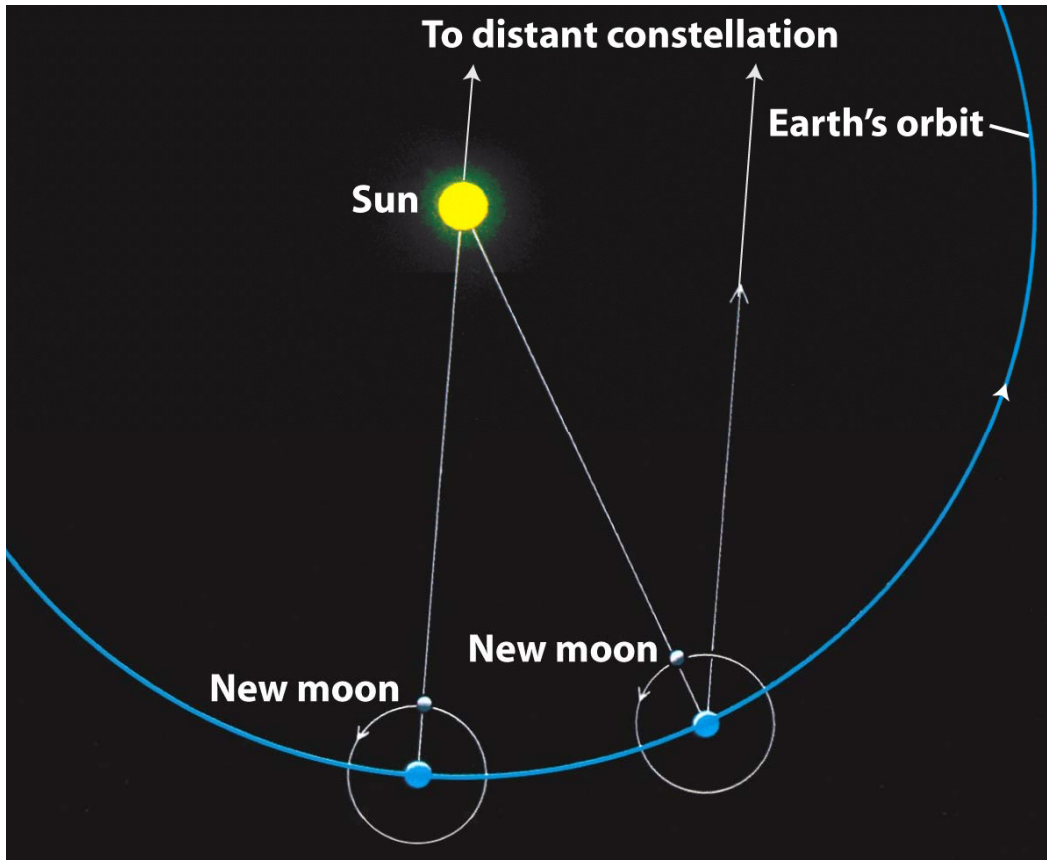
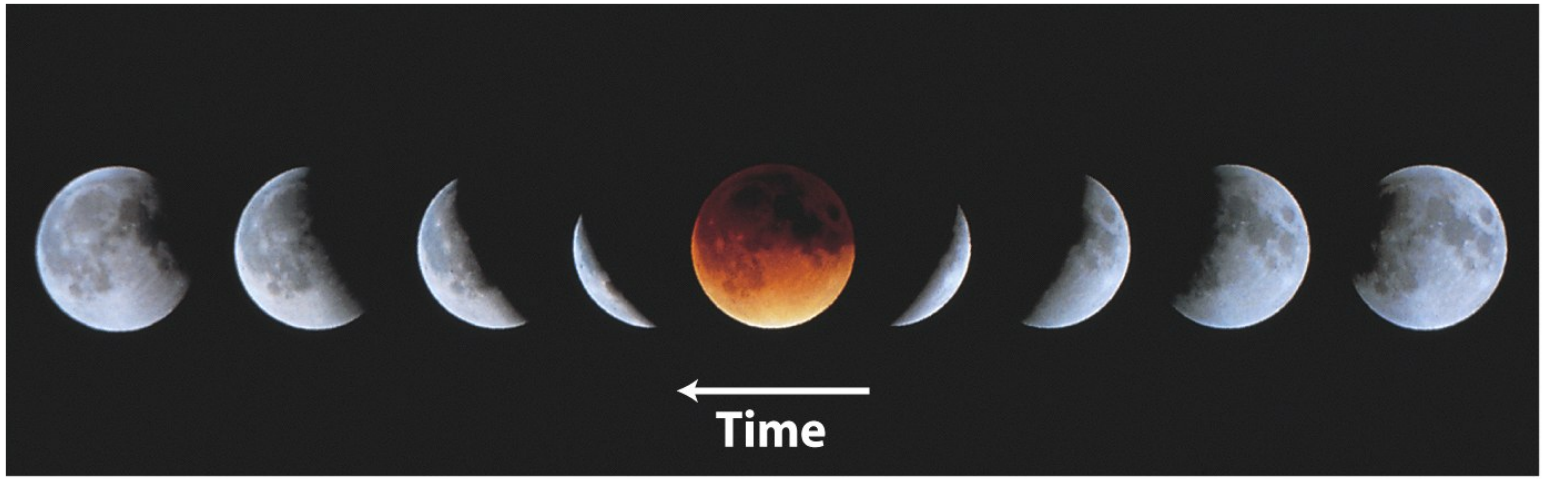
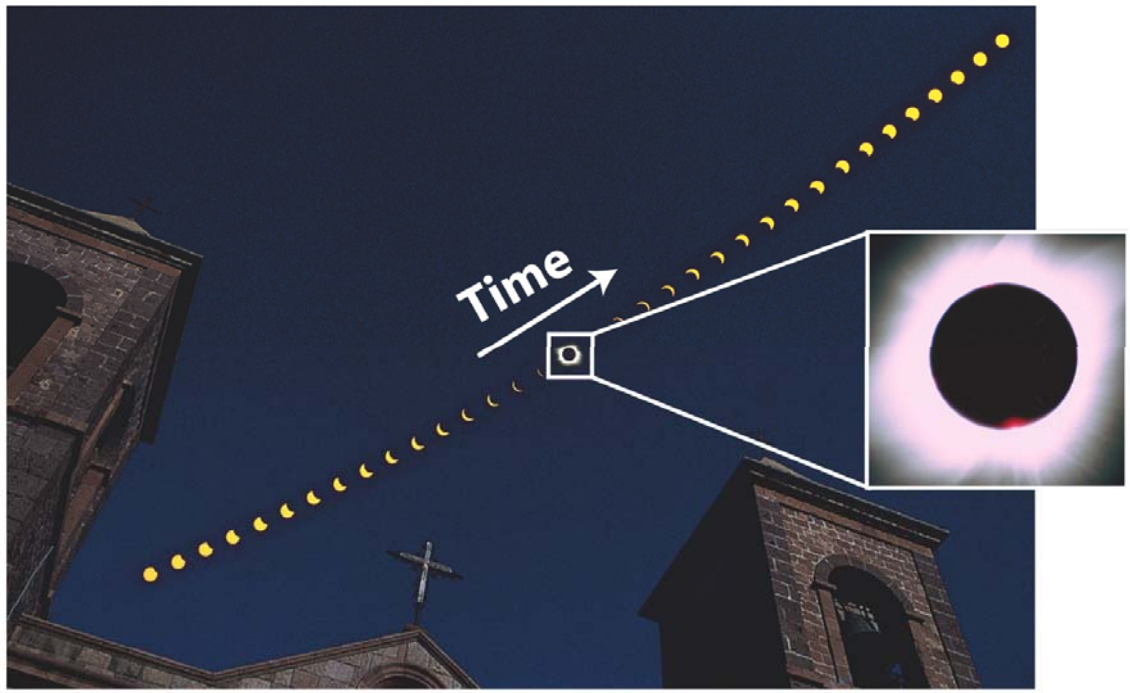
Synodic Month and Sidereal Month

- The synodic month is longer, because
  - After the Moon travels 360° along its orbit around the Earth (sidereal month), the Earth has also traveled about 27° along its orbit around the Sun
  - To complete a cycle of phases, the Moon must travel the additional 27° along its orbit around the Earth, which takes about 2 days more



Solar and Lunar Eclipses



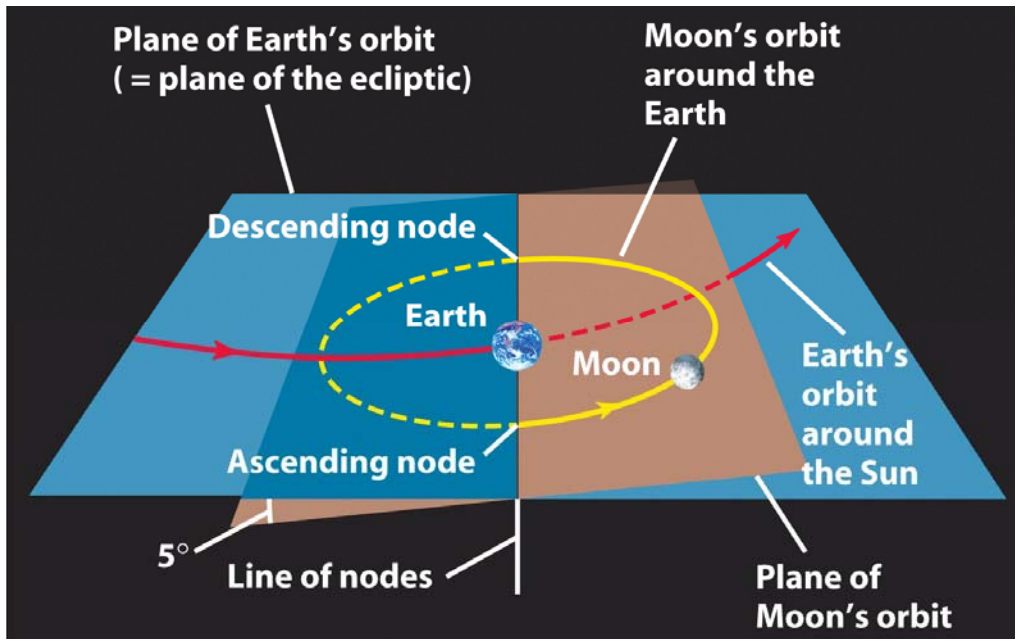


Solar and Lunar Eclipses

- **Eclipses** occur
  - when the Sun, Earth and Moon all lie exactly along a straight line, the shadow of Earth (Moon) falls on the Moon (Earth)
- **Lunar eclipse**: the Moon passes through the Earth's shadow
  - The Earth is between the Sun and the Moon
  - **The Moon is at full phase**
  - The full moon appears quite dim during lunar eclipse
- **Solar eclipse**: the Earth passes through the Moon's shadow
  - The Moon is between the Sun and the Earth
  - **The Moon is at new phase**
  - The Sun sometimes fully disappears in the clear sky during the solar eclipse.

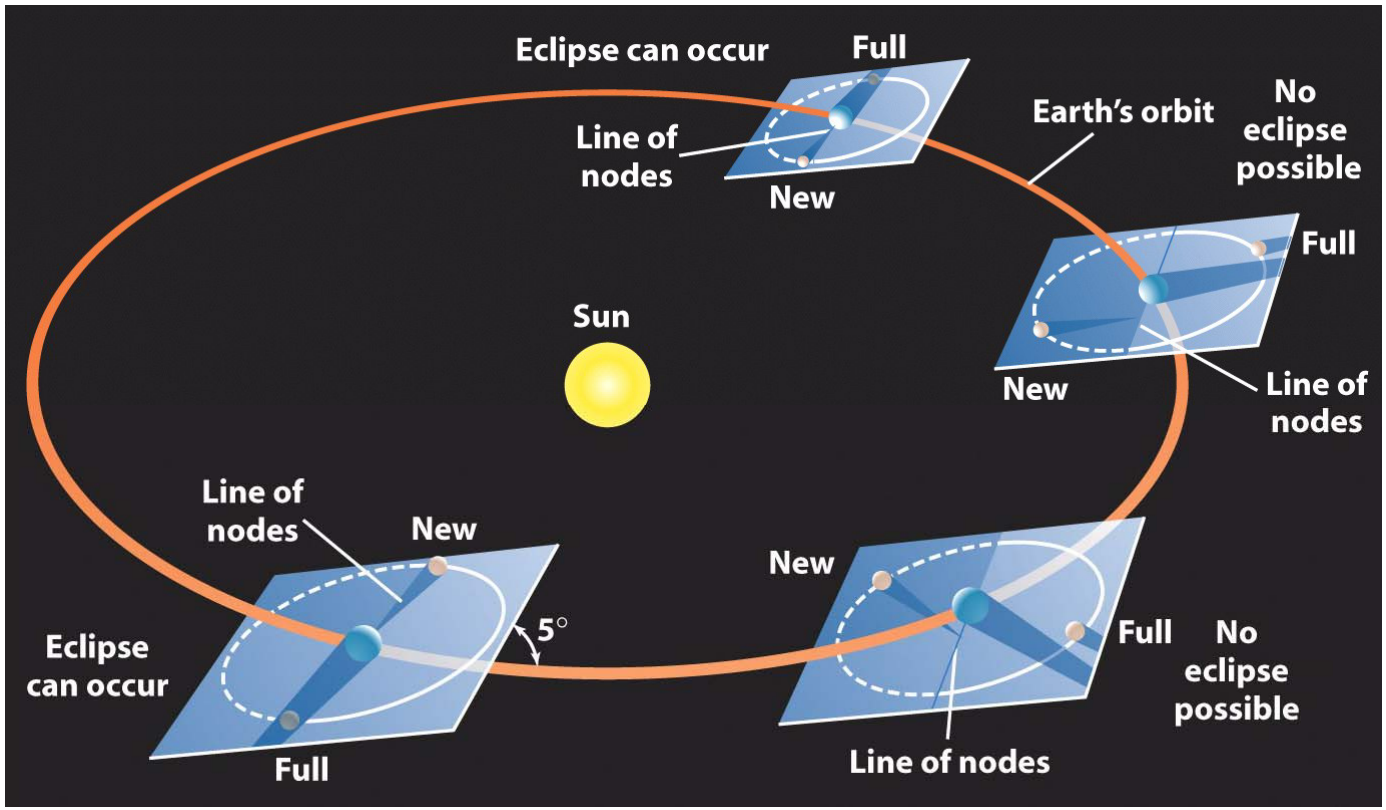
Eclipses do not Occur Every Month

- The plane of the Moon's orbit is tilted about **5°** with respect to the plane of the Earth's orbit (so called ecliptic plane)
- At new and full phases, the Sun, Earth and Moon are often not along a straight line.
- There are a few solar and lunar eclipses per year.
- The maximum number (combined) in a single year is seven



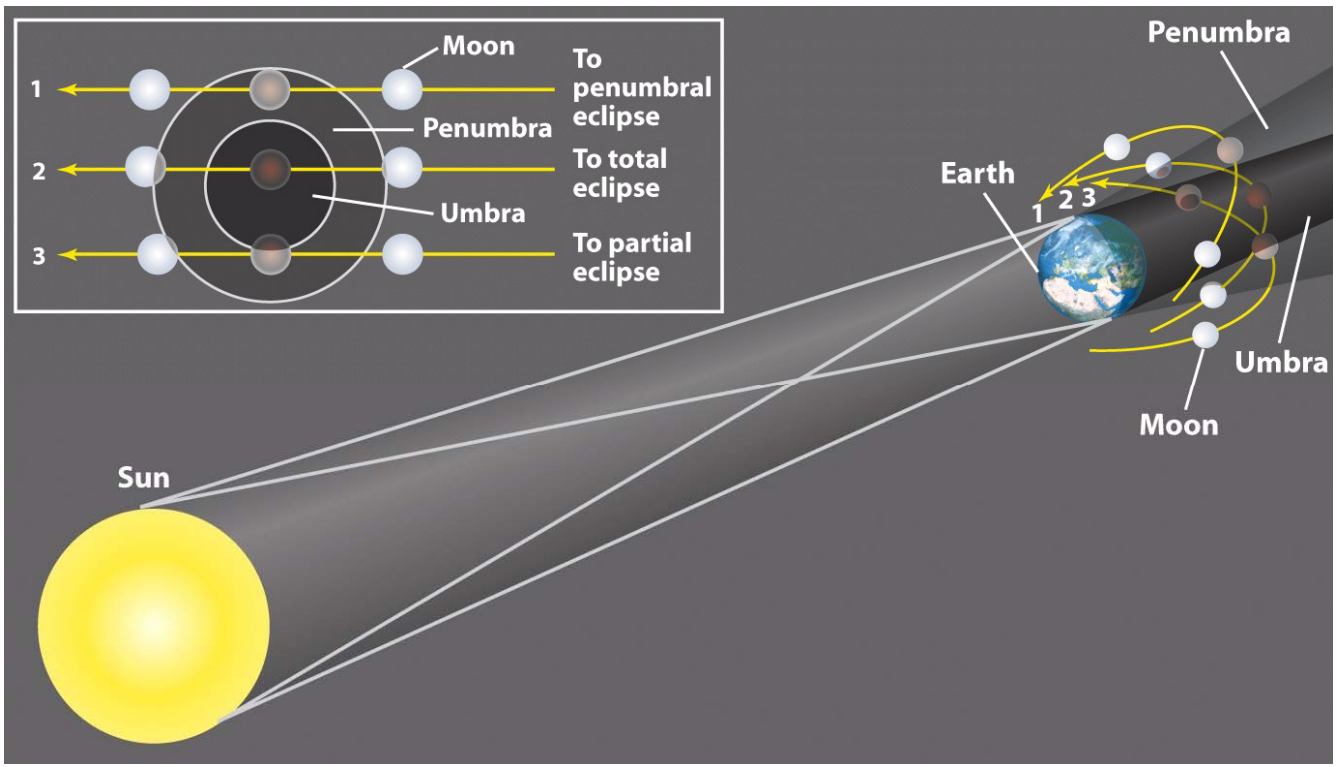
Eclipses and Line of Nodes

- **Line of nodes:** the line along which the plane of the Moon's orbit intersects the plane of the Earth orbit
- Eclipses occur only when the Sun and Moon are both on the line of nodes



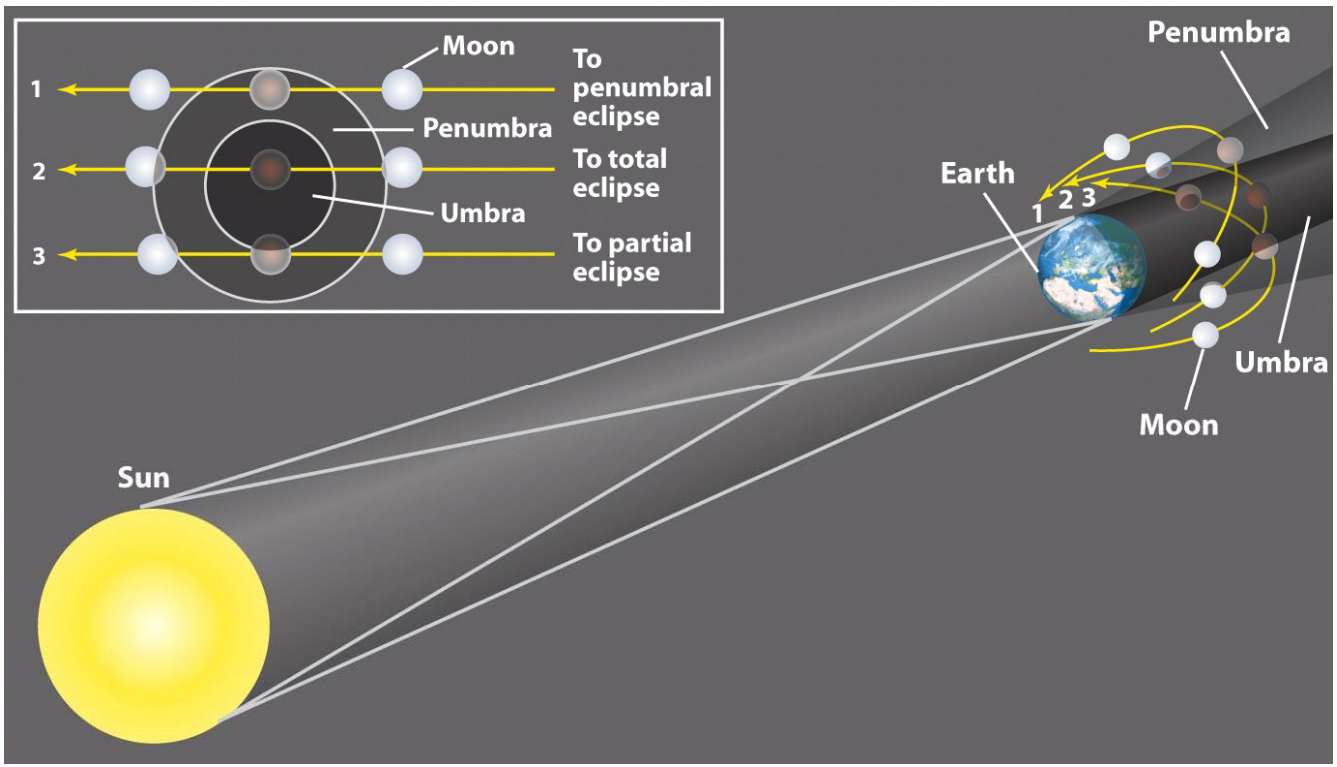
Lunar eclipses

- The Earth's shadow has two parts: **umbra and penumbra**
- **Umbra:** the darkest part of the shadow, no portion of the Sun's surface can be seen form the Moon.
- **Penumbra:** less dark of the shadow, only part of the Sun is covered by the Earth.



Lunar eclipses

- **Total lunar eclipse**
  - The Moon travels completely into the umbra
- **Partial lunar eclipse:**
  - Only part of the Moon passes through the umbra



Lunar eclipses

- **Totality**: the period when the Moon is completely within the Earth's umbra, which is a few times larger than the size of the Moon
  - **Totality** can last as long as 1 hour and 42 minutes.
- A lunar eclipse can be seen at any place on Earth where it is nighttime.

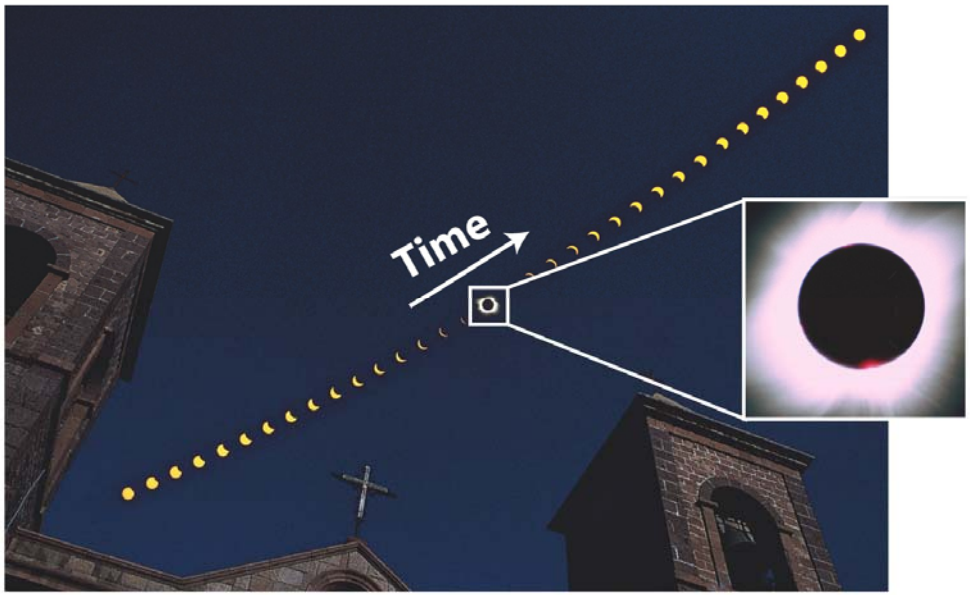
table 3-1 **Lunar Eclipses, 2004–2008**

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	—

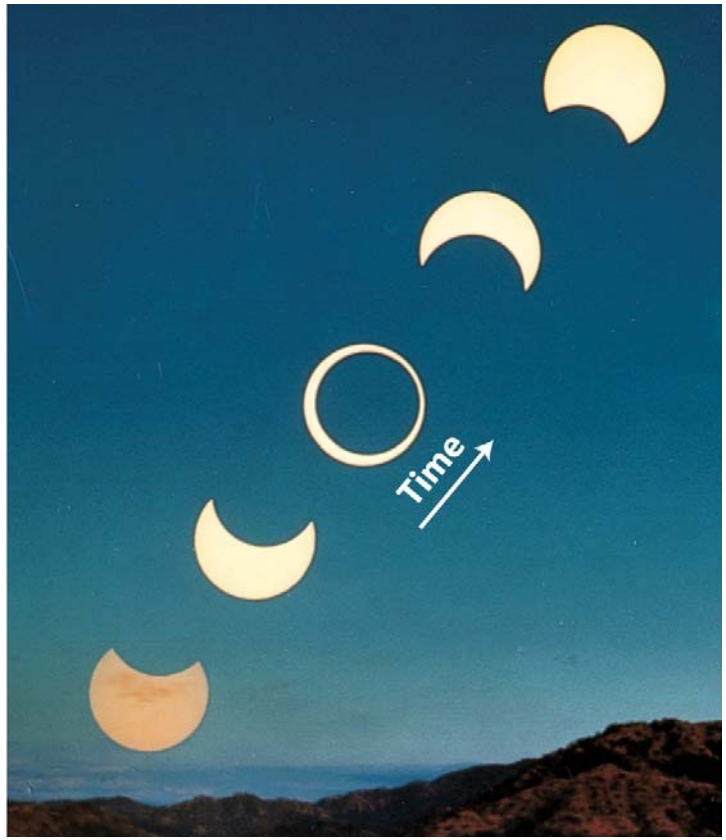
**Eclipse predictions by Fred Espenak, NASA/Goddard Space Flight Center. All dates are given in standard astronomical format: year, month, day.*

Solar eclipses

- **Total solar eclipse**
- **Partial solar eclipse**
- **Annular solar eclipse**



Total solar eclipse



Annular solar eclipse

Solar eclipses

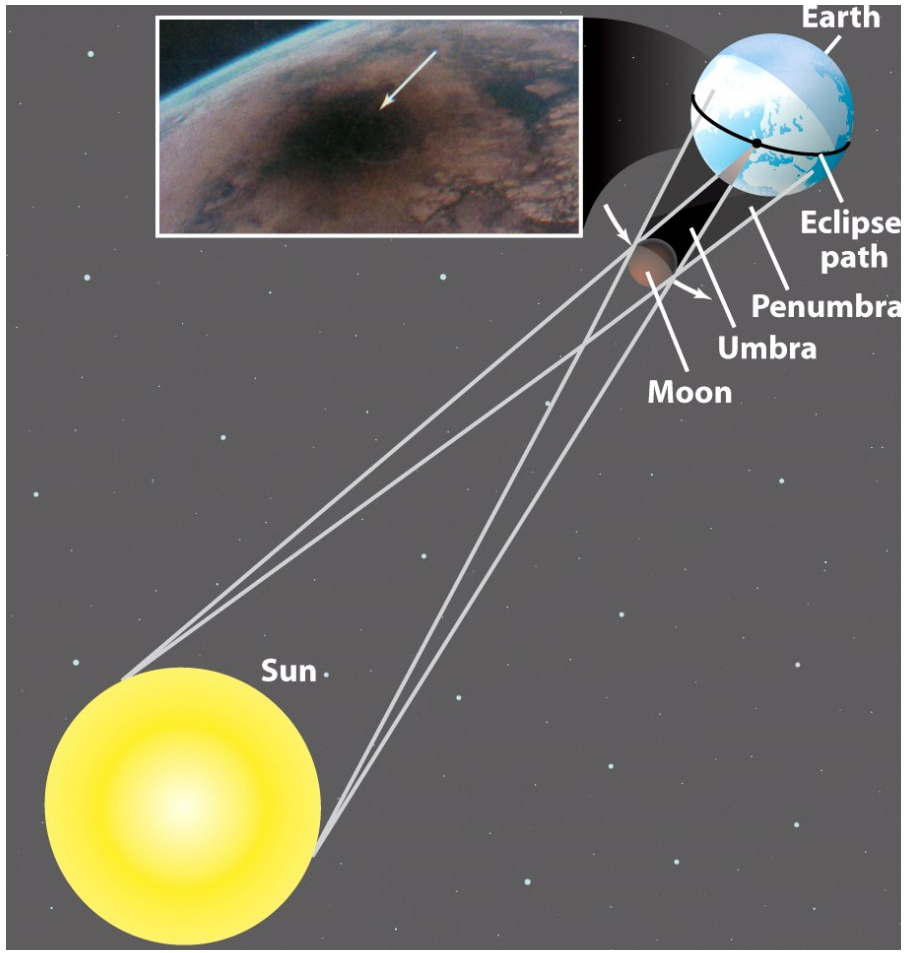
- The angular diameter of the Moon is almost the same as the angular diameter of the Earth – about 0.5°
- **Total solar eclipse:**
  - Completely blocked by the Moon
  - Seen by people inside the umbra of the Moon's shadow
- **Partial solar eclipse:**
  - Only part of the Sun blocked by the Moon
  - Seen by people inside the penumbra of the shadow
- **Annular eclipse:**
  - A thin ring of the Sun is seen around the edge of the Moon's shadow
  - This happens if the Moon is at or near apogee; the Moon appears too small to cover the Sun completely

Solar eclipses: Eclipse Path

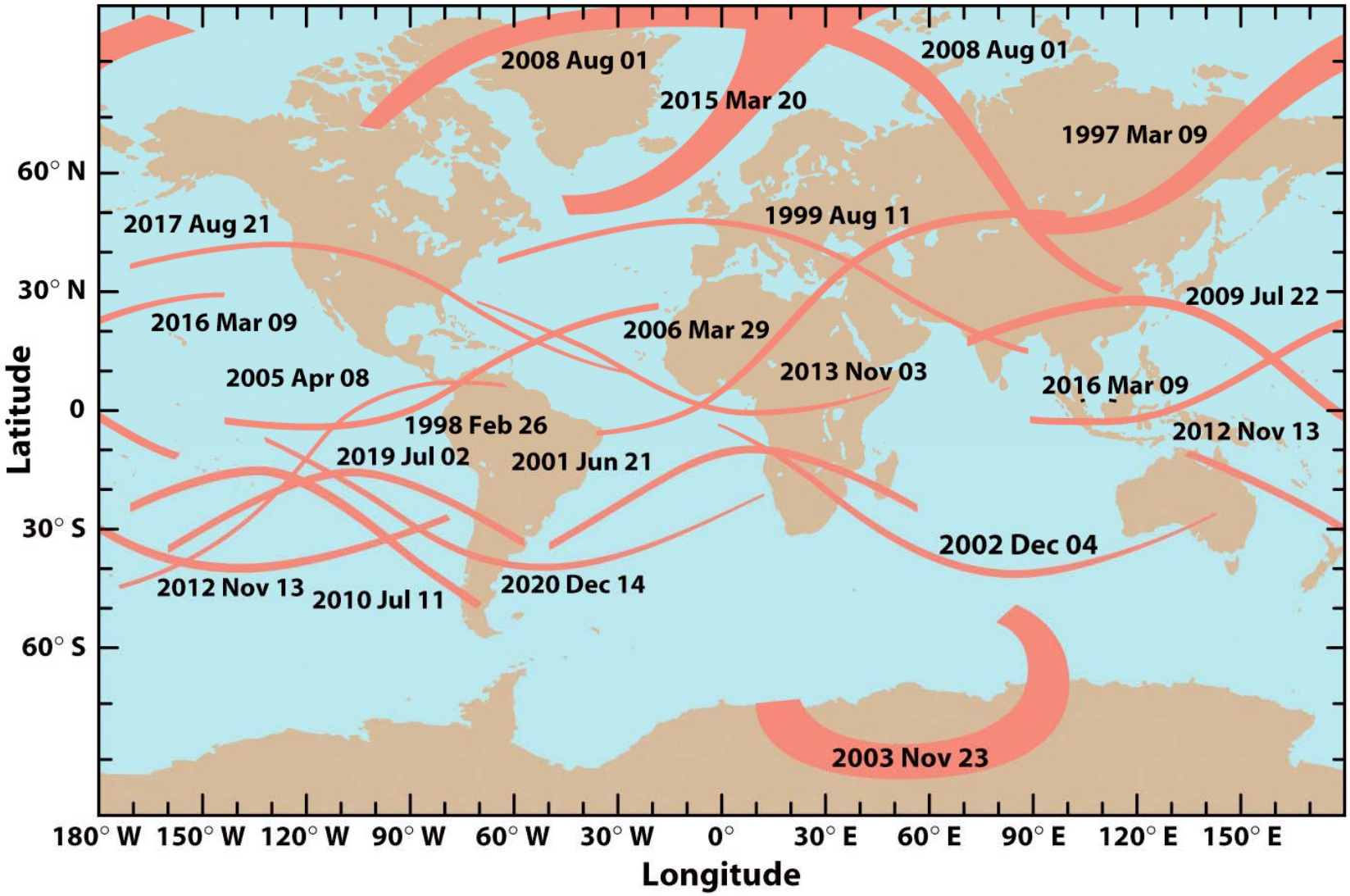
- **Eclipse Path:**
  - Because the relative small size of the Moon, only the tip of the Moon's umbra reaches the Earth surface, which is about 100 km wide
  - The tip of umbra traces an eclipse path across the Earth's surface, at a speed of ~1700 km/hour

(Moon's orbit motion + Earth rotation)

  - Totality never lasts for more than 7.5 minutes.
  - Only locations within the eclipse path are treated by a total solar eclipse



Solar eclipses



Eclipse Paths for Total Solar Eclipses, 1997-2020

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.

Final Notes on Chap. 3

- Covers section 3-1 to 3-5. Section 3-6 is not covered.

Advanced Question
Chap. 3, Q31 in P61

(a) The Moon moves noticeably on the celestial sphere over the space of a single night. To show this, calculate how long it takes the Moon to move through an angle equal to its own angular diameter (0.5 deg) against the background of stars. Give your answer in hours.

(b) (b) Through what angles (in degrees) does the Moon move during a 12-hour night? Can you notice an angle of this size?