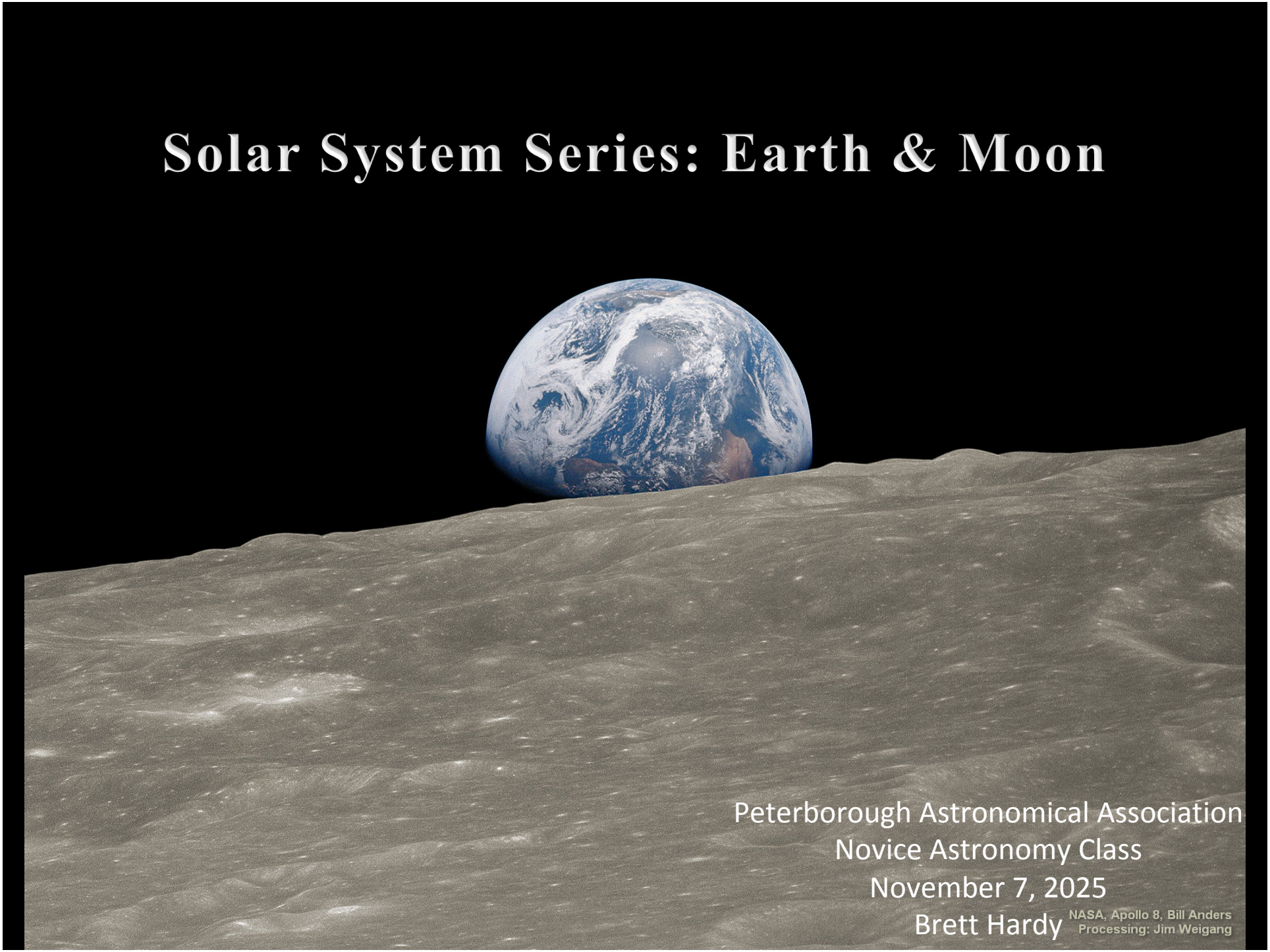
Solar System Series: Earth & Moon



Peterborough Astronomical Association
Novice Astronomy Class
November 7, 2025
Brett Hardy

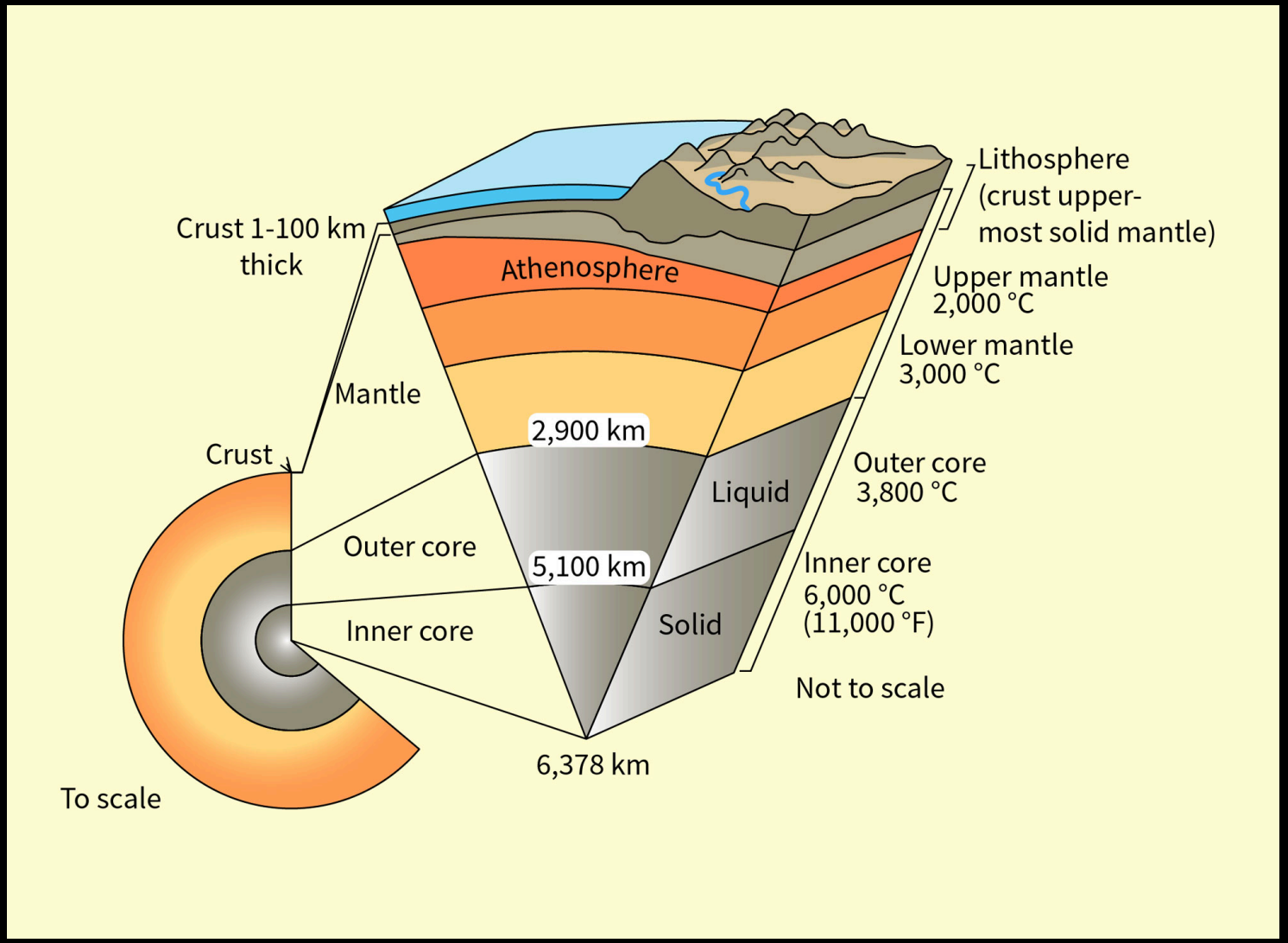
NASA, Apollo 8, Bill Anders
Processing: Jim Weigang

Earth

- Third rock from the Sun
- 150 million km - 1 AU
- Diameter: 12,742 km
- Circumference: 40,070 km
- Fifth largest planet
- 29 % land mass
- 97 % of Earth's water is in oceans
- Thick atmosphere: 78 % N_2, 21 % O_2, 0.93 % Ar, 0.04 % CO_2
- Magnetic Field: Magnetosphere
- One moon ¼ the size of Earth
- The only planet in our solar system to have an oxygen atmosphere, liquid water oceans on its surface and life
- Goldilocks Zone
- Extraordinary biodiversity

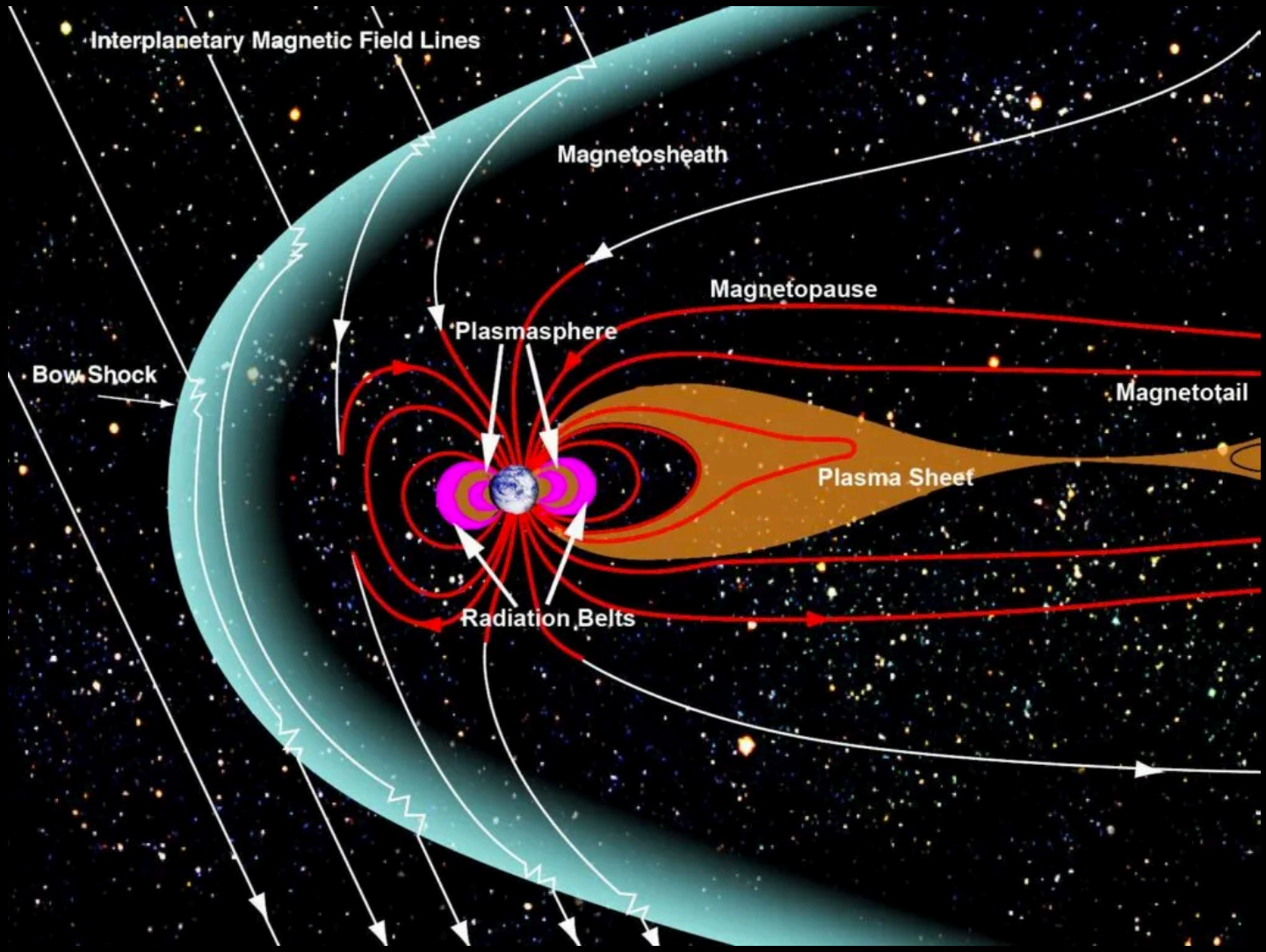
NASA

Structure of Earth



Adapted from USGS

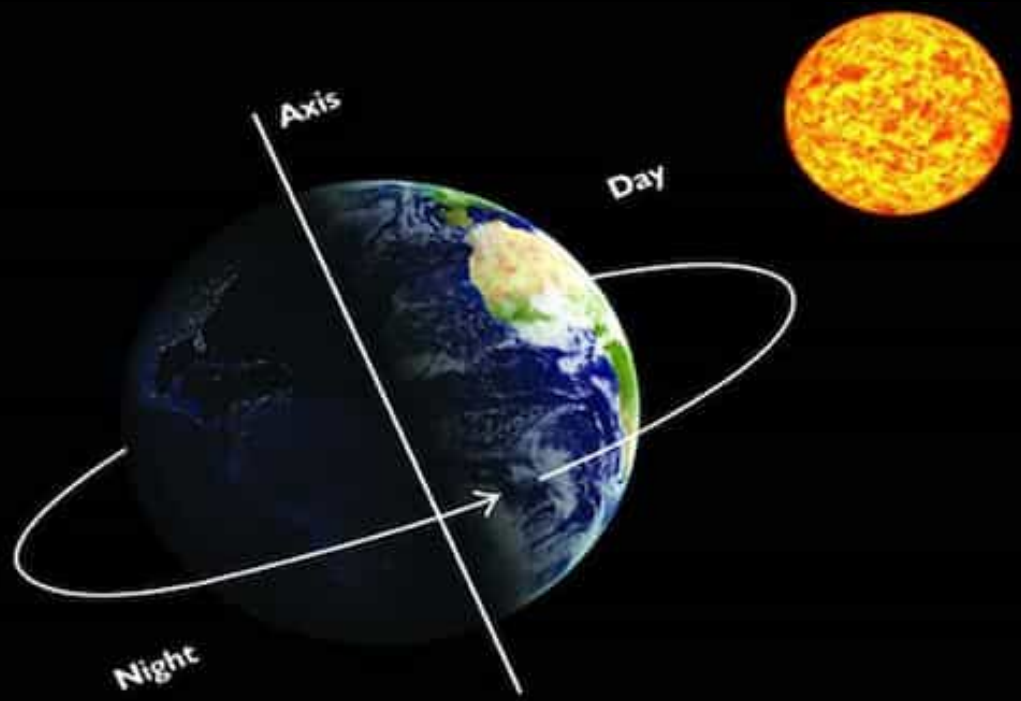
Earth's Magnetosphere



NASA/Aaron Kaase

Earth's Rotation

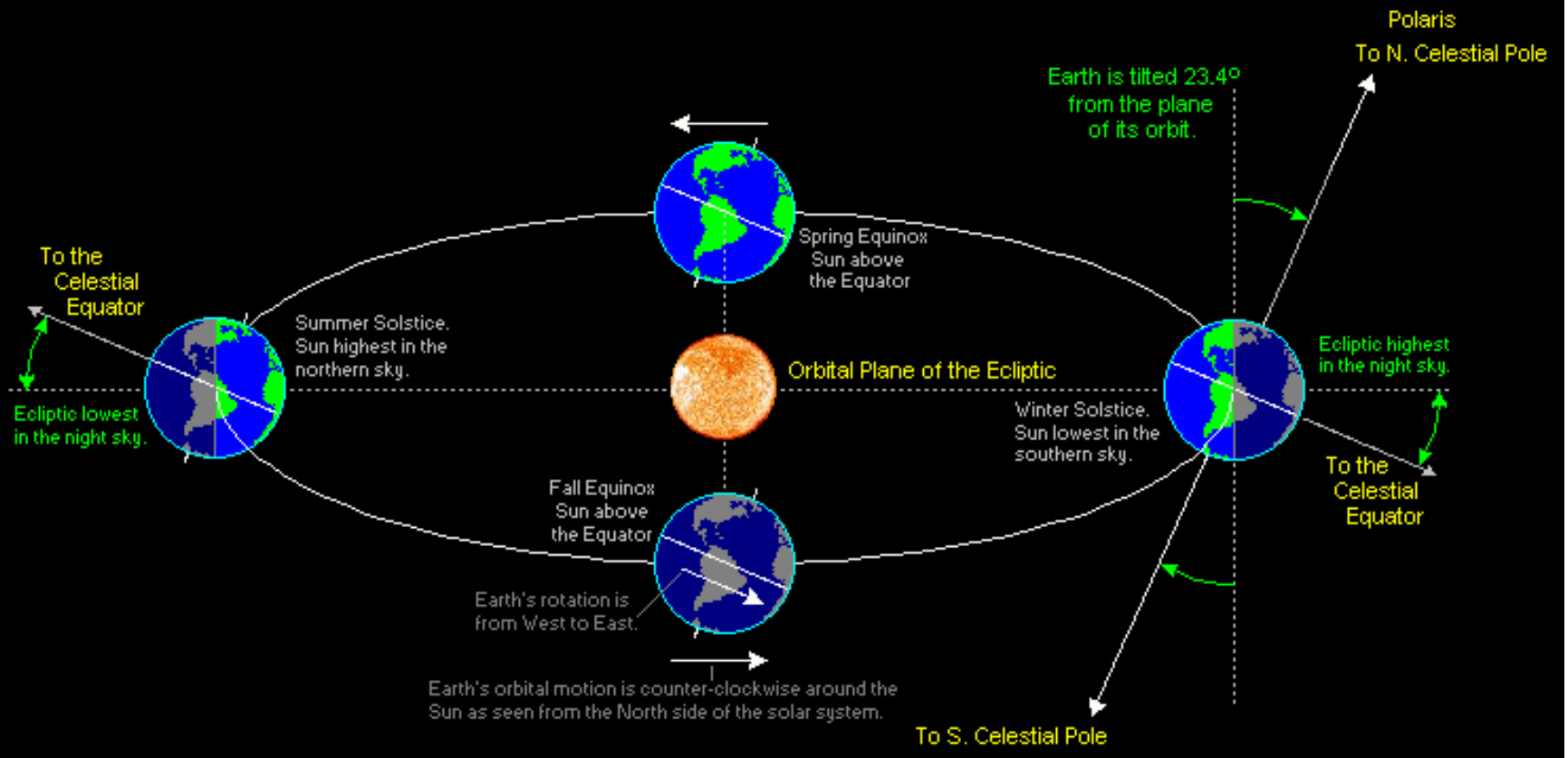
- Earth's rotation is counterclockwise
- Apparent rising and setting of the Sun
- Rotation speed: 1,670 km/hr (1,180 km/hr at 45° latitude)
- One complete rotation takes 23 hours 56 minutes 4.09 seconds = 1 day
- Day length is slowly increasing



BlueRing Media/
Shutterstock.com

Earth's Orbit

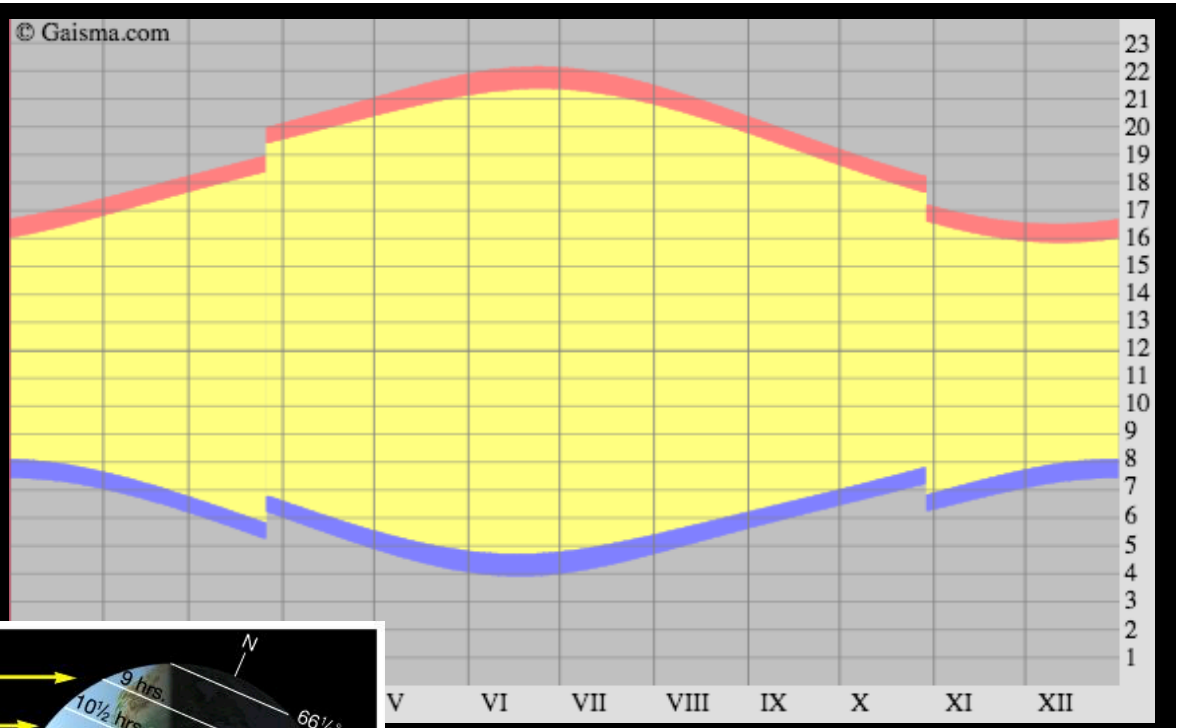
- All the planets orbit the Sun in an elliptical orbit
- Orbital speed: ~ 107,000 km/hr
- Distance Earth travels in one year: ~ 940 million km

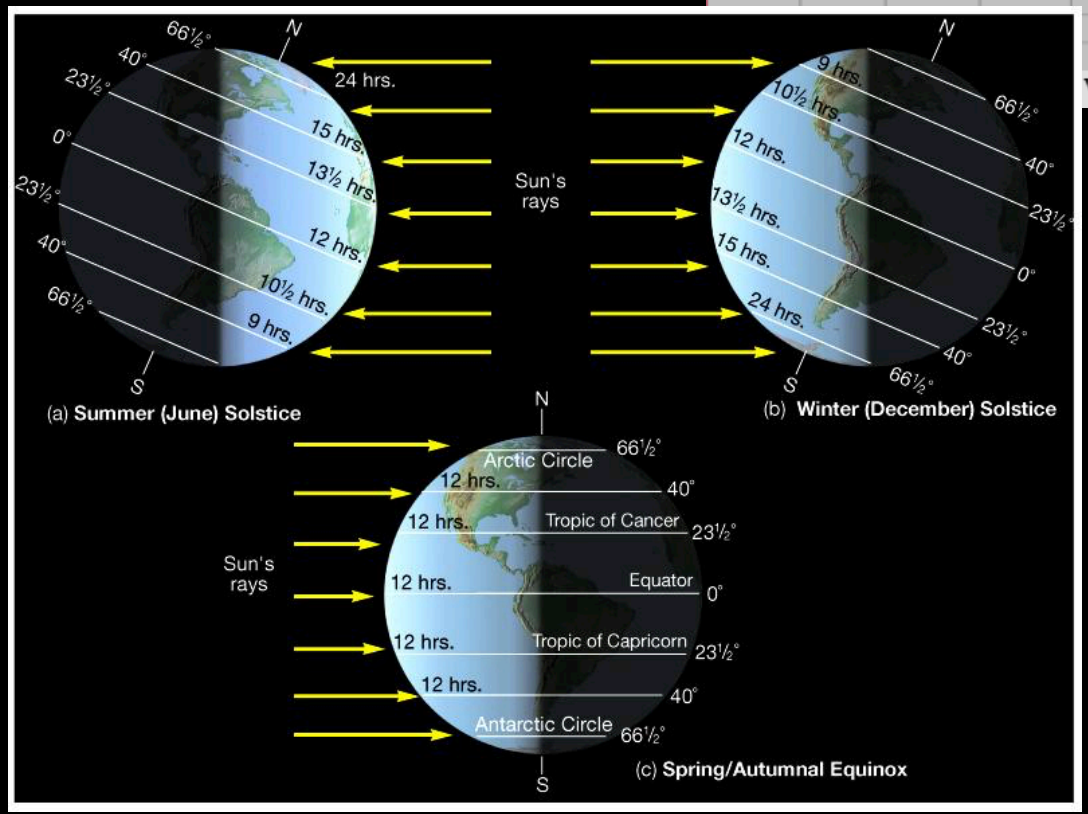


Larry McNish

Annual Daylight Variation

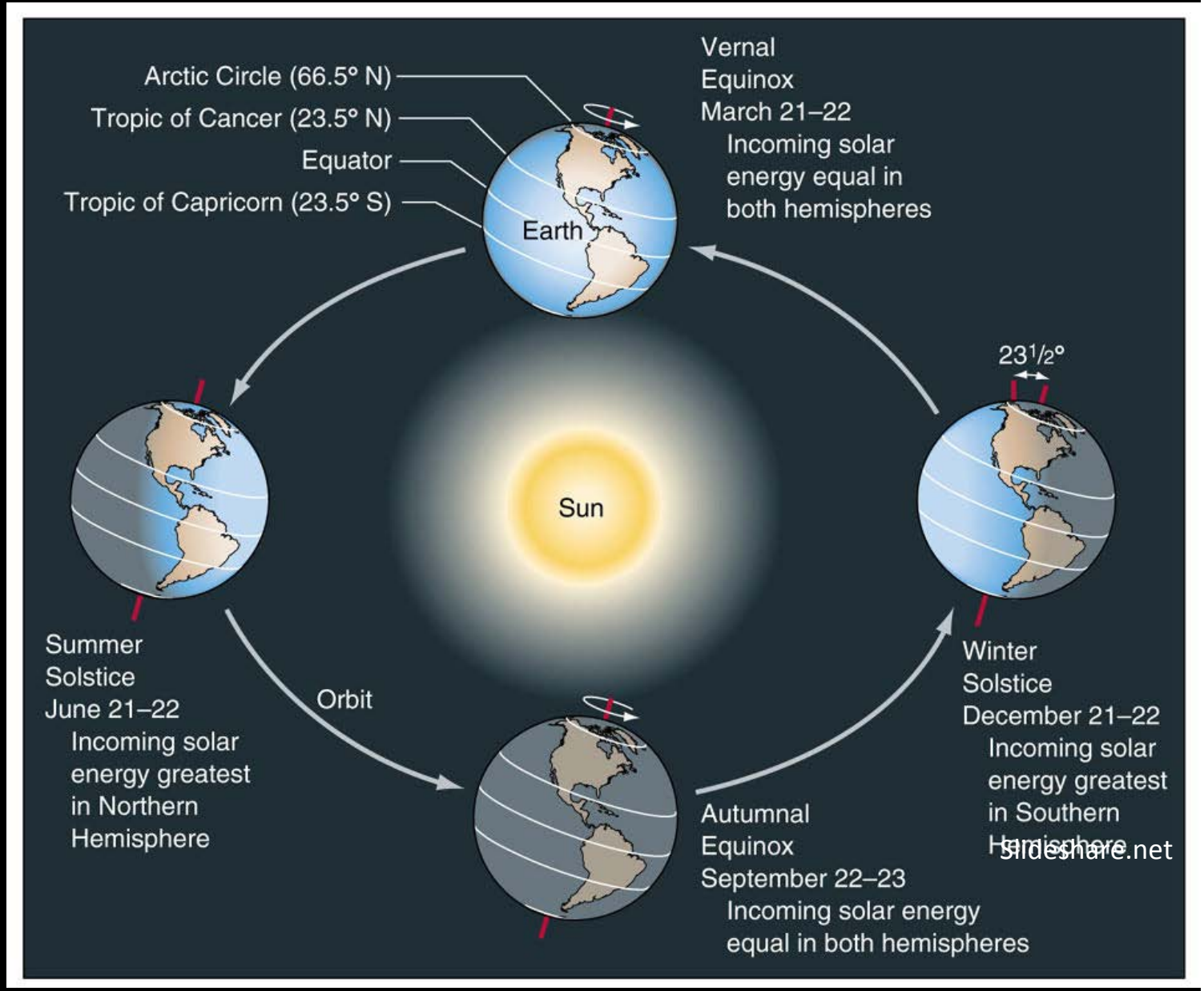
- Earth's orbit around the Sun has implications for the number of daylight hours



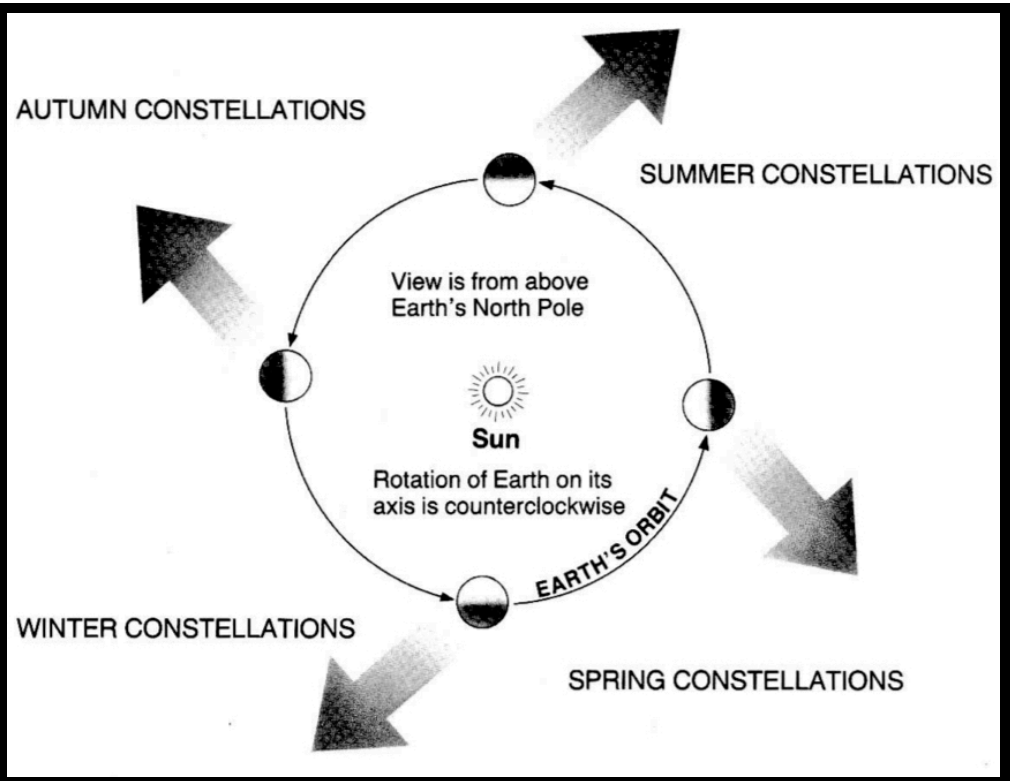


Seasons

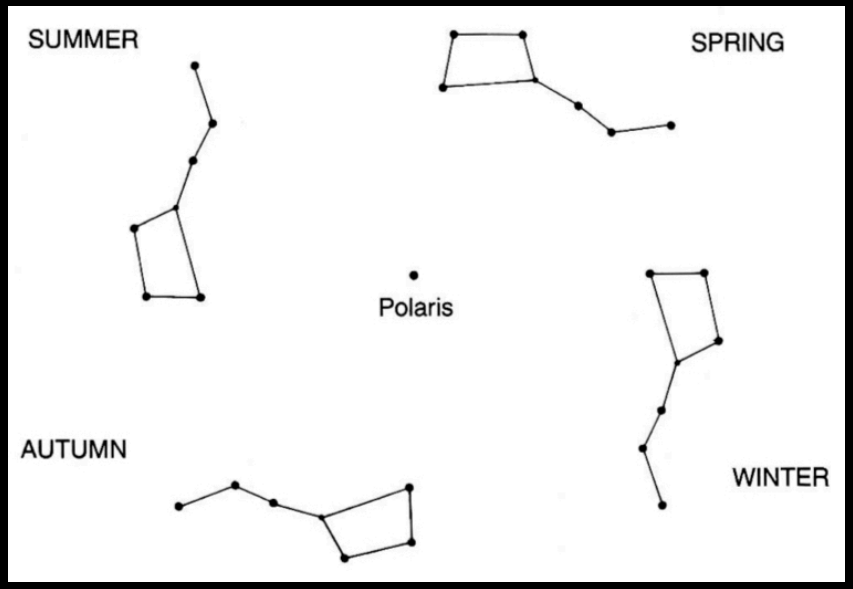
- The tilt of our Earth at 23.5° is what causes the seasons
- Known as obliquity
- Obliquity defines the intensity of the Sun's light
- Sun's intensity at the Summer Solstice is 2.5 times greater than at the Winter Solstice
- Hours of sunlight vary with seasons adding a secondary effect on temperature

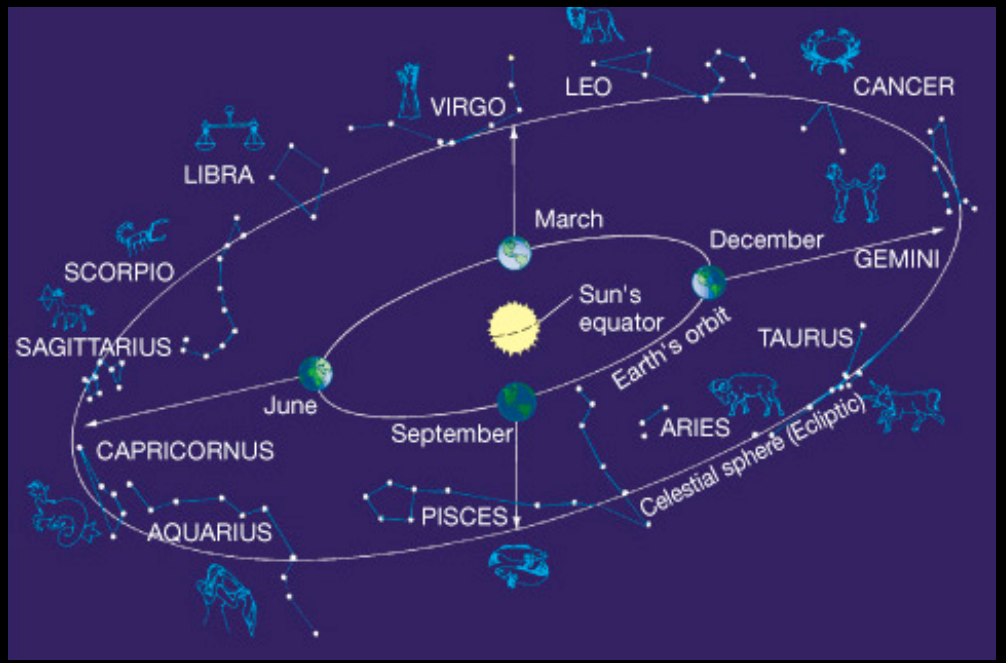


Seasonal Change



Terrance Dickinson: Night Watch





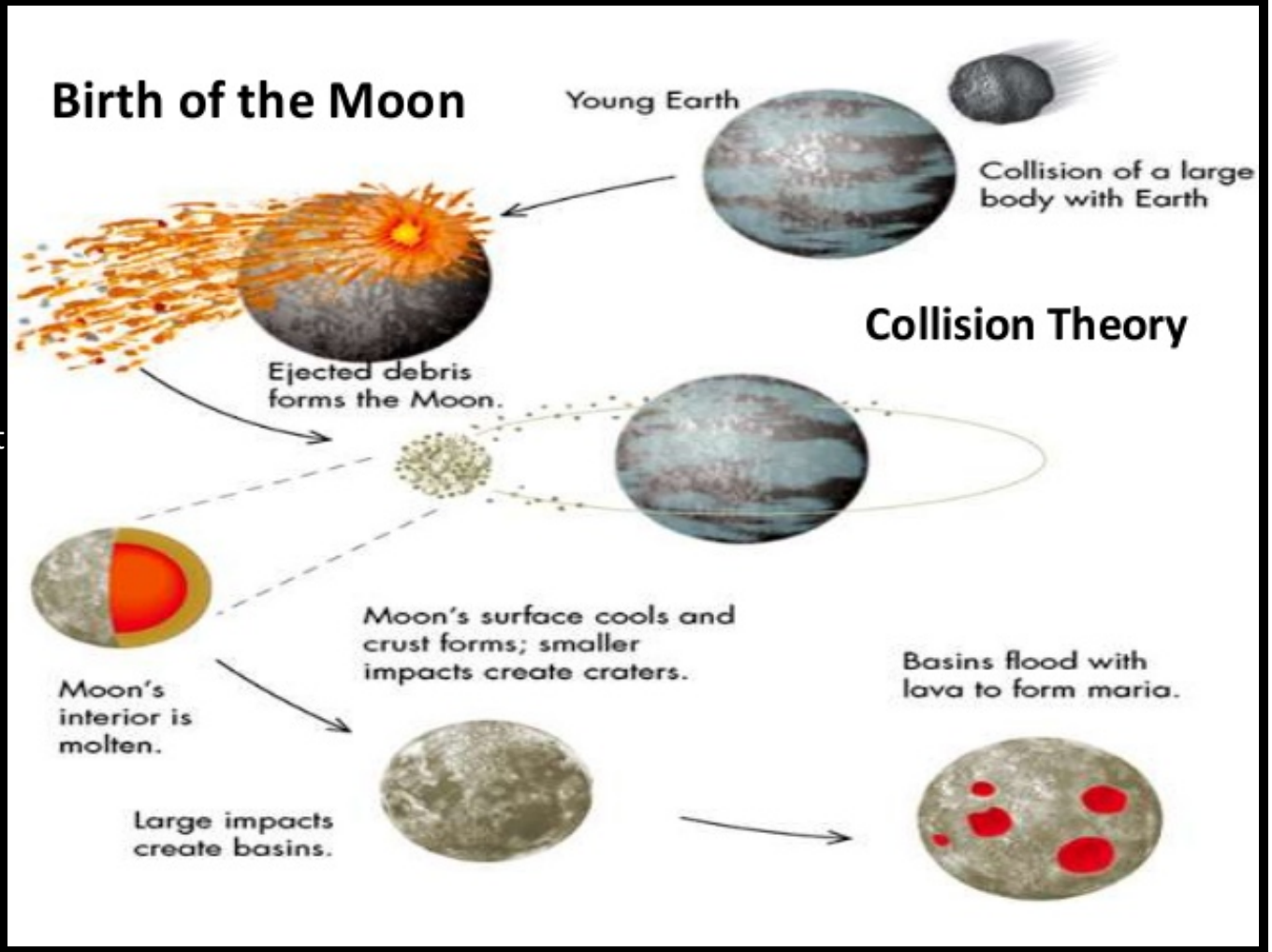
Moon's Formation

- Impact 4.3 billion years ago by Mars size planet Thea
- Moon is about 50 million years younger than Earth
- Completely melted Earth
- Imparted a very fast spin to Earth
- ~ 5 hour day
- + 2.3 milliseconds per century

National Geographic

Evolution

- Moon forms in about 100 years
- ~ 20,000 km from Earth
- Tides 8,000 X stronger
- Tidal forces synchronized Moon's spin and orbital period
- Late Heavy Bombardment 4.1-3.8 billion years ago creates large impacts
- Mare volcanism 3.8 - 1 billion years ago
- Ray craters 1 billion years ago to present
- Tycho 109 million years



Slideshare.net

Moon Characteristics

- Natural satellite of Earth
- 1/4 size of Earth
- Diameter: 3,475 km
- Circumference: 10,921 km
- 1/6 gravity of Earth
- Slightly > 1 % Earth's mass
- Average distance 384,000 km
- Distance increasing ~ 3.78 cm/ year
- Orbits in counterclockwise direction
- Rotational period: 27 days
- Lunar Month: 29.5 days
- Rotation is tidally locked to Earth
- Water ice deposits
- No atmosphere
- Extensive cratering
- Temperature range -233° to 123°C
- Extremely dry
- Far side thicker crust, few maria
- Light areas − highlands
- Dark areas − maria

Brett Hardy

Historical Importance

Ancient Observatories

- El Caracol - Observatory at Chichén Itzá (Circa 906 CE)

Time

- Earliest Calendars based on observations of the moon
- Month
- Monday

Illumination

- Work and travel at night
- Harvest Moon

Navigational Beacon and Indicator of Tides

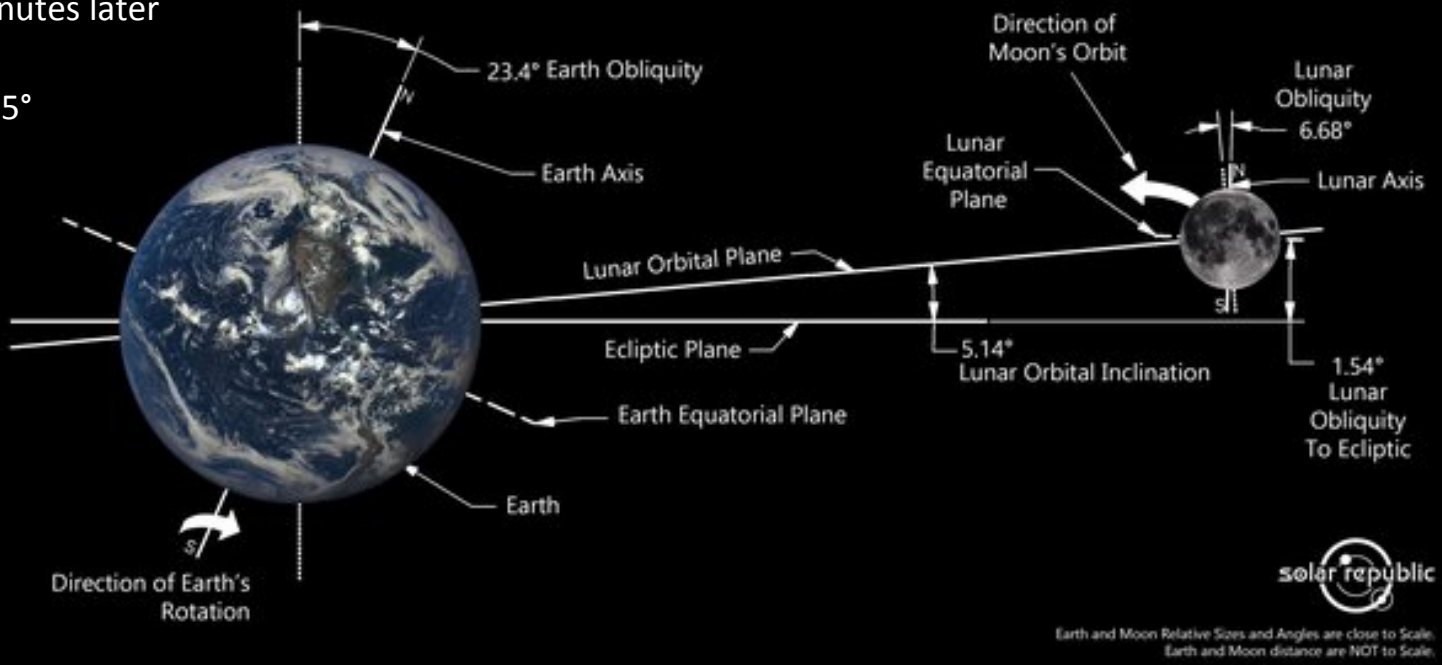
Cultural Significance

- Myth
- Visual Art: painting, photography
- Poetry
- Literature

Rob Shenk

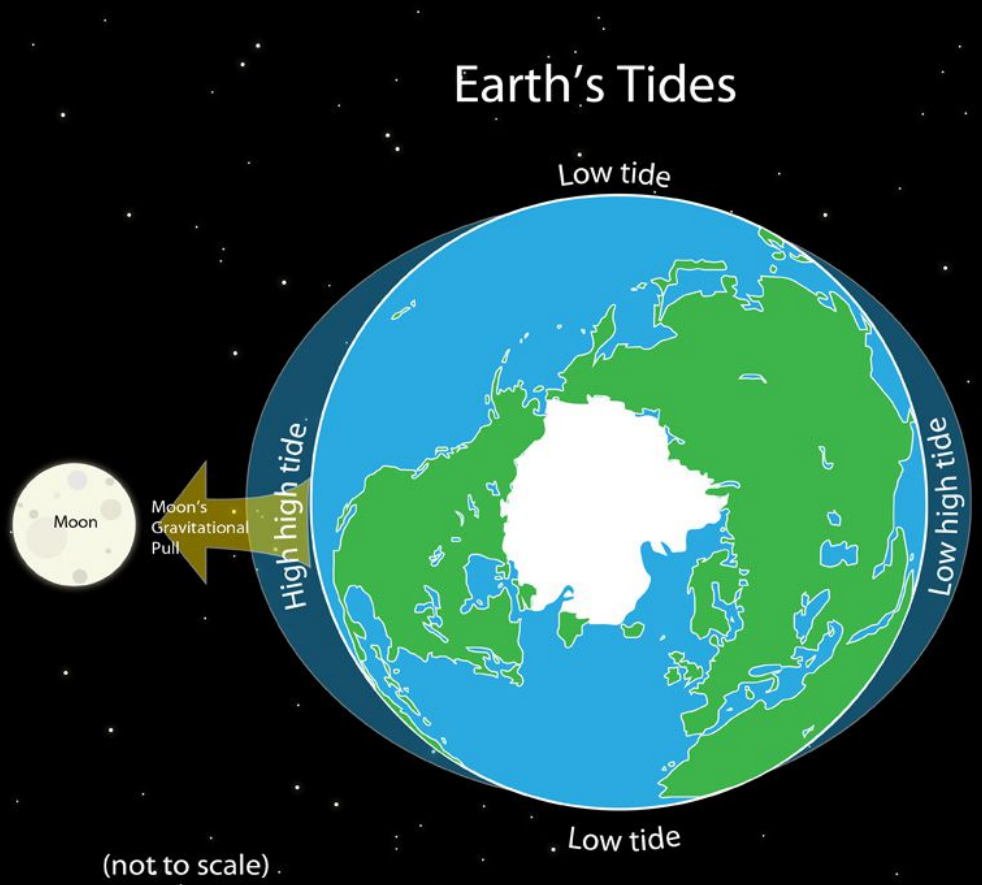
Lunar Orbit

- Elliptical orbit
- Distance varies from 362,000 km to 405,000 km
- Rises about 50 minutes later each night
- Orbit is inclined ~ 5°



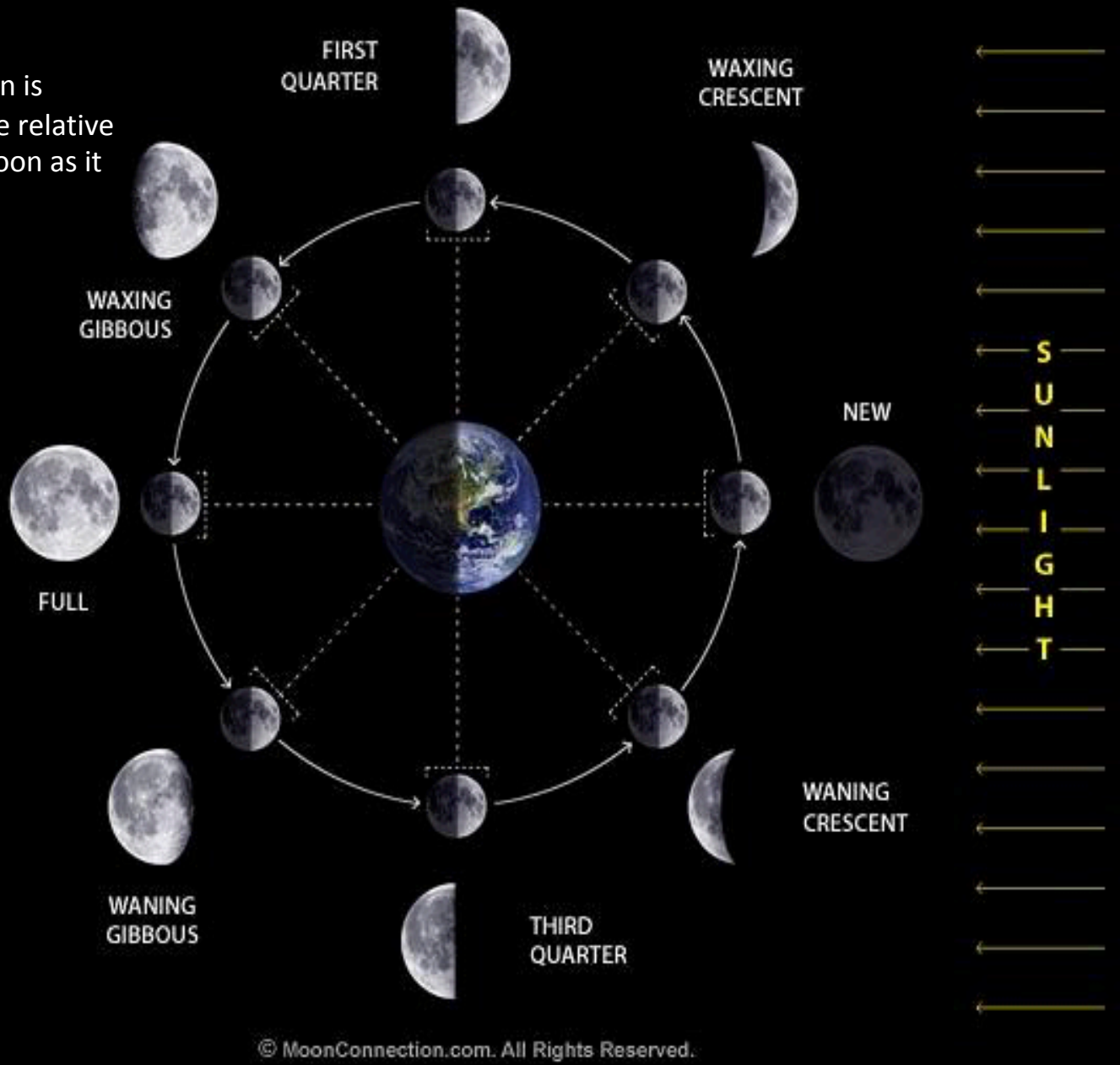
Tides

- Gravitational interaction of Moon and Sun cause tides
- Average height of tides: 2 - 3 m
- When Moon formed it was only ~ 20,000 − 30,000 km away − 15 x closer than today



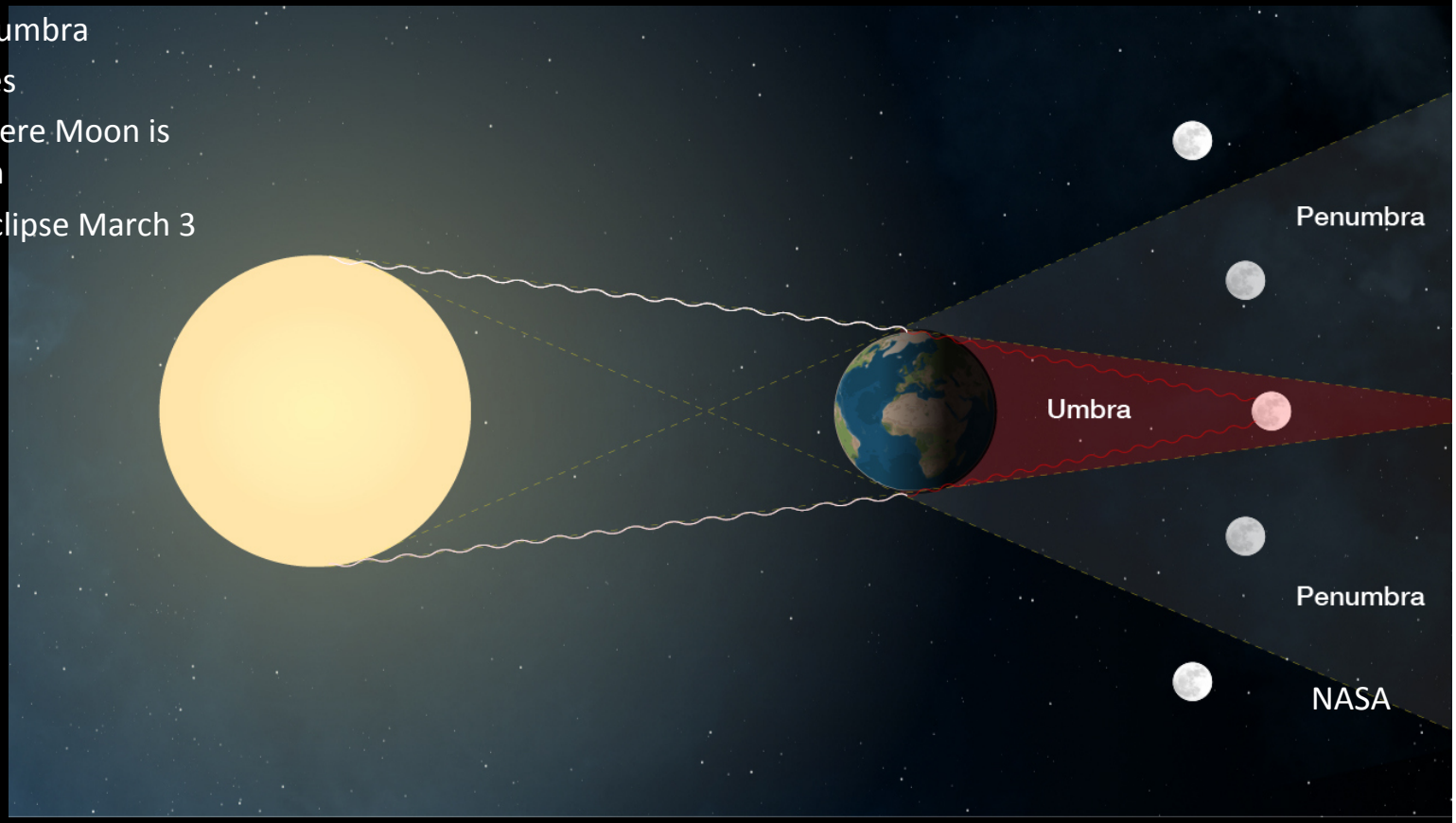
Lunar Phases

- Phase of the Moon is determined by the relative position of the Moon as it orbits Earth
- Limb
- Terminator
- Mare (Maria)
- Lunar phases
- Libration



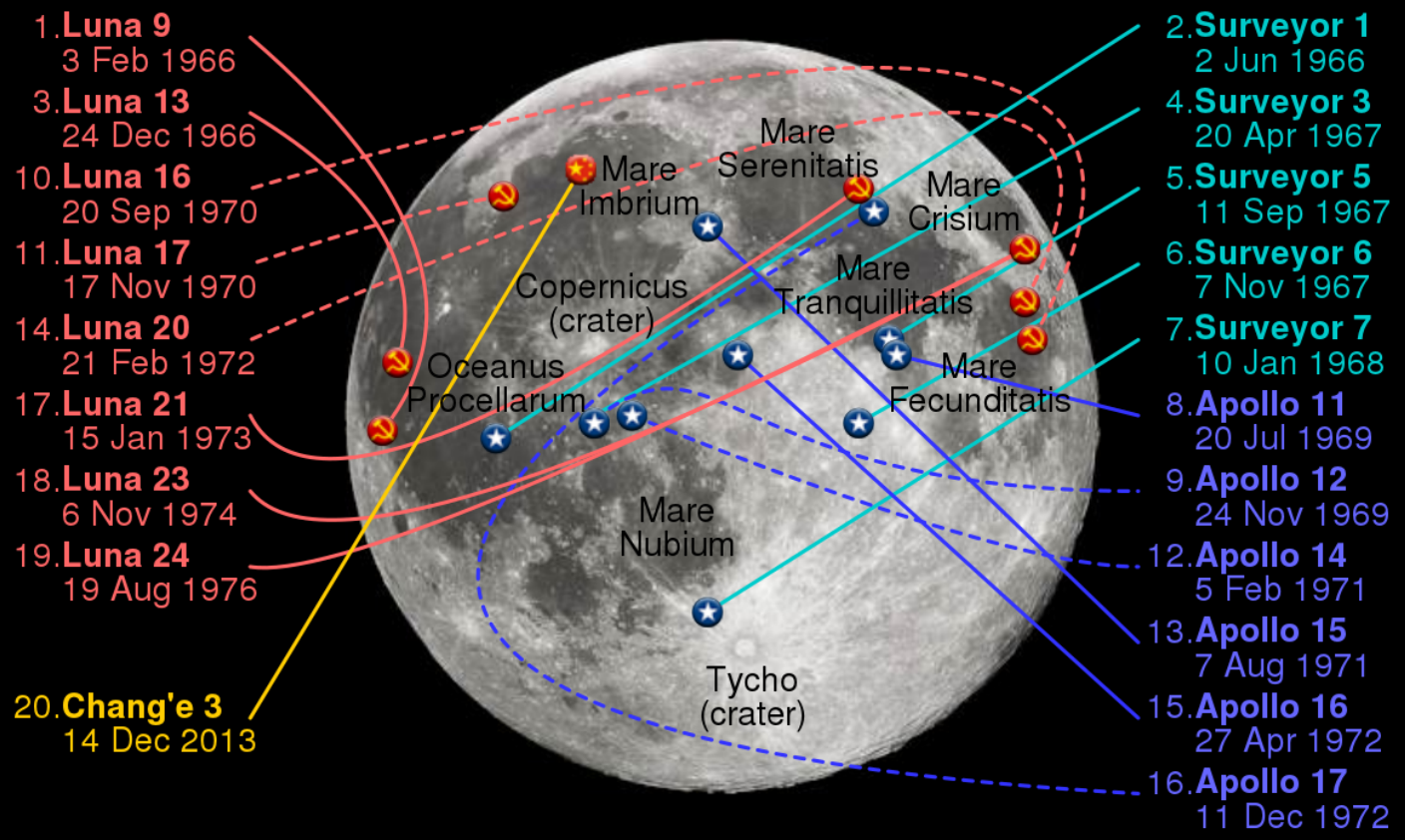
Anatomy of a Lunar Eclipse

- Relative position of Sun, Earth and Moon cause a lunar eclipse
- Only occur during a Full Moon
- Two weeks after a solar eclipse
- Umbra & Penumbra
- Different types
- Visible anywhere Moon is above horizon
- Total Lunar Eclipse March 3
- Begins 03:44



Early Exploration

- Successful landers



Recent Missions

India

Chandrayaan 1 – 2008 Orbiter & Moon Impact Probe

China

Chang'e 1 – 2007 Orbiter

JAXA

Hlten – 1990 Orbiter

KAGUYA – 2007 Orbiter

Israel

Beresheet – 2019 Lander crashed

SpaceIL - First private company lunar attempt

NASA

Clementine – 1994 Orbiter (DOD)

Lunar Prospector – 1998 Orbiter

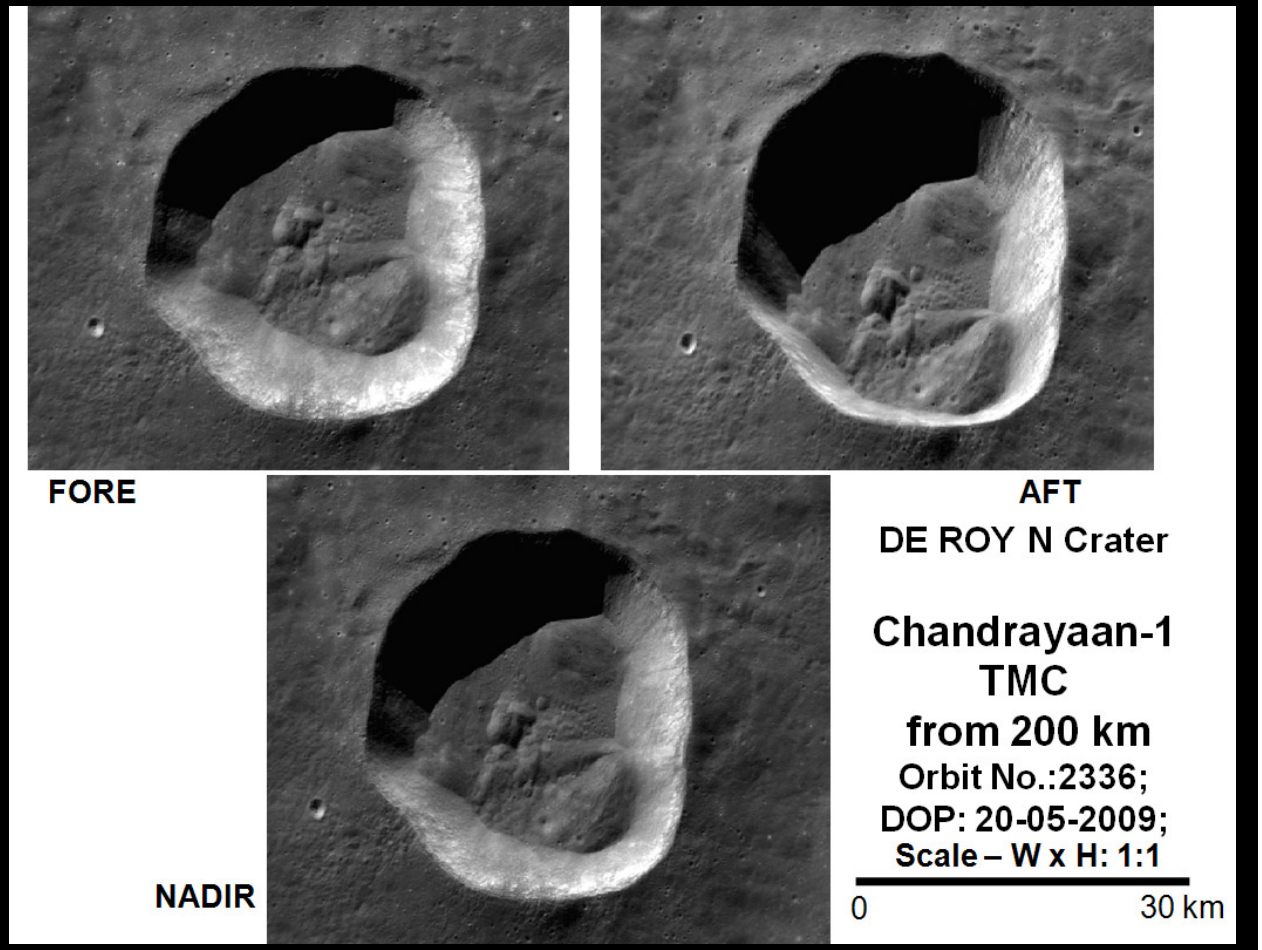
LCROSS – 2009 Orbiter

GRAIL – 2011 Orbiter

LADEE – 2013 Orbiter

ESA

SMART 1 – 2003 Orbiter



Current Exploration

Chinese

Chang'e 2 − 2010 Orbiter

Chang'e 3 − 2013 Lander & rover

Queqiao − 2018 Orbiter & radio relay for Chang'e 4

Chang'e 4 − 2019 Lander & rover

Chang'e 5 − 2020 Orbiter, lander, rover & sample return

Chang'e 6 - 2024 Orbiter, lander, rover & sample return

South Korea

Pathfinder − August 2022 Orbiter

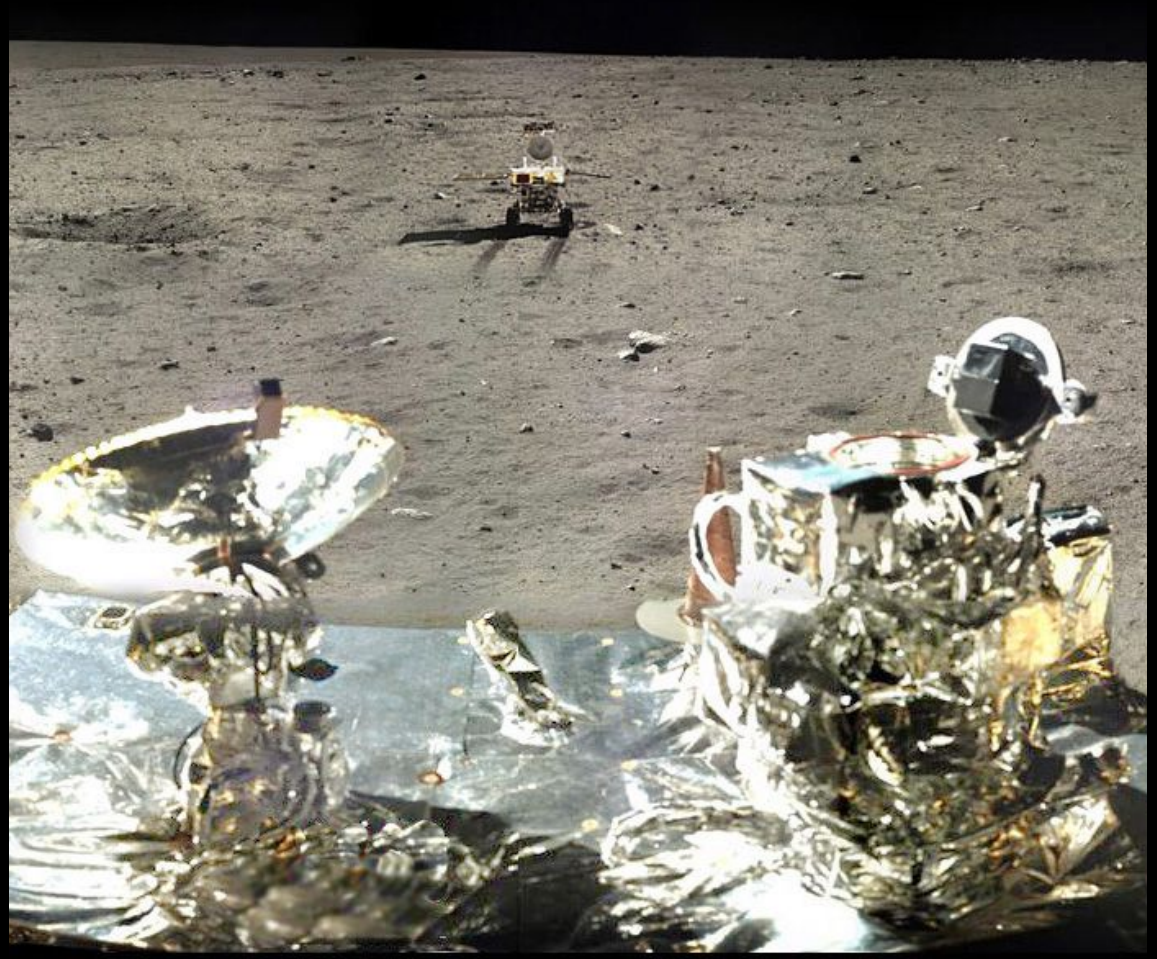
NASA

Lunar Reconnaissance Orbiter − 2009

ARTEMIS Program

India

Chandrayaan 2 − 2019 Orbiter, lander & rover (lander crashed)



Chang'e-3 Timelapse Color Panorama

Credit: CNSA/Chinanews/Ken Kremer/Marco Di Lorenzo

Discoveries

- Lunar geology: soil properties and chemical composition
- Rocks and soil contain same isotope content as Earth
- No global magnetic field
- Tenuous exosphere
- Global magma ocean
- 700 million year span of lava flooding
- Enormous lunar pits
- Lunar samples provided evidence for Late Heavy Bombardment 3.9 billion years ago
- Large impacts − South Aitken Basin provides evidence for Near Side and Far Side topography and mineralogy differences and Earth extinction events
- A window into Earth's formation and evolution
- Very little iron in core
- Retreating ~ 3.8 cm/year
- Water Ice discovered at north and south poles by Chandrayaan 1 in 2008
- High resolution imaging of entire surface

USRA

Future

NASA

Capstone − 2022 CubeSat orbiter

Artemis Program − 2026 Crewed orbiter

Lander − 20??

Deep Space Gateway − Manned orbiter & Mars staging − 20??

China

Chang'e 7 − 2026 Lunar survey utilizing an orbiter, lander and rover

Chang'e 8 − 2028 Lunar Technology Test

Manned lander − 2029 - 2030

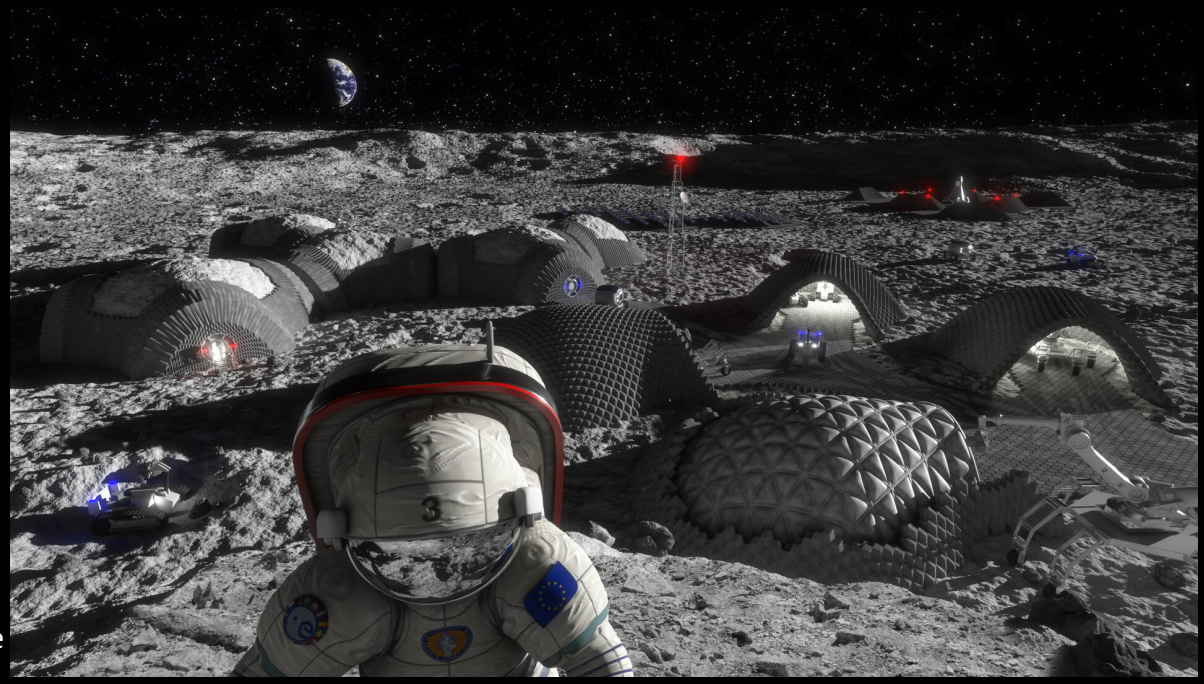
Japan

Lunar Cruiser to support Artemis

Lunar Polar Exploration Mission − 2028 lander and rover

ESA

Argonaut − cargo transport, rovers, science instruments and infrastructure



ESA

Private Sector

Space X

Blue Origin

Habitation

Sky Coordinates

December 5