AP Environmental Science

Earth Systems: Part 1

Astronomy

In the beginning....

- Our Universe began as a very hot, very dense cloud of high energy hydrogen plasma
- The “Big Bang” is the finite point, 13.7 BYA when for some reason the universe started to expand in all directions
- The universe has expanded and cooled ever since this point

- In the first microseconds after the big bang, elementary particles (quarks and leptons) dominated the universe independently

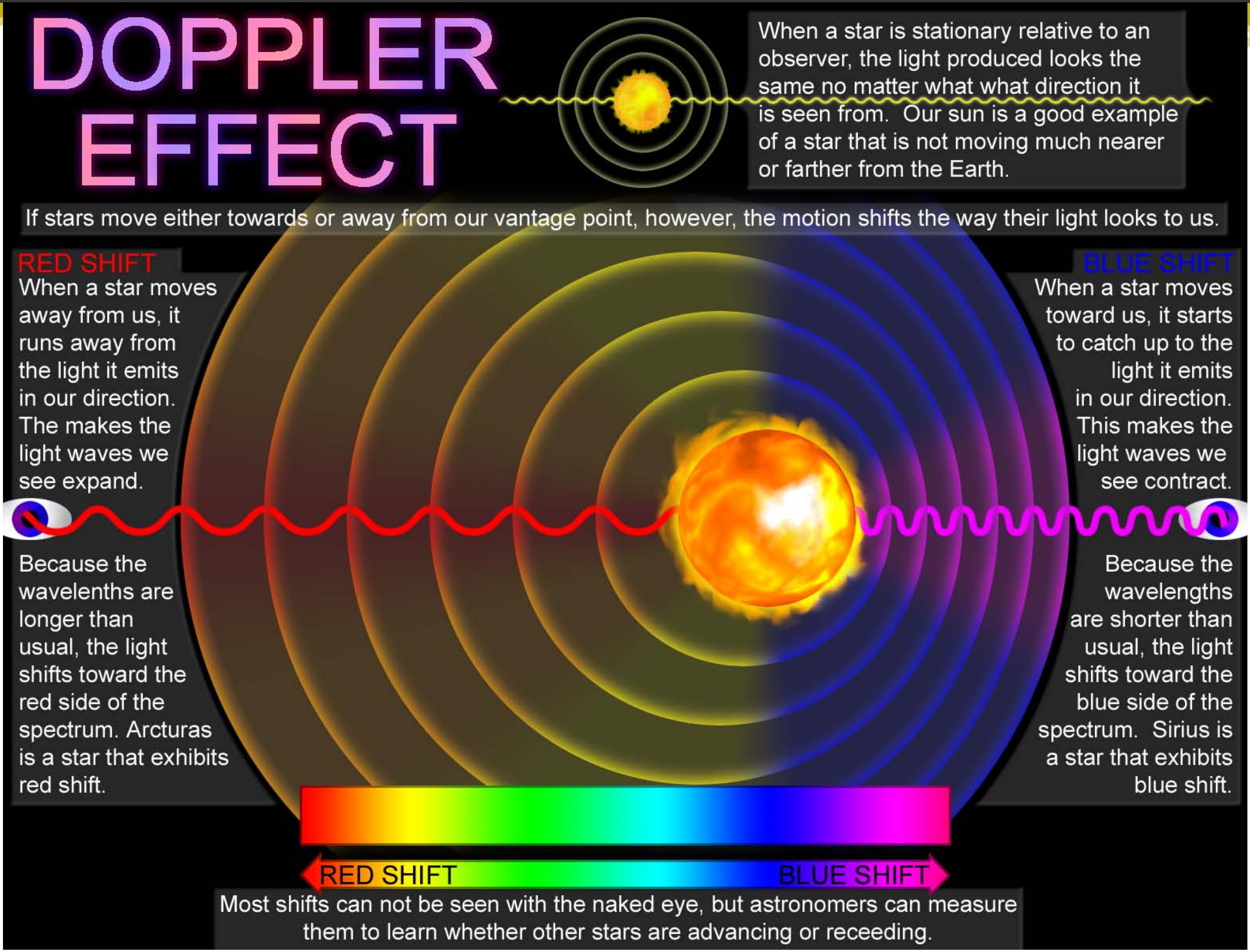
- As the universe cooled, layer upon layer of structure began to form, first neutrons and protons→ atomic nuclei → atoms→ stars → galaxies → galaxy clusters

- Our universe is now populated by an estimated 100 billion galaxies, each with 100 billion stars each of those having planets orbiting

How do we know, why do we think..

- 1) We know that the universe is expanding
  - By looking at the color of distance stars we can tell whether they are approaching or receeding
  - If the color of the star appears blue (blueshift) then the star is approaching earth, shortening the wavelengths of light turning it blue

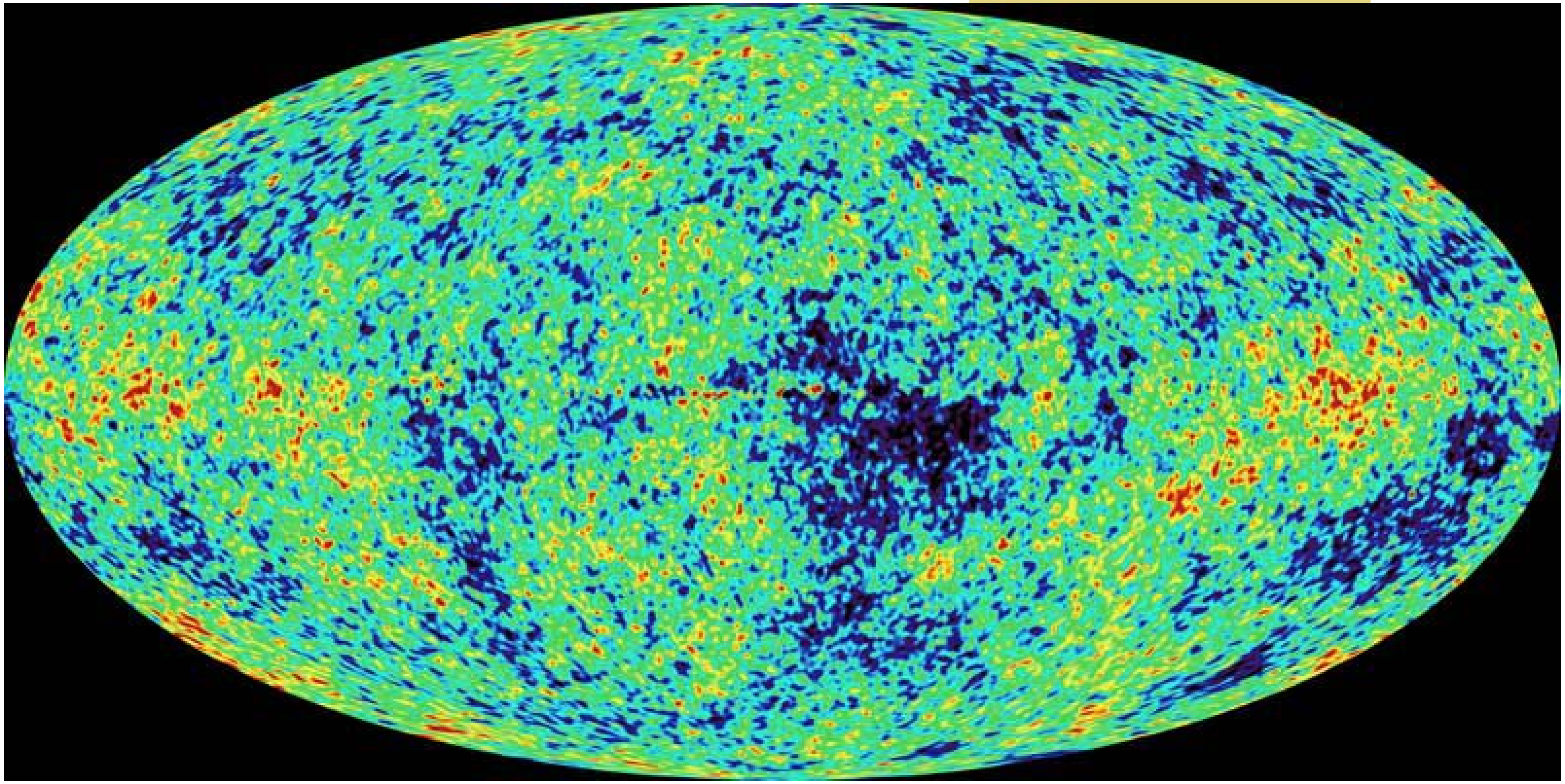
- If the color appears red(redshift) then the distance between us and the star is increasing stretching the wavelengths of light shifting them toward the longer red wavelengths
- The further the distance between us and the star the greater the redshift because they are travelling at higher speeds (Edwin Hubble,1929)
- This is known as a Doppler wobble or Doppler shift



http://diagrammar.wordpress.com/

- 2)Helium and Deuterium is universally abundant, and predates the formation of stars.
  - The only things today beside nuclear bombs that can create these elements are stars
- 3) Cosmic Background Radiation
  - When looking at the sky with a radio telescope, there is a universal “glow” of microwaves the blankets the universe.
  - The uniformity indicates one original source of the radiation, the big bang

http://www.ugcs.caltech.edu/~yukimoon/BigBang/BigBang.htm



Temperature variations of the cosmic background radiation as measured by WMAP (difference between colors is 0.0002 Kelvin, average temperature 2.75 Kelvin)

http://faculty.washington.edu/

Home Sweet Home in the Milky Way

- The Milky Way is a barred spiral galaxy
- 100,000 light years in diameter
- 1000 light years in thickness
- 100 -400 billion stars
- Oldest star is 13.2 BYO
- We are located 26,000 light years from the galactic center
- We are spiraling at roughly 552km/s

Infrared image of the center of the Milky Way Galaxy taken by the Spitzer Space Telescope

Photograph of the night sky highlighting our galaxy as the hazy band of stars across the sky

Our location on one of the spiral arms

Howdy Neighbor..

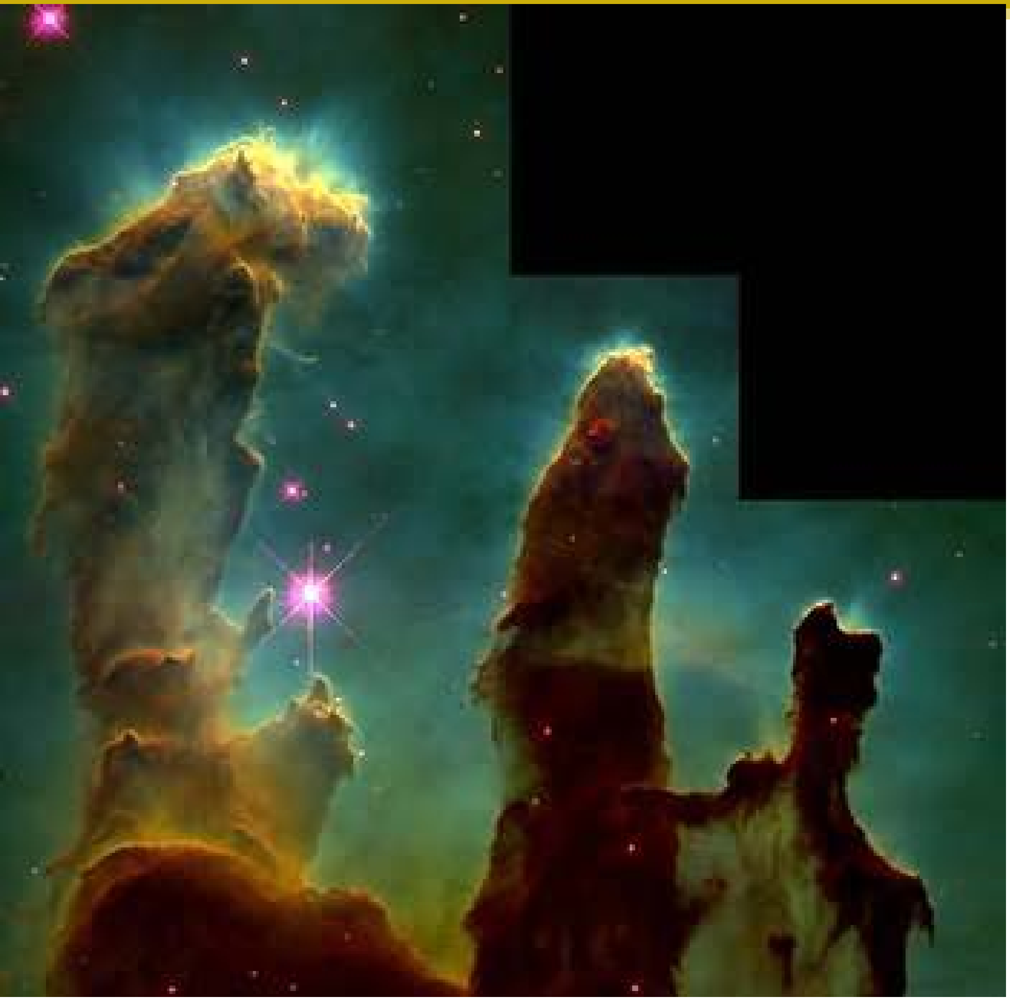
- The Andromeda Galaxy is our nearest relative
- It contains roughly 100 trillion stars
- Located 2,500,000 light-years away
- 220,000 light-years in diameter
- It is approaching us at roughly 140 km/s and we will collide in about 2.5 billion years to possibly form one giant galaxy

Infrared Image of Andromeda Galaxy taken by the Spitzer Space Telescope

Twinkle, Twinkly little star...

- Space is thinly filled with gas (H_2 & He) and dust (carbon & silicon) called interstellar medium
- In some places the gas and dust collect into large clouds called nebula- the birthplace of stars
- The nebula contains pockets of higher gravity that cause the matter to clump together, the clumps get bigger and bigger in a process called accretion

- The continued process of accretion will eventually form a protostar
- The functional life of a star is complicated balancing act between the gravity pulling atoms inward and the physical forces pushing heat and light away from the center
- When equilibrium is first reached the star ignites-
  - if because of temperatures it fails to ignite it becomes known as a brown dwarf
  - If it does ignite, nuclear fusion begins to happen and the star is born



Eagle Nebula-Pillars of Creation

Star Forming Region of Doradu Nebula

Turbulent Gases in the Omega/ Swan Nebula

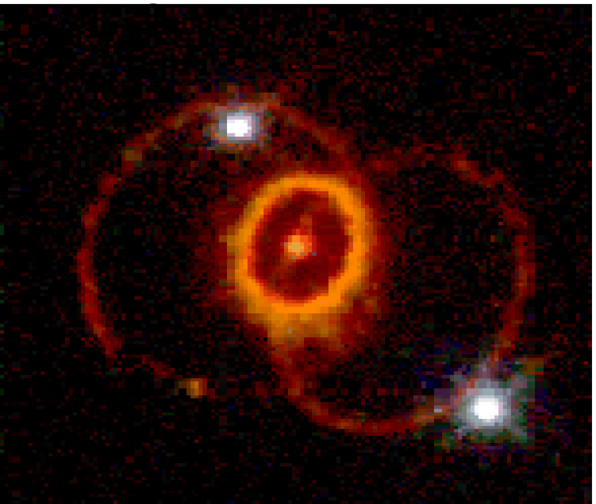
The Orion Nebula

http://hubblesite.org

- A star spend the majority of its life in what is known as the main sequence- where it constantly fuses hydrogen into helium
- Stars constantly contract during their life, about 50 million years for a medium size star, increasing the temperature and pressure inside the star to compensate for the loss of heat and energy

The Death of a Star

- Once the hydrogen fuel source in the core is gone it will start burning helium.
- The outer shell will burn the last bits of hydrogen causing the outer shell to expand aiding in the release of heat from the core creating a red giant

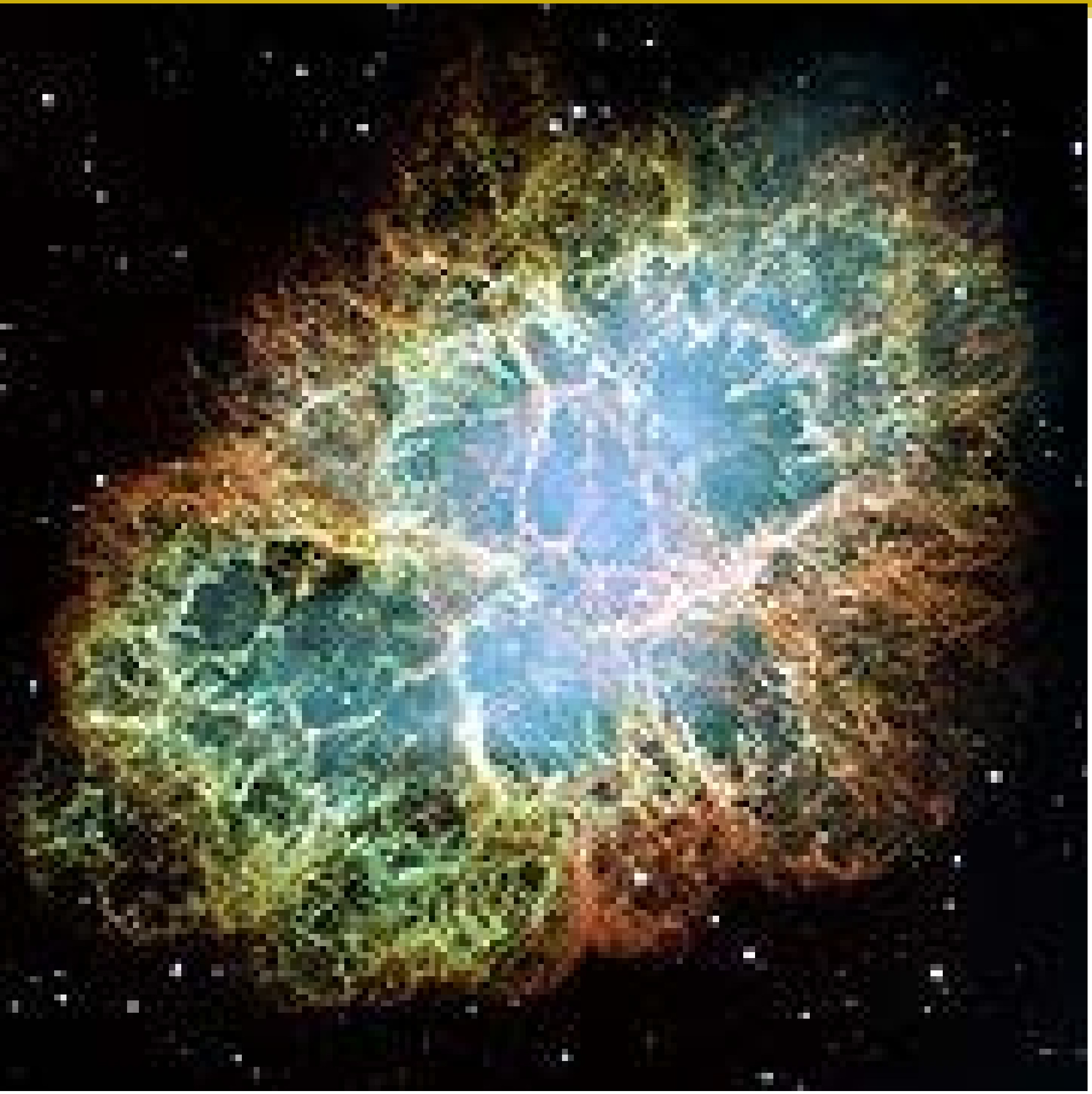


Supernova of a star first seen in 1987 by the Hubble Telescope

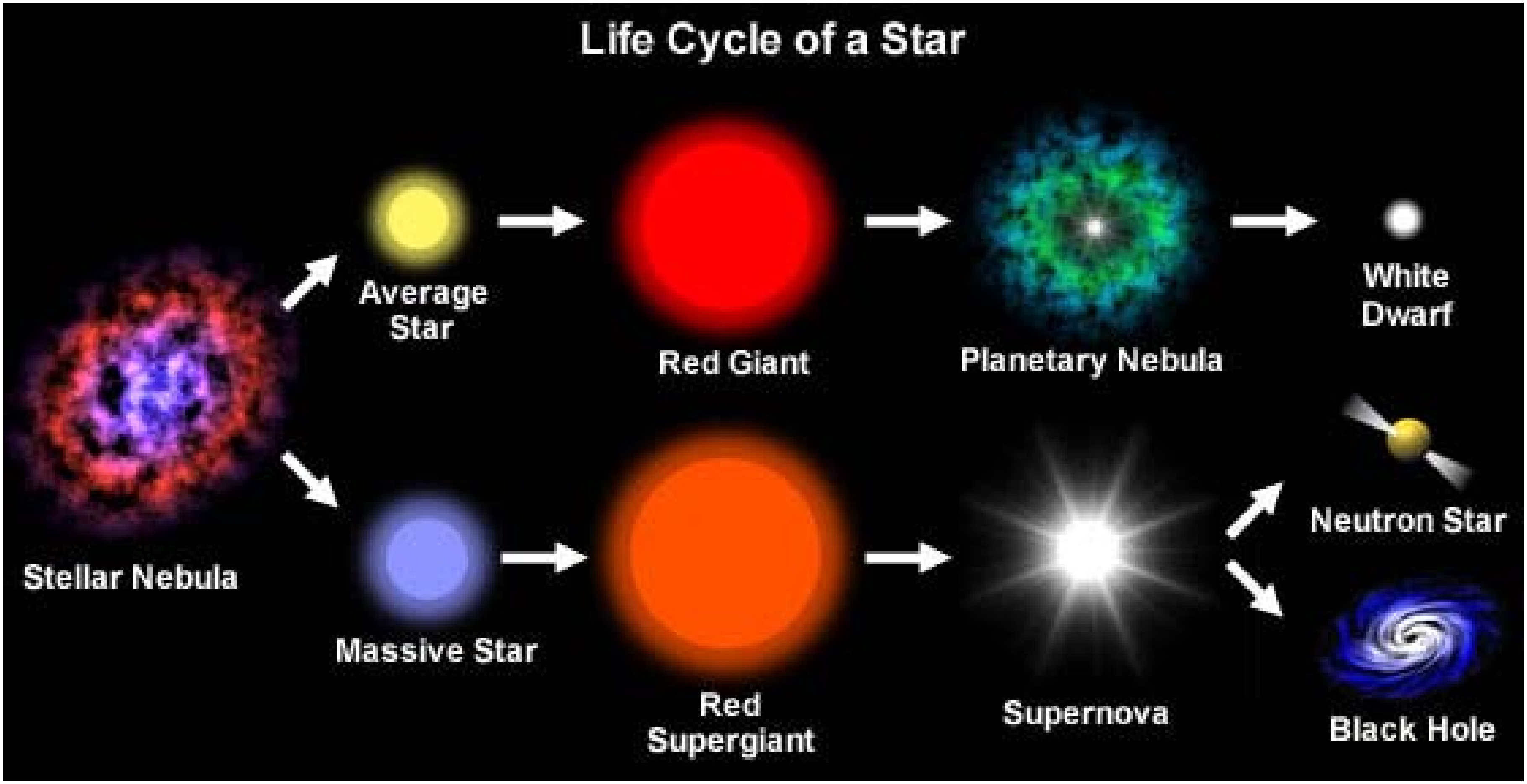
- The expanding gases will then be cast off producing one of the following
  - Small stars- white dwarf (size of Earth) and a planetary nebular
  - Medium stars – supernova producing a neutron star(size of a city)
  - Large stars – form black holes
- It is the death of stars that is responsible for the creation of the heavier elements

White Dwarf in the center of a planetary nebula, the result of the death of a smaller star, like ours

http://sunshine.chpc.utah.edu/



The Crab Nebula is a pulsar wind nebula associated with a 1054 BCE supernova

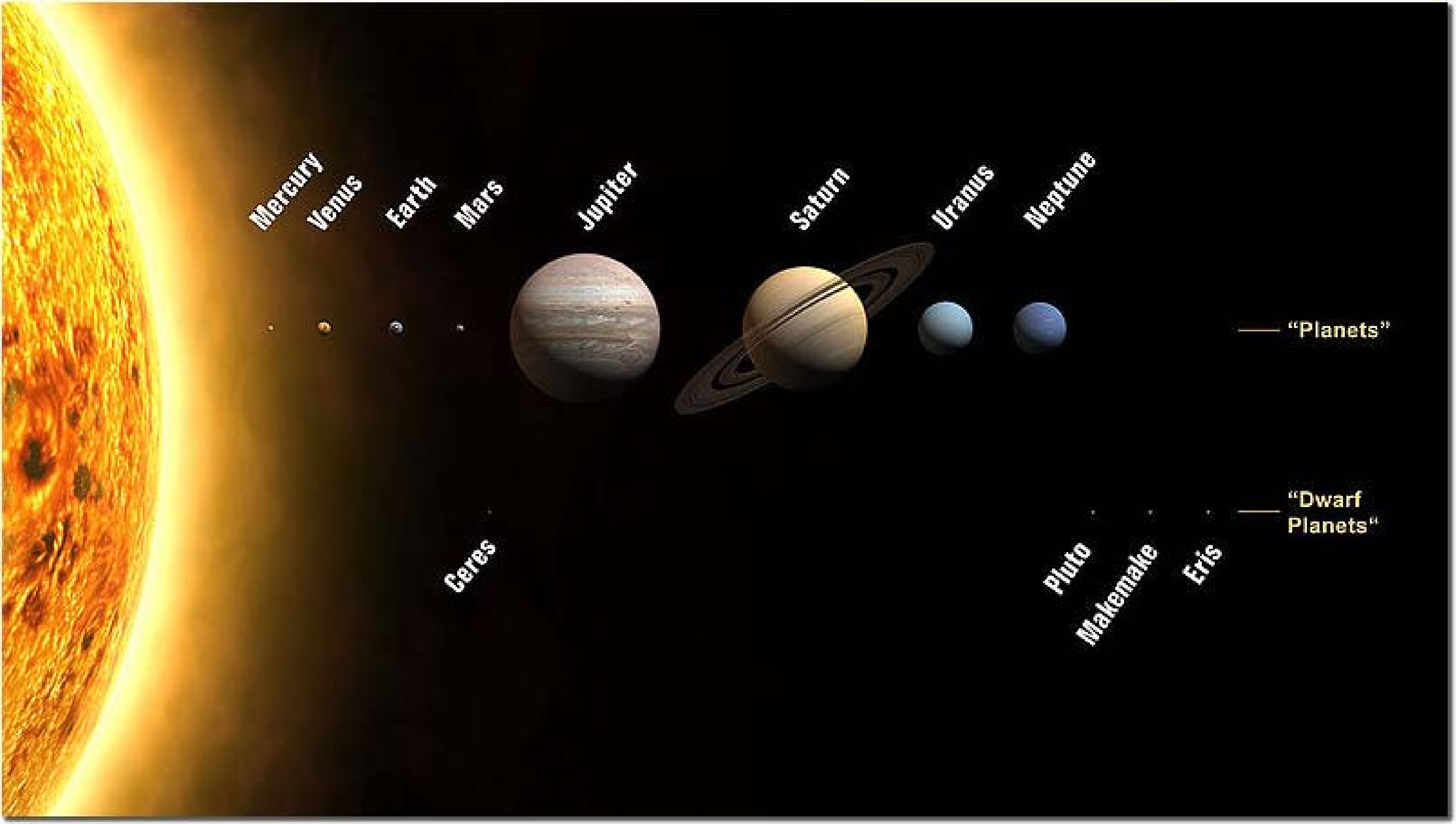

Life Cycle of a Star
Stellar Nebula
Average Star
Red Giant
Planetary Nebula
White Dwarf
Massive Star
Red Supergiant
Supernova
Neutron Star
Black Hole

Another Trip Around the Sun

- From the nebula come not only stars but also protoplanetary disks of gas and dust
- Our solar system might have formed from the disruption caused by a nearby supernova
- Accretion in this disks once again causes the dust to pile up and it will start to rotate around the solar center, the center become the star and the outer bands form planets

- The gravity of the disk pulls heavier materials toward the center giving way to rocky planets such as Earth, Venus and Mars
- Lighter icy materials remained in the outer reaches of the spiral forming the giant planets like Jupiter
- From studying meteorites it is believed that our solar system is 4.6 billion years old

http://www.windows.ucar.edu



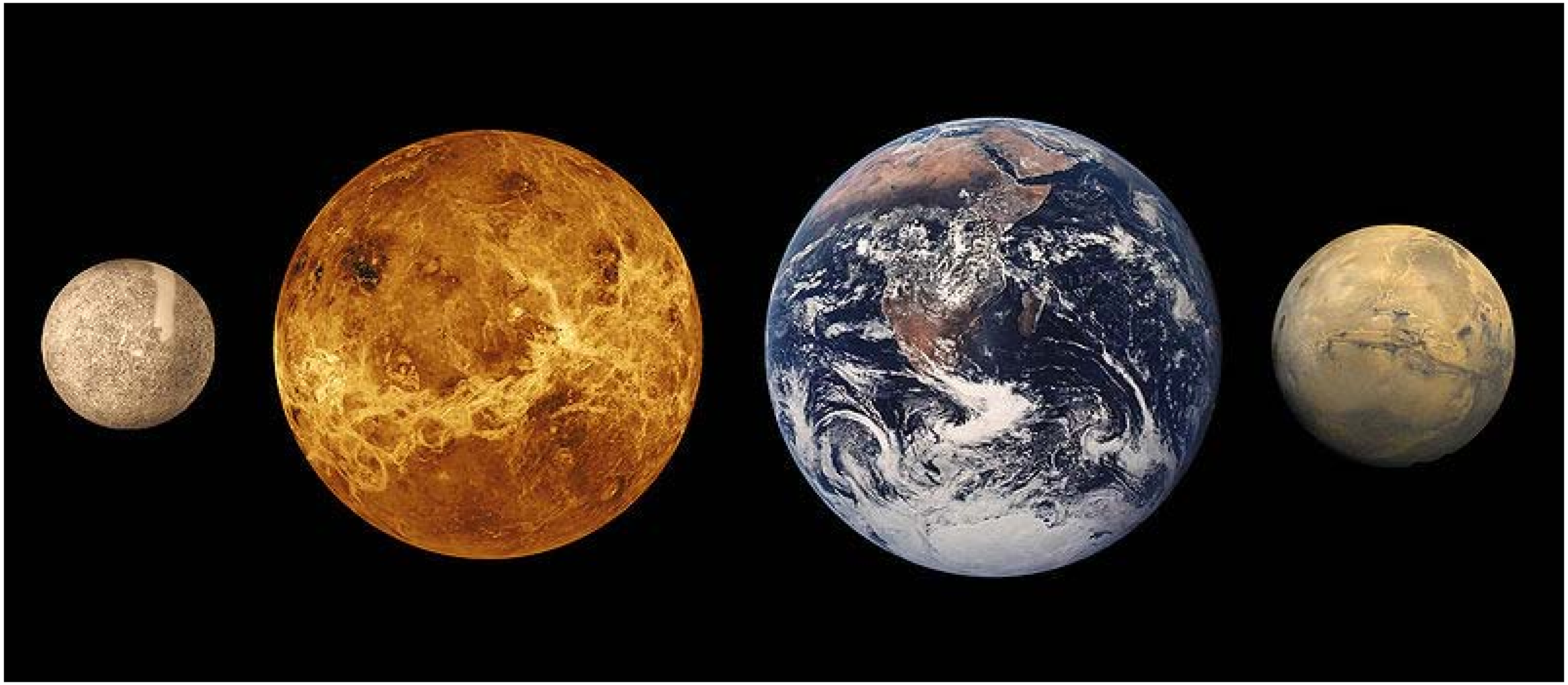
A diagram of our solar system

http://www.diagramofsolarsystem.com/

- Our Sun
  - Age- 4.5 billion years old
  - Distance from Earth-150,000,000 km
  - Diameter-109x the size of Earth
  - (1,390,000 km)
  - Mass- 333,000x the mass of Earth
  - Composition -73 % hydrogen, 25% helium, 2% other (carbon, iron, neon, nitrogen, silicon, magnesium, sulfur)

The Inner Planets

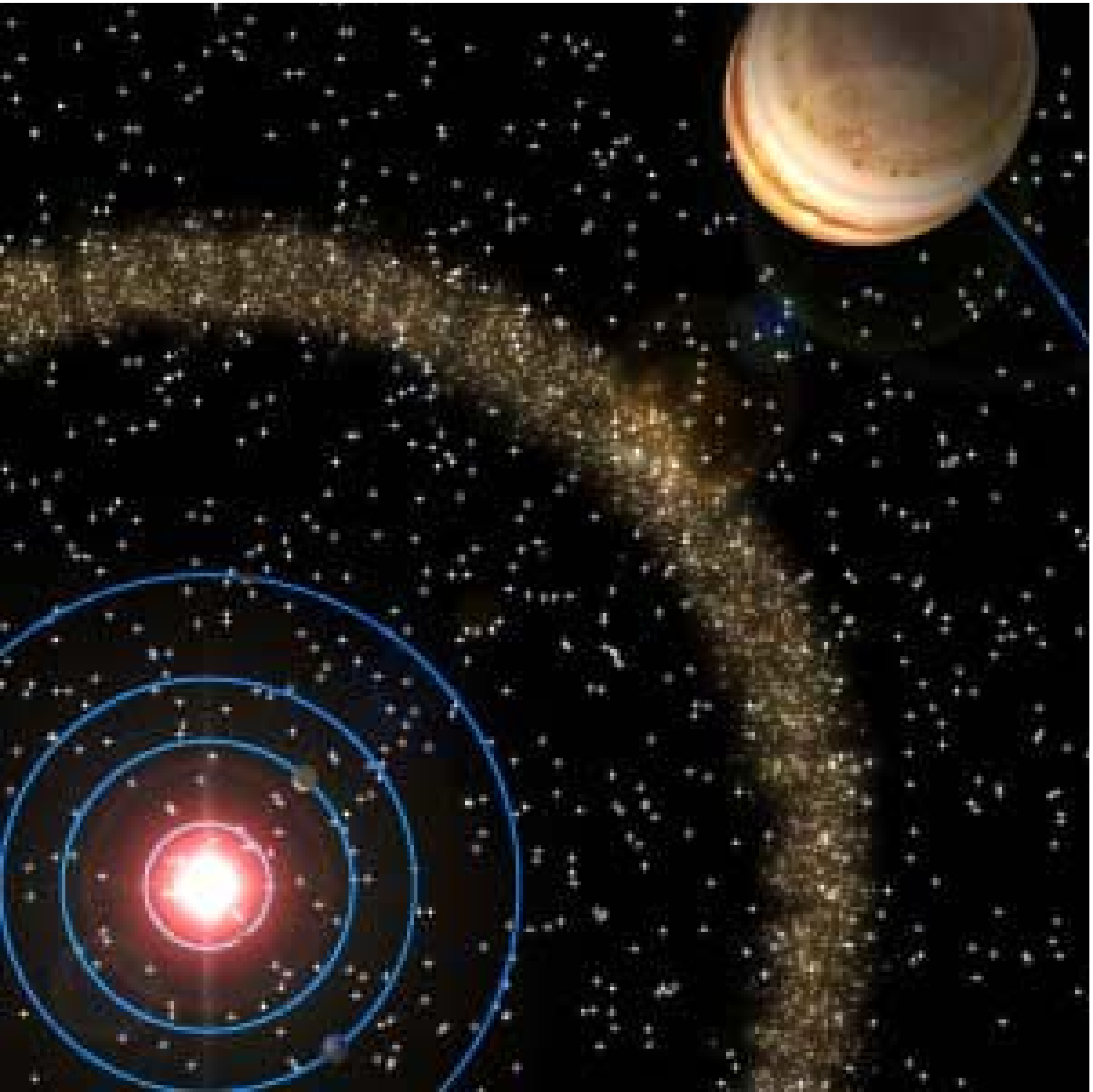
- Terrestrial Planets
- Dense rocky compositions
- Few or no moons, no ring systems
- Silicate minerals form their crust
- Iron and nickel cores
- 3 of 4 have atmospheres (Venus, Earth, Mars) and weather patterns
- Mercury’s was blown off by stellar winds



Size comparison of the inner planets (NASA)

Asteroid Belt

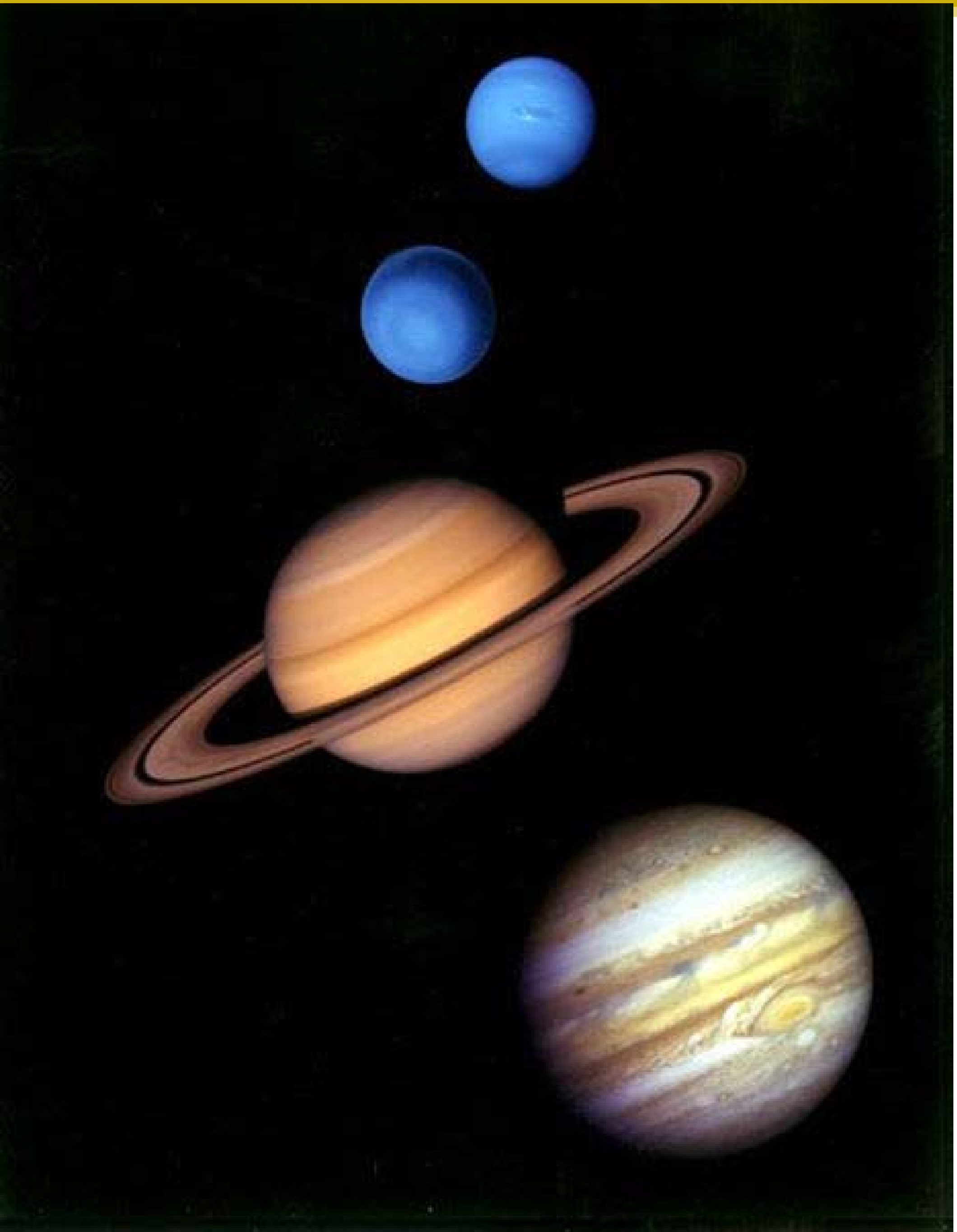
- Asteroid- small solar system bodies that orbit the sun
- Located between the planets Mars and Jupiter
- From a few feet to hundreds of miles wide
    - It contains over 40,000 rocks over ½ mile across



The asteroid belt between Mars and Jupiter

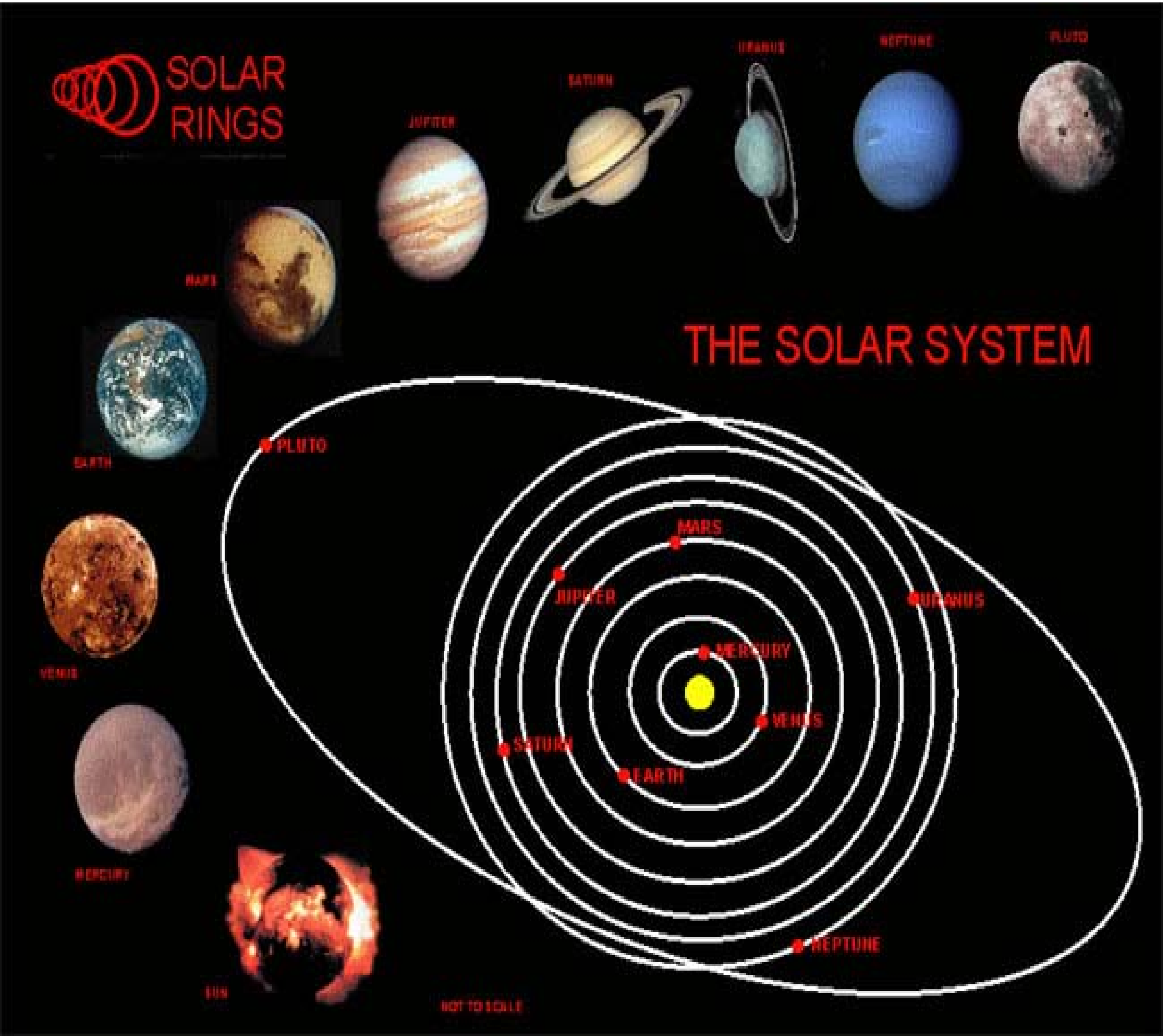
The Outer Planets

- Gas Giants
- Jupiter and Saturn consist of a large amount of hydrogen and helium
- Uranus and Neptune possess a greater proportion of ices (frozen water, ammonia, methane)
- All of the gas giants have ring systems but only Saturn's is observable from earth



The outer Jovian Planets

BBC-Jupiter Explosion Video



The orbits of the solar system

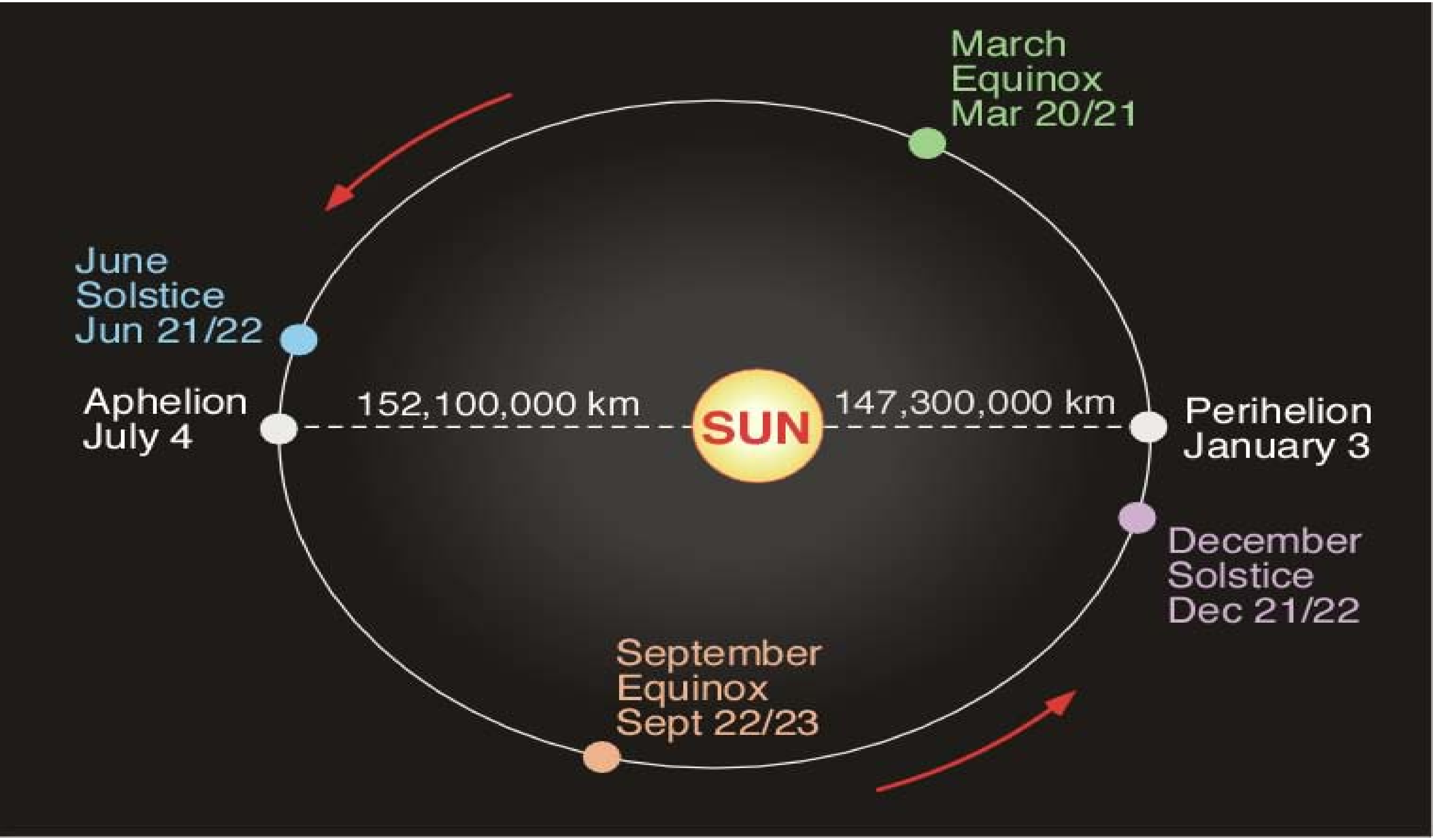
Earth-Sun Relationships

Earth-Sun, Like peas in a pod

- The Earth’s orbit around the sun is called a revolution, this revolution takes 365.26 days
- Hence every four years we have a leap year to catch up
- The orbit is elliptical, causing our distance from the sun to vary, and our energy from the sun fluctuates by about 6%

Round and Round we go..

- On January 3rd the Earth is closest to the sun(147.3 million Km), this is called the perihelion
- On July 4th the Earth is the farthest from the sun(152.1 million Km), this is called the aphelion
- The average distance from the sun is 149.6 million Km



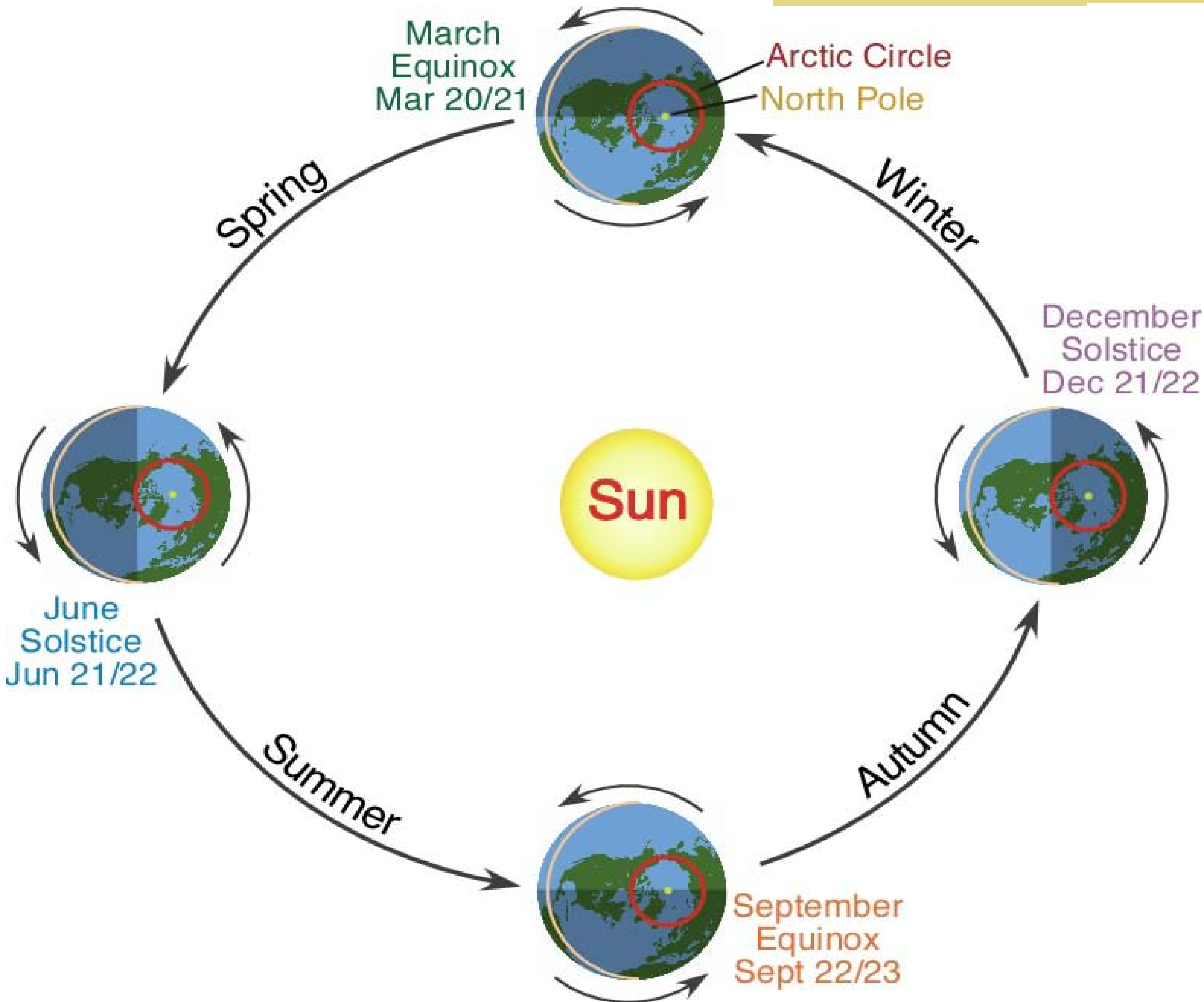
Earth’s Orbit

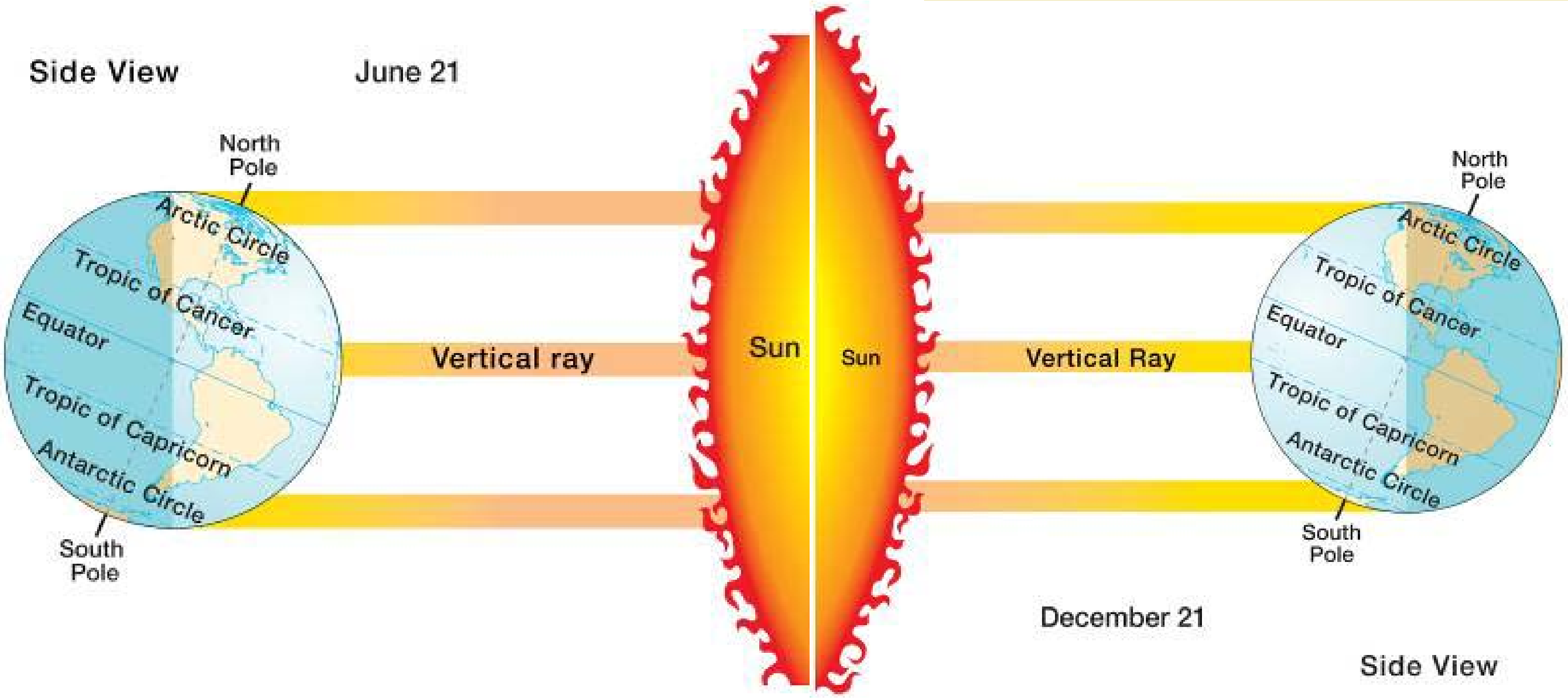
- There are two major events in the Earth's orbits- the solstice and the equinox
- The solstices occur in the winter (Dec 21/22) and in the summer (June 21/22)
- The equinoxes occur in the spring (Vernal, March 20/21) and the fall (Autumnal, Sept. 22/23)
- During the equinoxes there are 12 hours of day/12 hours of night
- The summer solstice is the longest day of the year

You spin me right round...

- The Earth rotates on an axis, and imaginary line that runs through the poles of the Earth
- Earth's axis is not completely vertical, it is tilted 23.5^{o} from perpendicular
- It is the relationship between Earth's tilt and its orbital revolution that creates the seasons

http://www.physicalgeography.net/fundamentals/6h.html

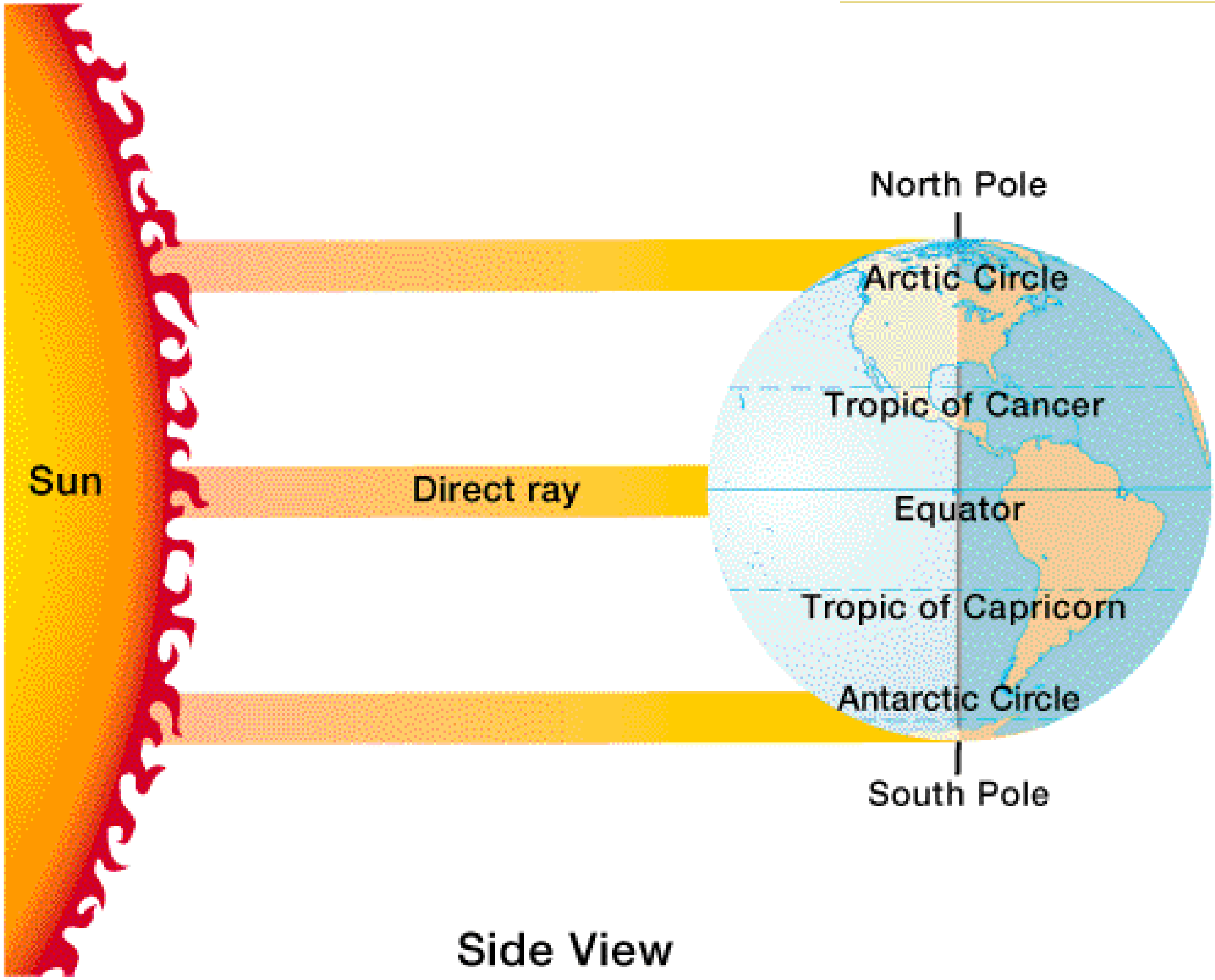

March
Equinox
Mar 20/21
Arctic Circle
North Pole
Spring
Winter
December
Solstice
Dec 21/22
Sun
June
Solstice
Jun 21/22
Summer
Autumn
September
Equinox
Sept 22/23



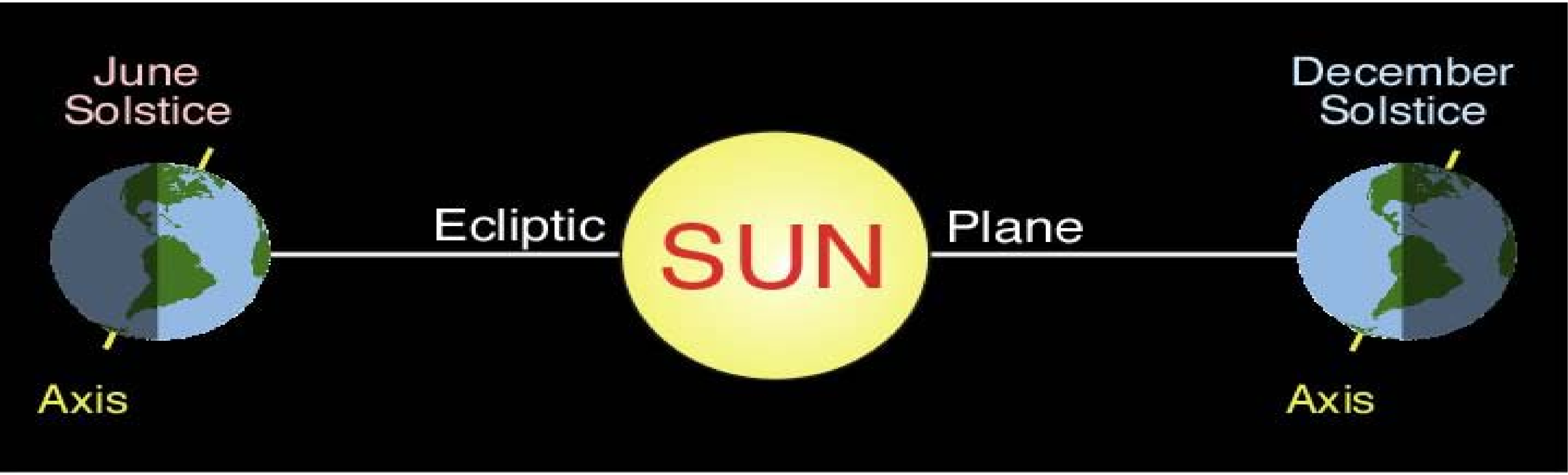
Summer Solstice

Winter Solstice

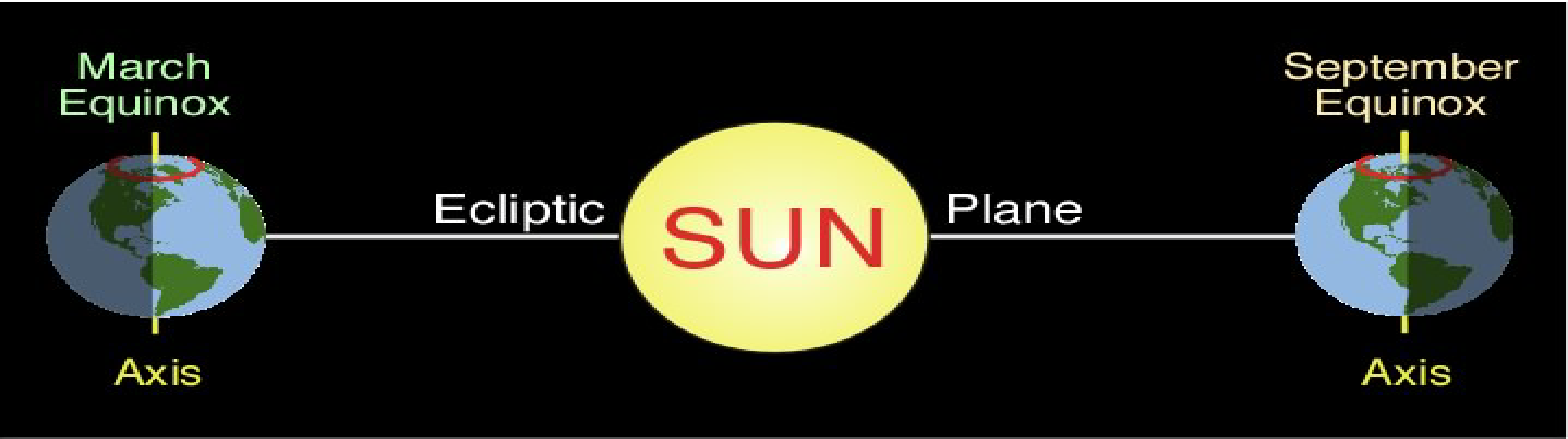
Earth's Orbit and the seasons



Vernal and Autumnal Equinox



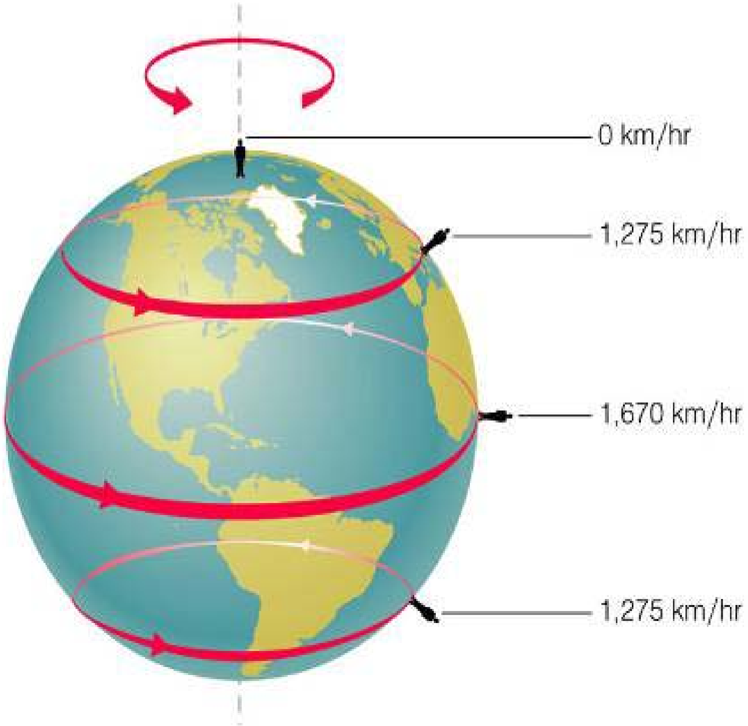
How the tilt of the Earth affects which hemisphere is facing the sun



- Earth is actually closest to the sun in the winter time, and furthest away in the summer
- When it is summer in the northern hemisphere then it is winter in the southern hemisphere

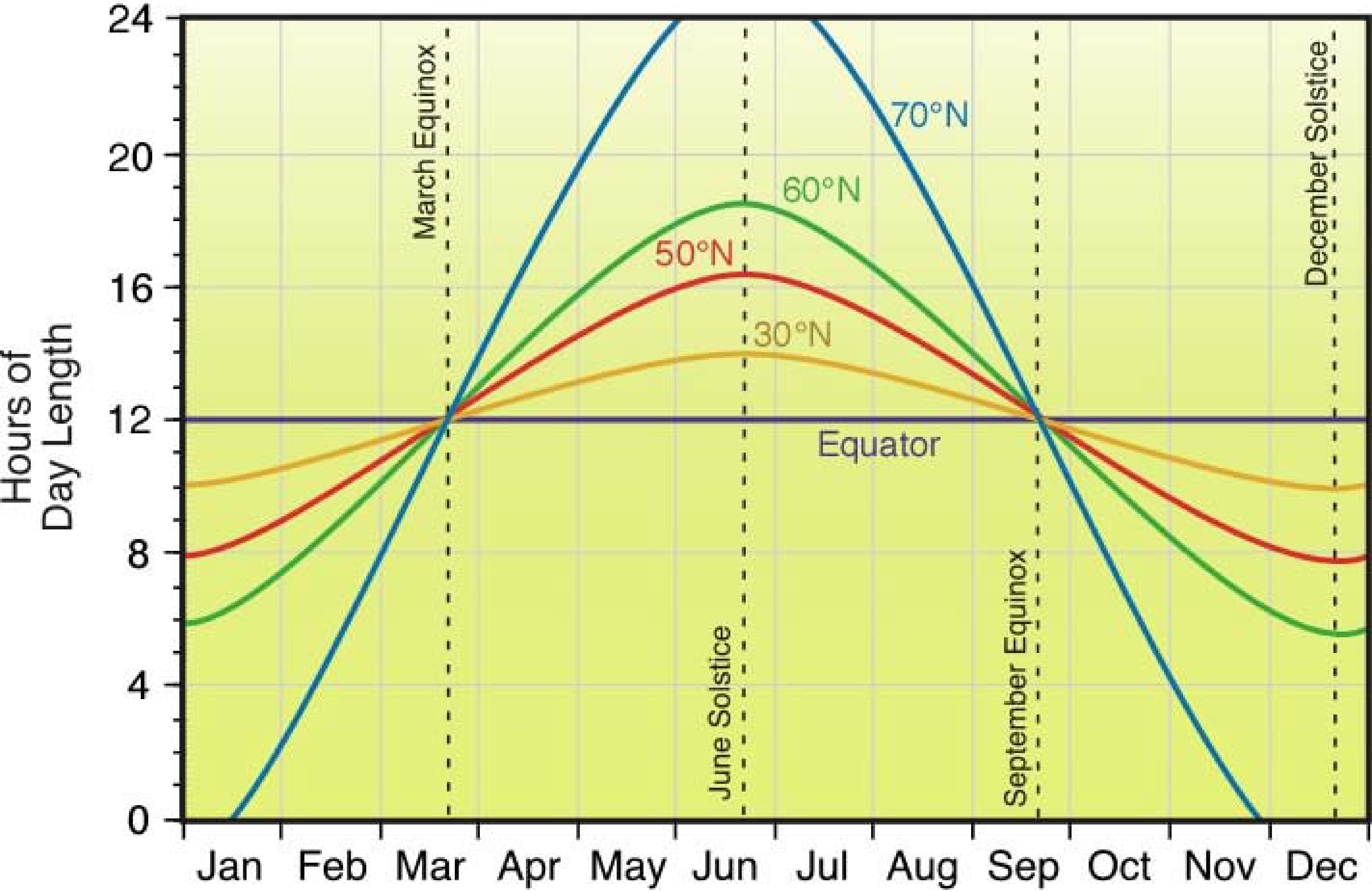
Round and Round..

- The Earth rotates east to west, or counter-clockwise (when viewed from the North Pole)
- The rotation of the Earth takes approx. 24 hours



- Seasonal effects on the Earth
  - Changes in solar altitude
  - Changes in day length
  - Changes in apparent solar intensity
  - Changes in temperature

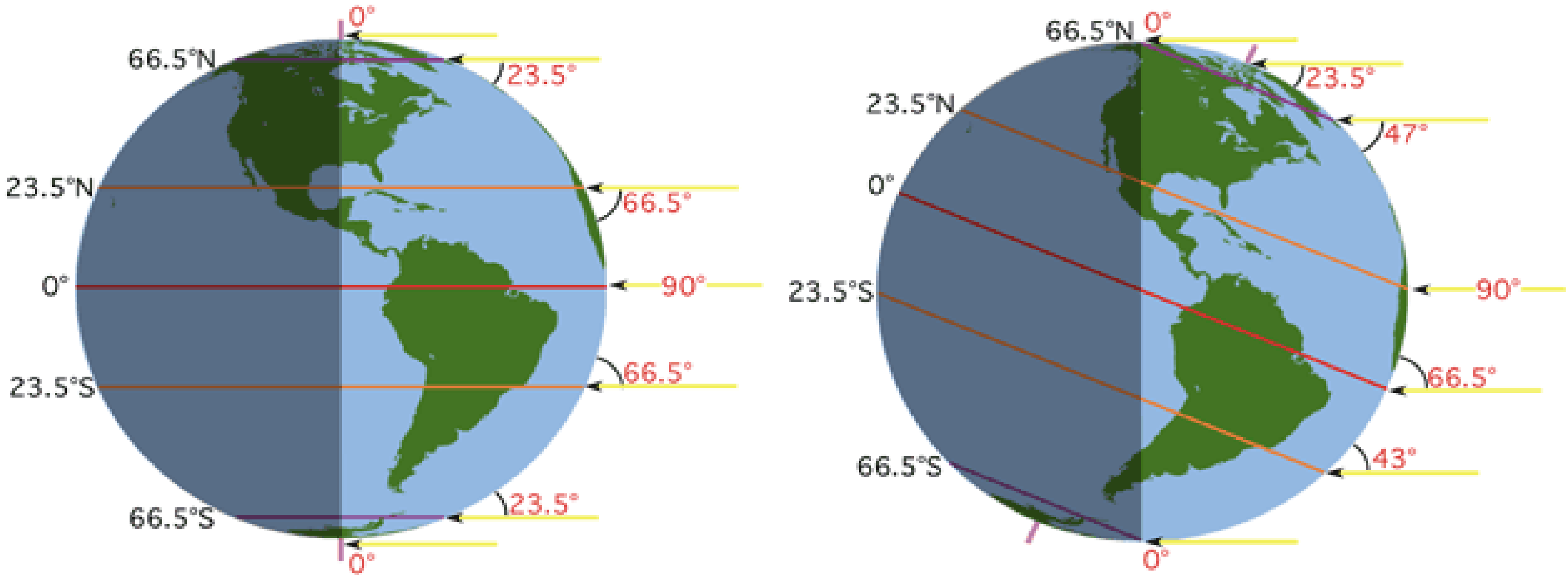
- Changes in the seasons are the most extreme at the poles and minimized at the equator



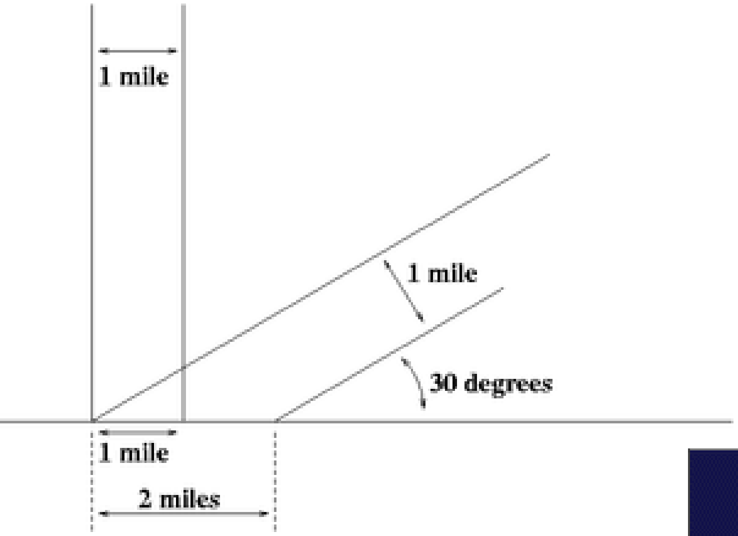
Hours of Day Length
24
20
16
12
8
4
0
March Equinox
June Solstice
September Equinox
December Solstice
70°N
60°N
50°N
30°N
Equator
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Light from the sun

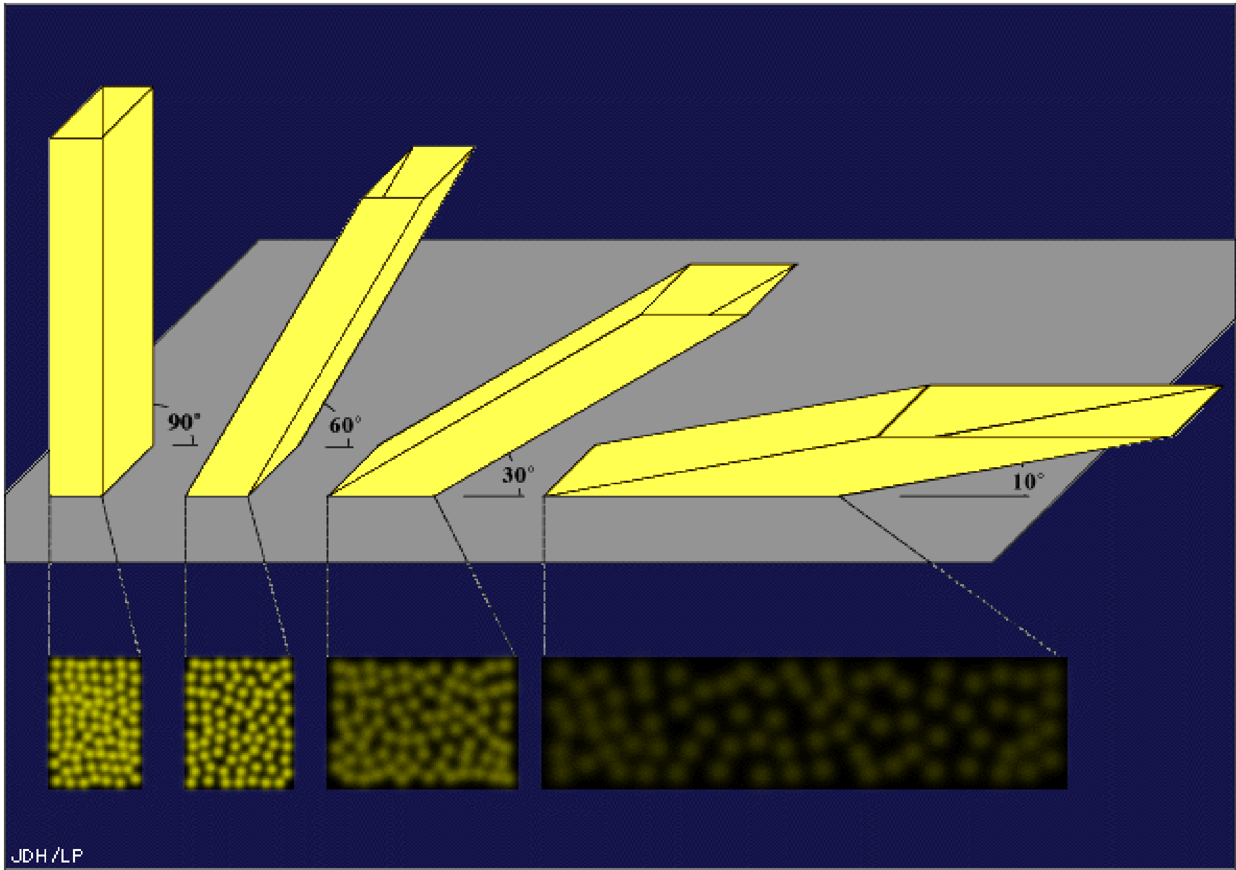
- Solar Radiation is received in parallel rays of energy
- Insolation- the measurement of solar energy received on a given surface(Earth)
- Commonly expressed as the average irradiance, W/m^2 or $kWh/(m^2*day)$
- Intensity of incoming solar radiation (insolation) is related to angle of incidence. Higher angles = higher intensity



- The sun irradiates 63,000,000 W/ m^2
- Depending on distance and size of an object, we can calculate the amount of energy that we receive

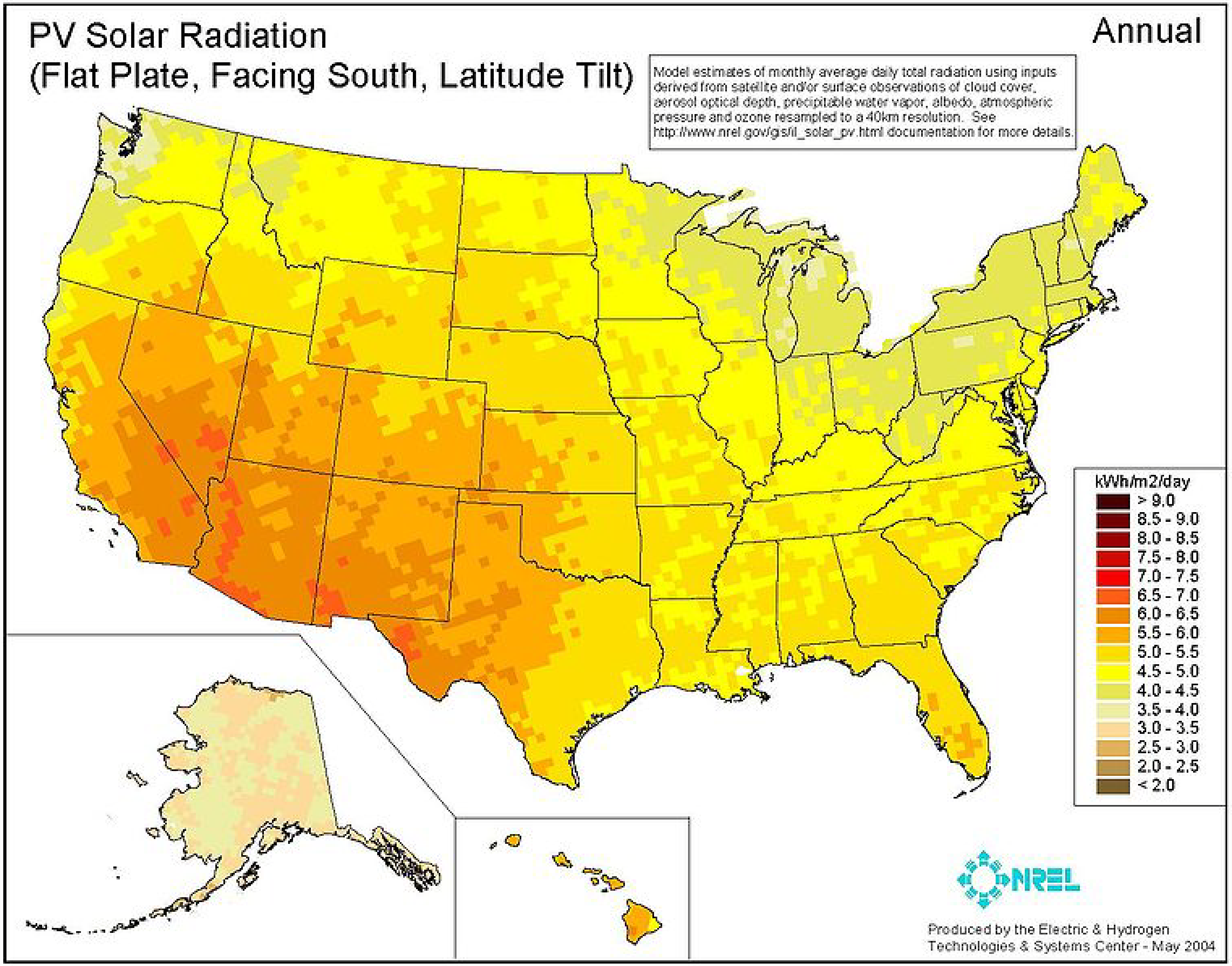


A 1 mi sunbeam striking the Earth at 90º disperses it energy over 1mi of surface, while a sunbeam striking at 30º spreads the energy over a surface area of 2 miles

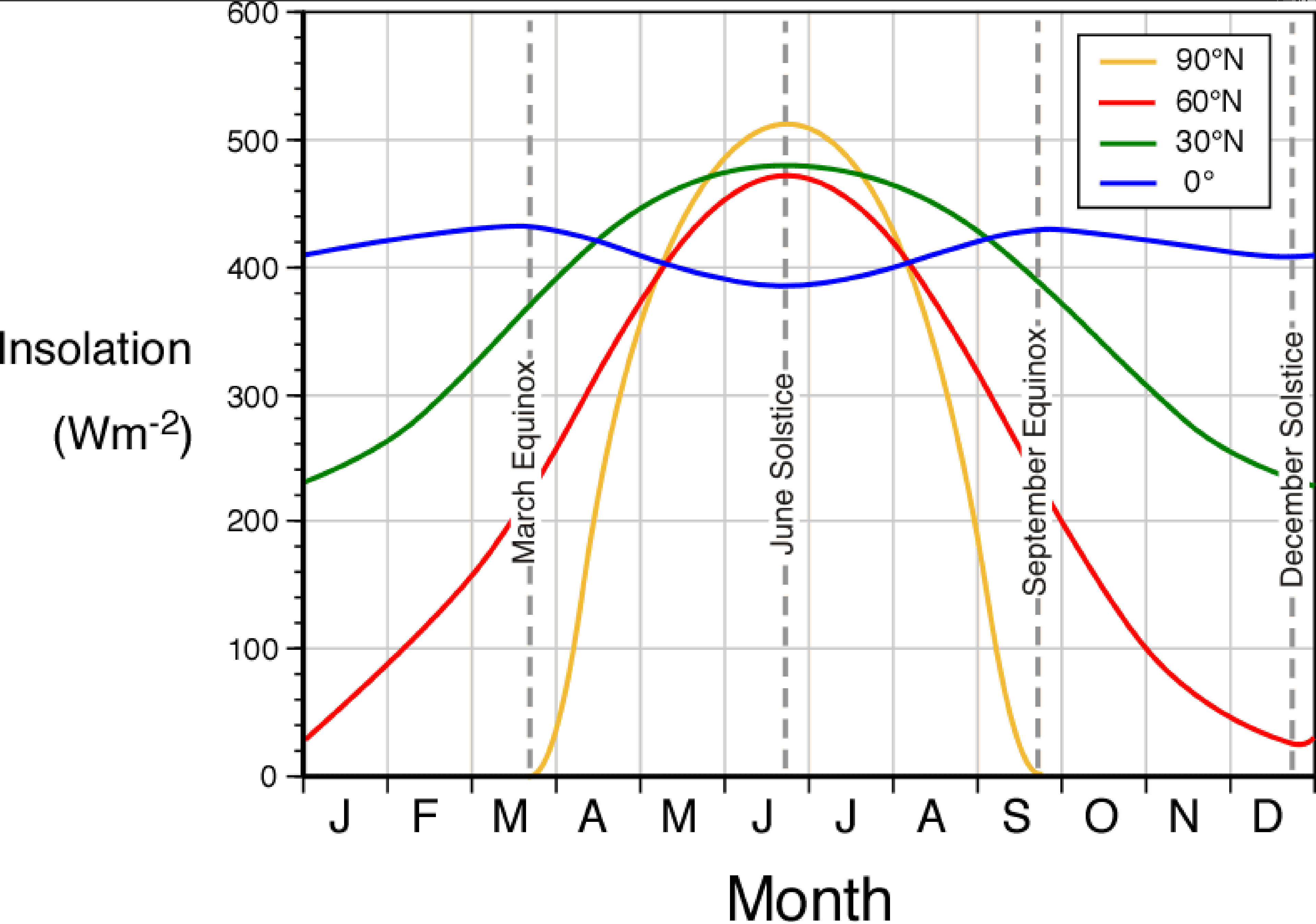


- At the top of the atmosphere- 1,366 W/ m^2 of energy is received (2 billionths)
- Atmospheric phenomena such as clouds and weather patterns affect the amount of solar energy that reaches the surface
- Geographic location, time of day and landscape can also affect the amount of energy received
- Perpendicular locations receive roughly 1000 W/ m^2 on a clear day
- Earth's average insolation is 250 W/ m^2

http://www.eoearth.org/article/Solar_radiation



Average solar radiation received in the Us



600
500
400
300
200
100
0
Insolation
(Wm-2)
March Equinox
June Solstice
September Equinox
December Solstice
90°N
60°N
30°N
0°
J
F
M
A
M
J
J
A
S
O
N
D
Month

Earth’s energy budget

- 30% of the sun’s energy is reflected by the atmosphere and the surface
- 19 % is absorbed by the clouds and atmosphere itself, an reradiated back into space
- 51% of the energy is absorbed by the landscape and oceans to warm it
- 70% of the total energy we receive is reradiated back into space
- 0.023 % of that energy is used for Photosynthesis to fuel the food chain

EARTH'S ENERGY BUDGET