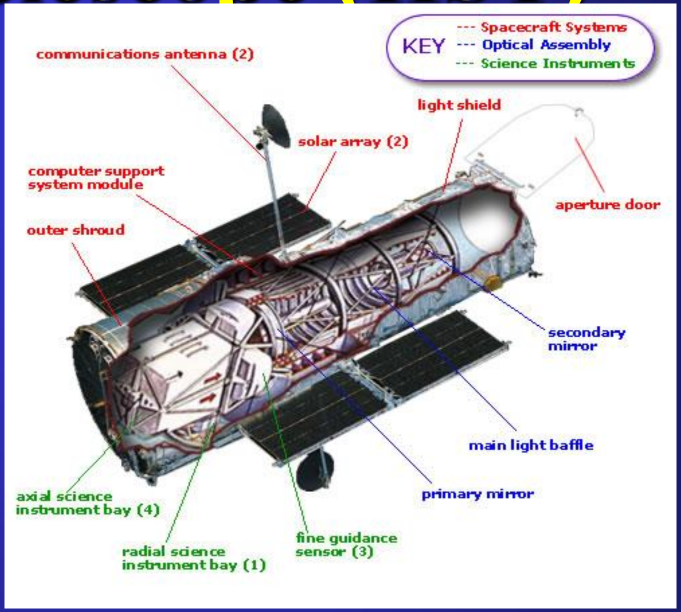
Stars and Galaxies

The Hubble Space Telescope (HST)



- Launched in 1990, the HST has taken images of the early universe by being able to receive dim light that has traveled through space for 13 billion years.
- Its high orbit allows it to take images that are not distorted by Earth's atmosphere. On a May 2009 servicing mission by the space shuttle, astronauts made repairs and installed new instruments that will keep the HST operational until 2014.
- The **James Webb Space Telescope** is planned to be launched in 2018. It will only be a partial successor to the HST because it will only observe in the infrared portion of the electromagnetic spectrum.

http://www.jwst.nasa.gov/videos_general_3.html

- **Mission Goals**
- Search for the first galaxies or luminous objects formed after the Big Bang.
- Determine how galaxies evolved from their formation until now
- Observe the formation of stars from the first stages to the formation of planetary systems
- Measure the physical and chemical properties of planetary systems and investigate the potential for life in those systems
- http://www.jwst.nasa.gov/videos_science.html

Stars and Galaxies

A. ___**Star**___________: A hot gaseous sphere that radiates energy from its surface into space.

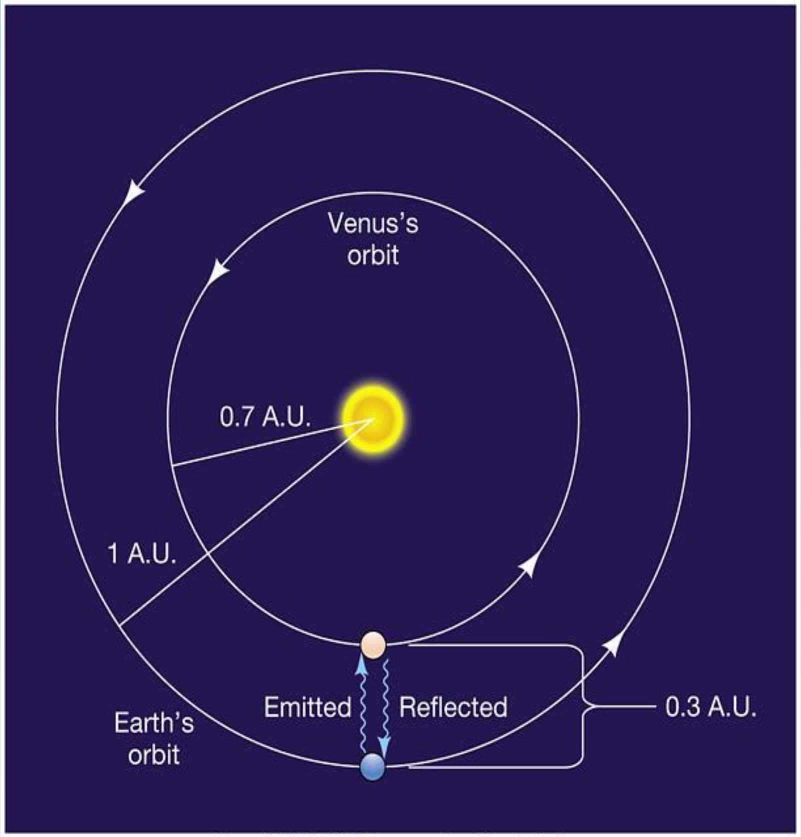
1. Distances to Stars

a. **Astronomical Unit** ________________

(1) Distance measured to the __Sun______ , the closest star to Earth

(2) Equal to the average distance between the Sun and Earth (150,000,000 km or 93,000,000 mi.)

(3) Used for distances within our Solar System.



b. **The Light Year**

No . . .

Not this guy (Buzz Lightyear of Toy Story)

Light Year

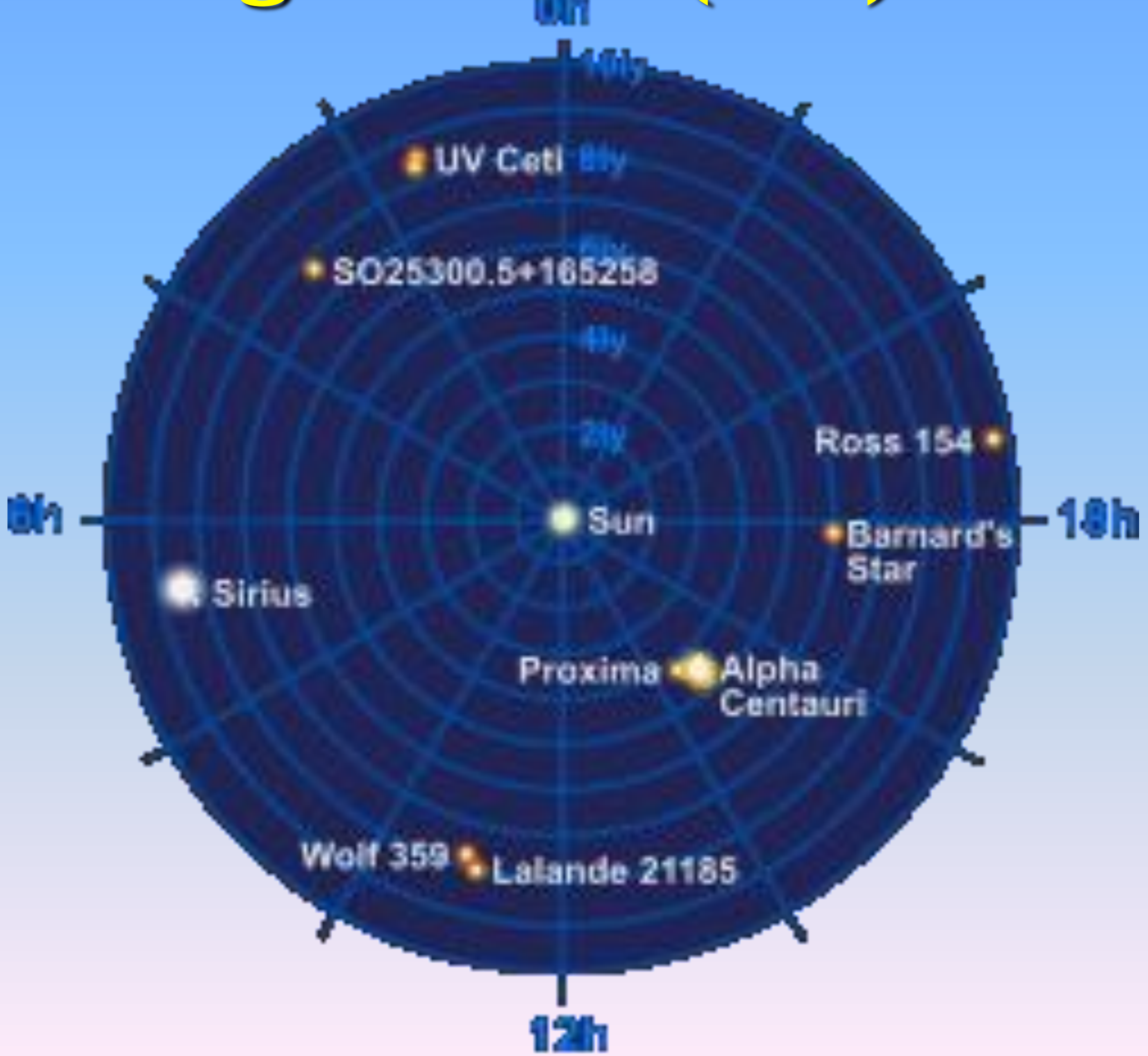
(1) The distance that a ray of light travels in one year

(2) At the speed of light (300,000 km/sec or 186,000 km/sec) light travels about 9.4 trillion kilometers (5.8 trillion miles) in one year

(3) Double stars of Alpha Centuri are about 4.3 LY from Earth.

(4) The red giant star Betelgeuse is nearly 490 LY from Earth.

Light Year (LY)



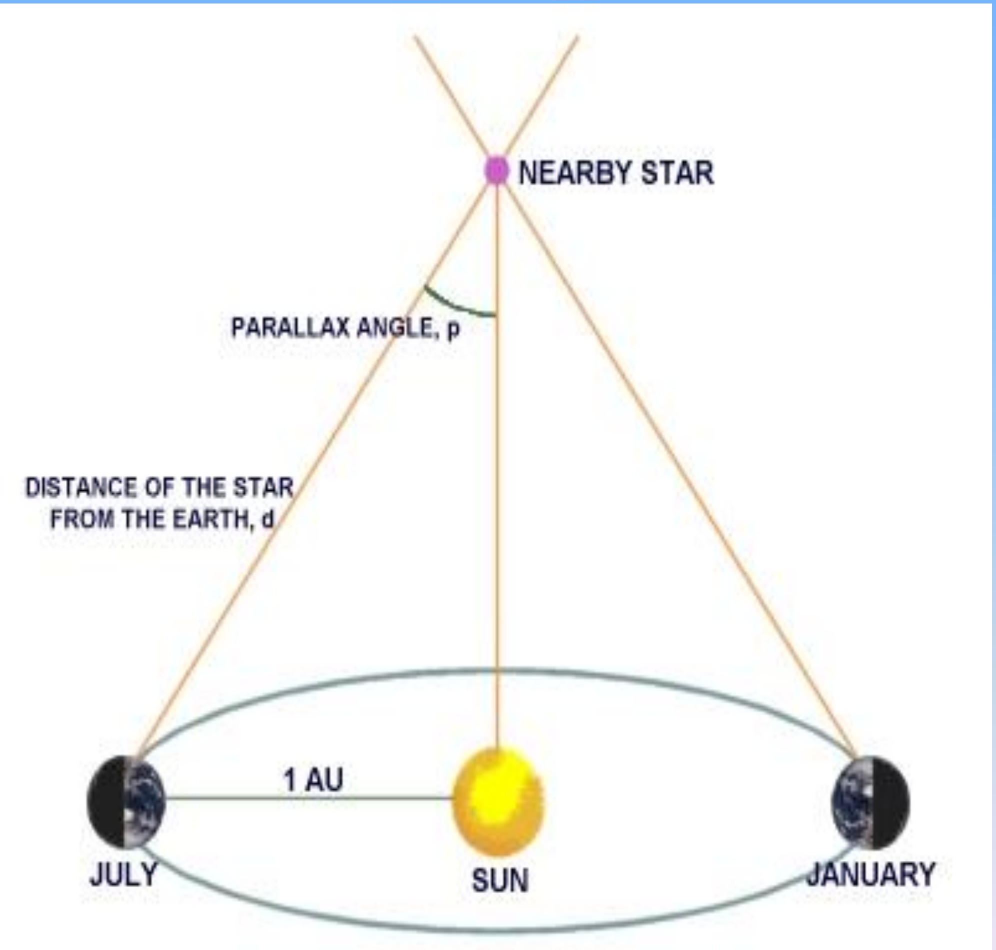
Distance from Earth to Proxima Centauri, the next nearest star

~40,000,000,000,000 km

or

~4.24 light-years

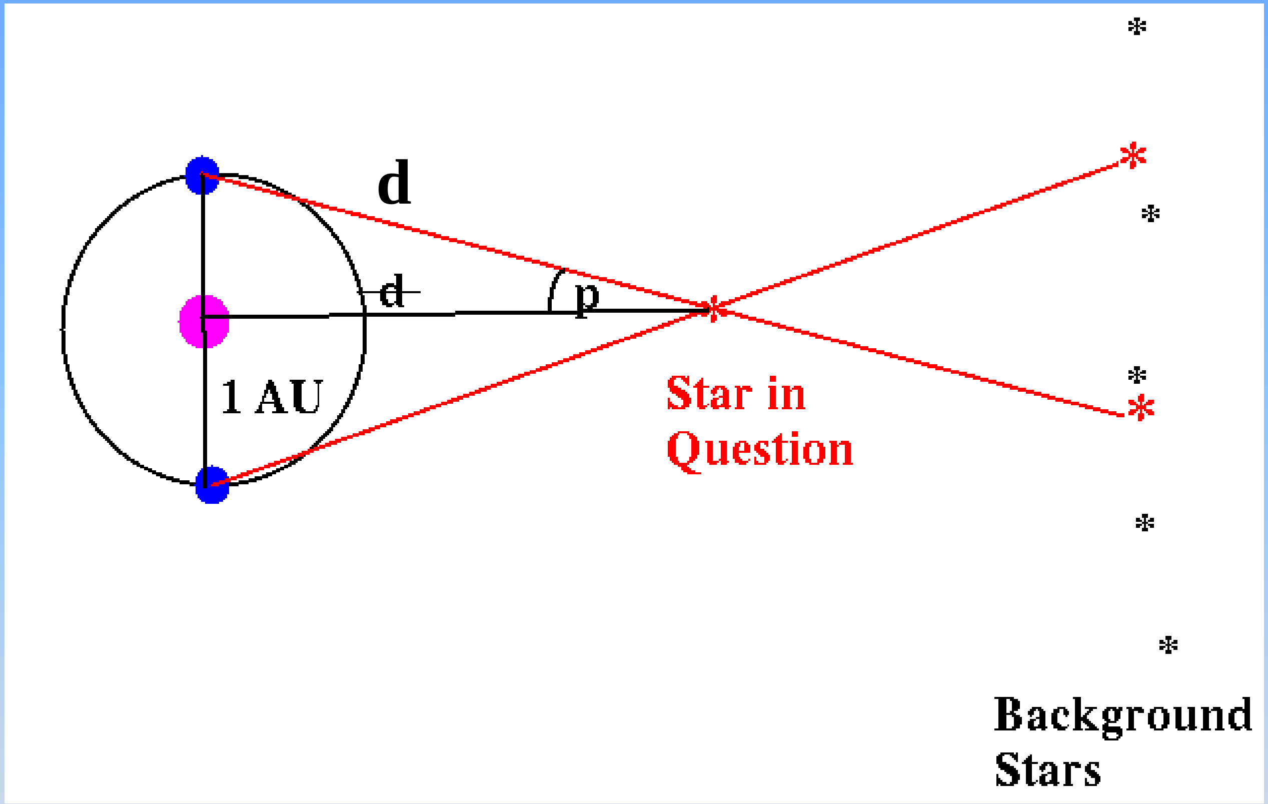
Using parallax to determine distance to a star!



- For a right triangle,
- where *p* is the parallax, 1 AU (149,600,000 km) is approximately the average distance from the Sun to Earth, and *d* is the distance to the star.

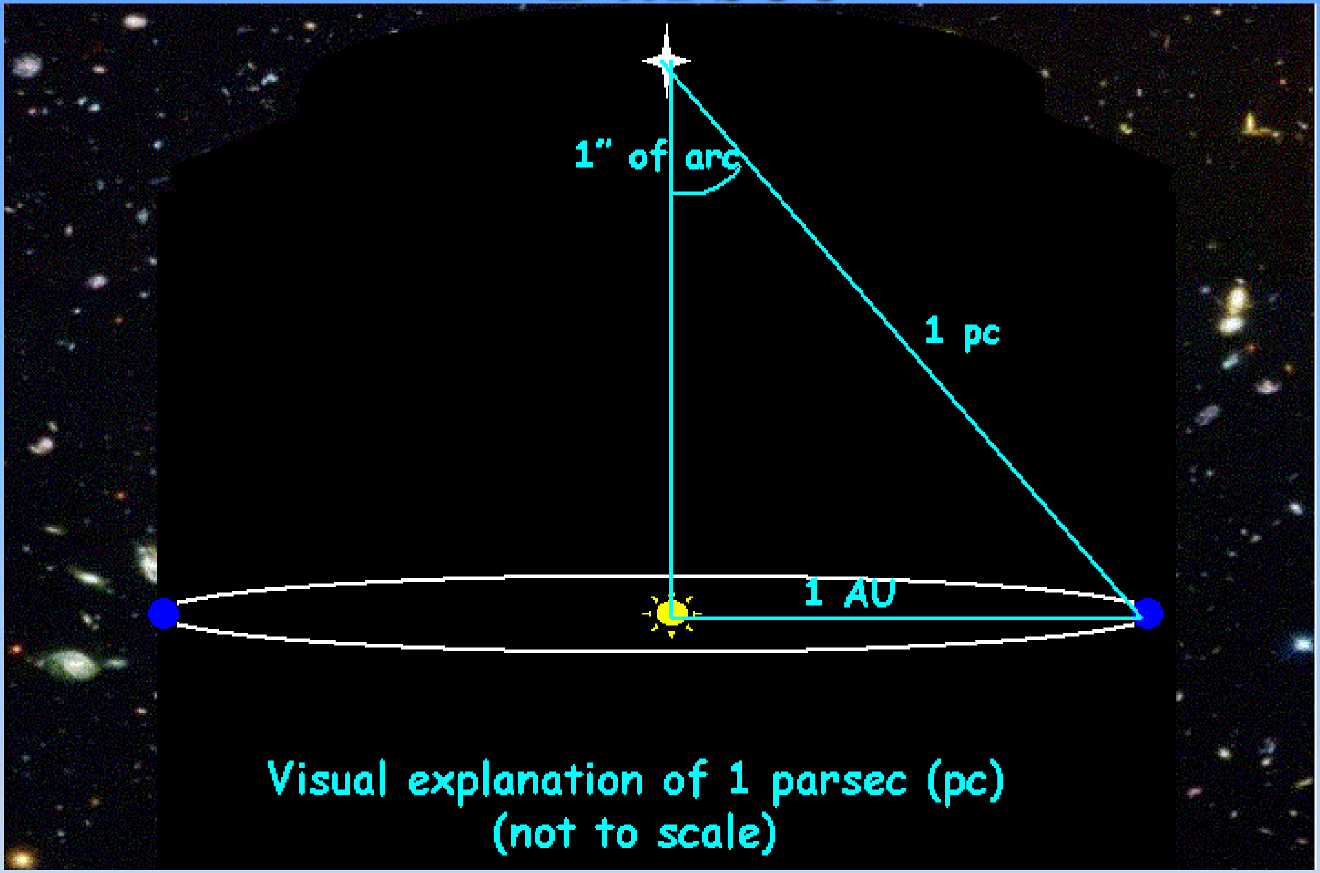
$$\mathbf{Sin}\ \boldsymbol{p} = \frac{\mathbf{1\ AU}}{\mathbf{d}}$$

c. **Parsec**: A larger unit of distance equal to 3.26 ly



- Calculated using parallax to a star that is one second (p = 1”) of arc.
- Parsec is derived from the words “**par**allax” and “**sec**ond”

Parsec



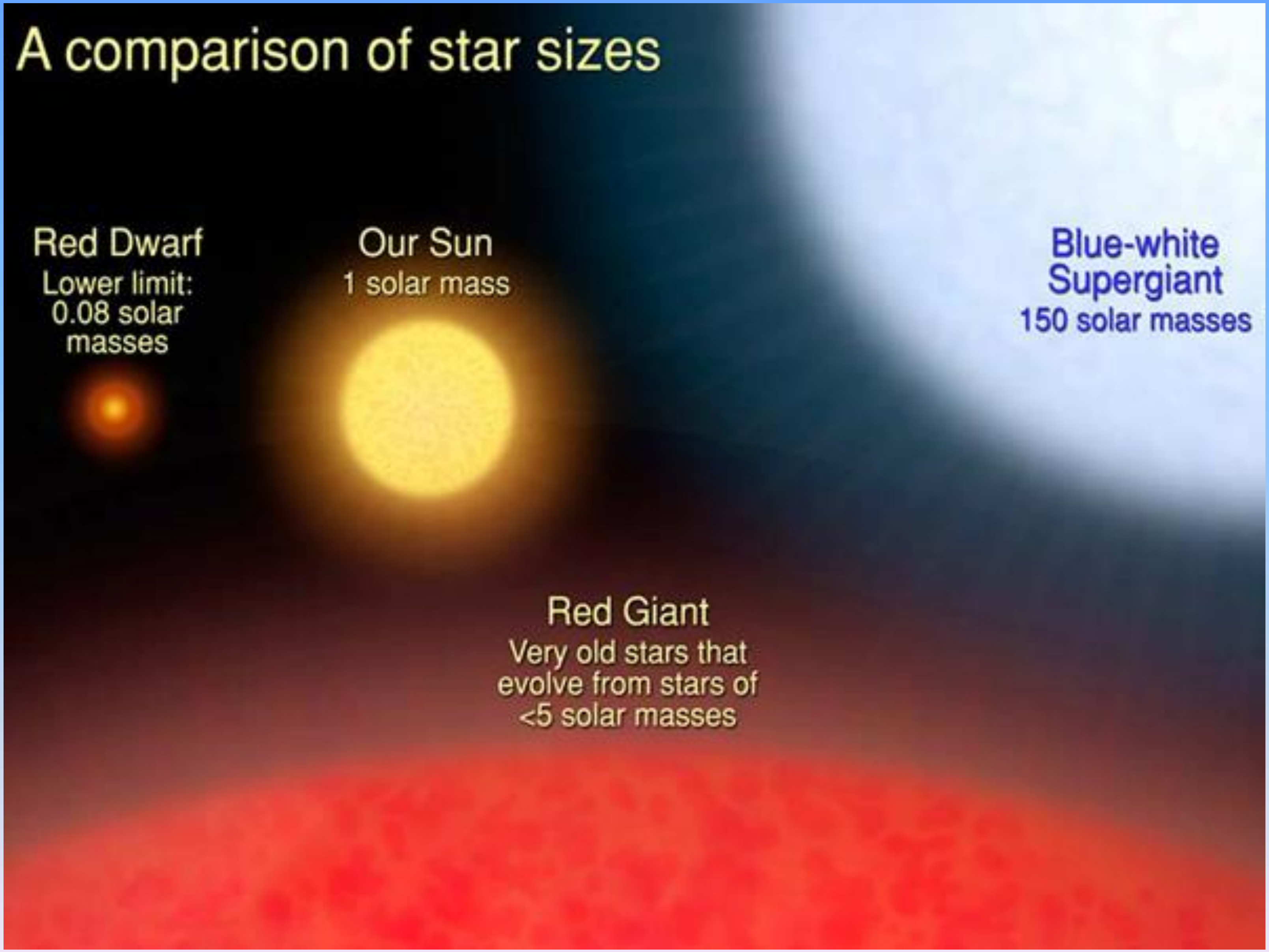
- A parsec is the distance to a star, as seen from the Earth, when the star has a half-parallax of 1 second of arc, when observed at two opposite positions in the orbit of the Earth around the Sun, taken 6 months apart.
- A parsec is equal to:
  - approximately 206,265 Astronomical Units
  - 3.26 light years.

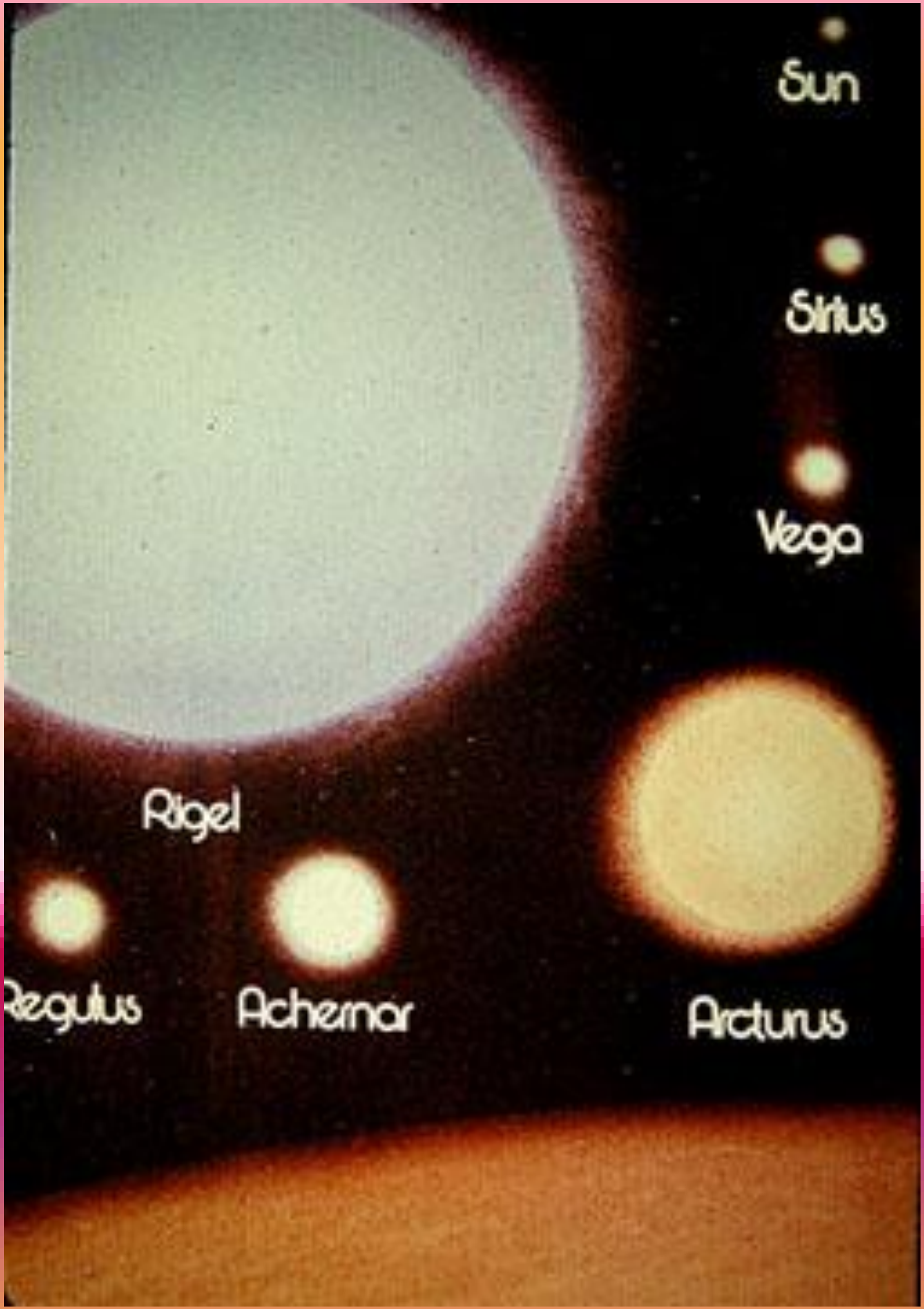
Physical Properties of Stars

a. *Sizes vary over a great range.*

(1) Smallest stars may be smaller than __**Earth**__.

(2) Largest stars can be more than 2000 times the diameter of the __**Sun**__.


A comparison of star sizes
Red Dwarf
Lower limit:
0.08 solar
masses
Our Sun
1 solar mass
Blue-white
Supergiant
150 solar masses
Red Giant
Very old stars that
evolve from stars of
<5 solar masses



Sun
Sirius
Vega
Rigel
Regulus
Achernar
Arcturus

Physical Properties of Stars

a. *Density*:

(1) ___**Light**_______: Betelgeuse (a red giant) is one ten millionth (**1.0×10^{-7}**) of the Sun's density.

(2) ___**Heavy**_______: Companion star to Sirius is so dense that one teaspoon would weigh more than **one ton** on Earth.

Physical Properties of Stars

a. *Mass*

(1) Variation in mass is less than variation in density.

(2) Most stars have masses ___**1/100**___ of the Sun's to ___**50**___ times that of the Sun.

Physical Properties of Stars

a. ***Composition*:**

(1) One or two percent of a star's mass may be *heavier elements* such as oxygen (**O**), carbon (**C**), calcium (**Ca**), and sodium (**Na**).

(2) Main elements in the Sun are

(a) **Hydrogen (H)**

(b) **Helium (He)**

Brightness of Stars

(1) ___Apparent Magnitude___________

(a) How bright the star ____appears_______ to an observer on Earth.

(b) Brightest stars are first magnitude.

(c) Faintest stars are sixth magnitude

(d) Each magnitude represents a change by a factor of 2.5 magnitudes.

i) A first magnitude star is 2.5 times brighter than a second magnitude star.

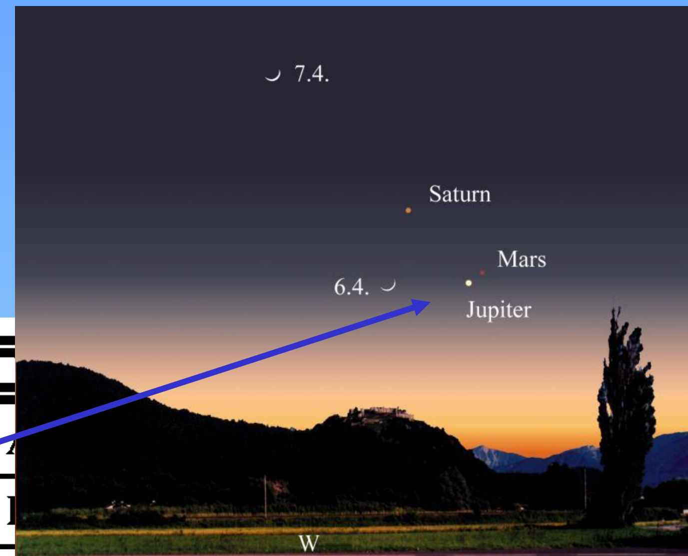
ii) A first magnitude star is 100 times brighter than a sixth magnitude star.

(e) Objects brighter than first magnitude objects are ___negative numbers___.

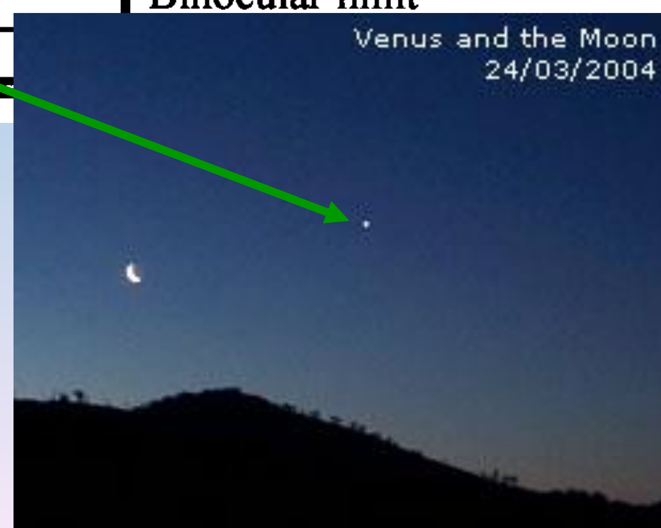
Why are there negative numbers?

- The Greek Astronomer Hipparchus (c. 190 BC - 120 BC catalogued about 800 stars.
- The brightest star he observed he assigned a magnitude of 1. The dimmest was 6.
- Brighter stars have now been observed.
  - Using Hipparchus' system they must be smaller numbers than one.
    - So negative numbers are used for very bright celestial objects.

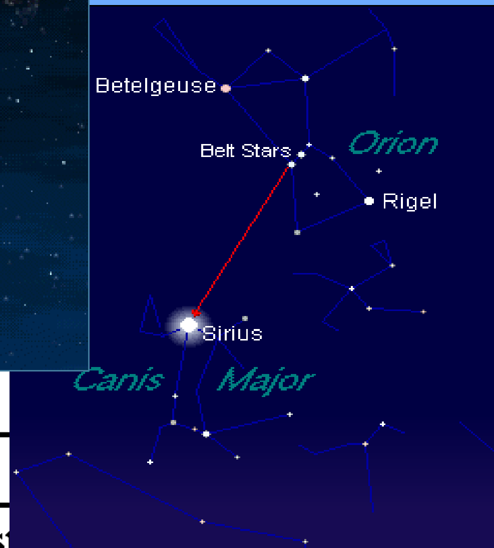
Apparent Magnitudes of Familiar Objects



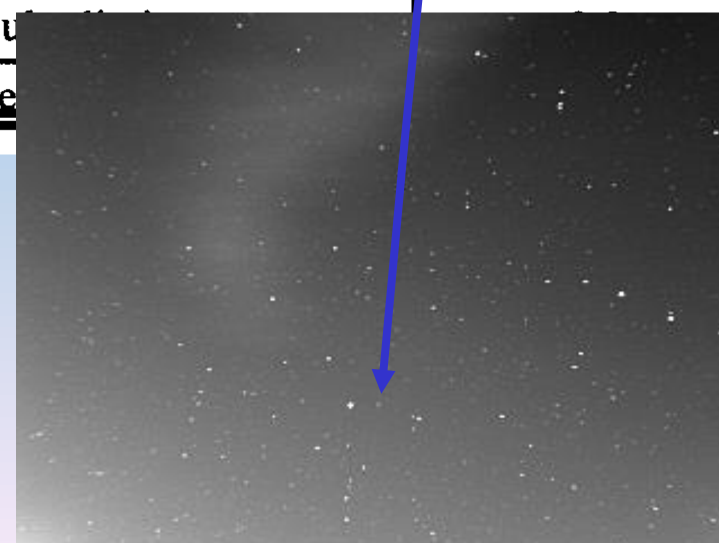
	...ITUDE		...TUDE
Sun	-26.5	A...	0
Full Moon	-12.5	I...	9
Venus at Brightest	-4.4	Naked Eye Limit	+2.0
Jupiter	-2.5	Binocular limit	+9.0
Sirius	-1.4		+20.0



Apparent Magnitudes of Familiar Objects



		OBJECT	MAGNITUDE
Sun		Aldebaran	+0.0
Full Moon		Polaris	+0.9
Venus at Brightest		Naked Eye Limit	+2.0
Jupiter	-2.5	Binocu	
Sirius	-1.4	5-mete	



Factors Affecting Apparent Magnitude

(a) **Distance**

The farther a star is from the observer, the dimmer it appears *if all other factors are equal*

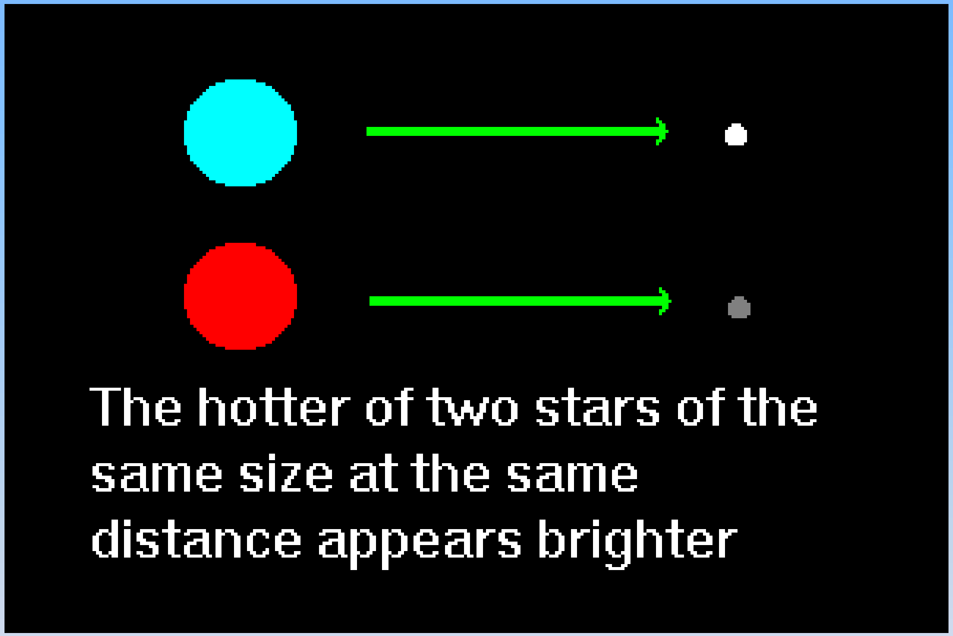
Factors Affecting Apparent Magnitude

(b) **Size**: Larger Stars will appear brighter than smaller stars

Factors Affecting Apparent Magnitude

(c) **Temperature**:

Hotter stars will appear brighter than cooler stars *if all other factors are equal.*



(3) Absolute Magnitude

(a) Called ___Absolute Brightness___

(b) This is the ___actual___ brightness of a star.

(c) Depends on two factors

i) ___Temperature___: Hotter stars emit greater intensity light than cooler stars

ii) ___Size___: Larger stars are brighter than smaller stars

(d) Compares the brightness of stars on an ___equal___ basis. Astronomers determine the ~~*luminosity*~~ by mentally moving all stars to a distance of 32.6 light years (10 parsecs) and then determining their magnitudes as seen from that distance.

Absolute brightness

Note: This must be added to your fill-in notes.

(4) Luminosity

(a) This is the **rate of energy output** of a star.

(b) It is usually measured in watts/second.

(c) Luminosity can also be expressed using ***solar units***.

- This is a comparison to the Sun's rate of energy output.
- The **<u>Sun is assigned 1 energy unit.</u>**
- A star that has a luminosity of 100 energy units . . .

  - Emits energy at 100 times the Sun's rate.

See your ESRT : "Luminosity and Temperature of Stars" Chart

(The H-R Diagram)

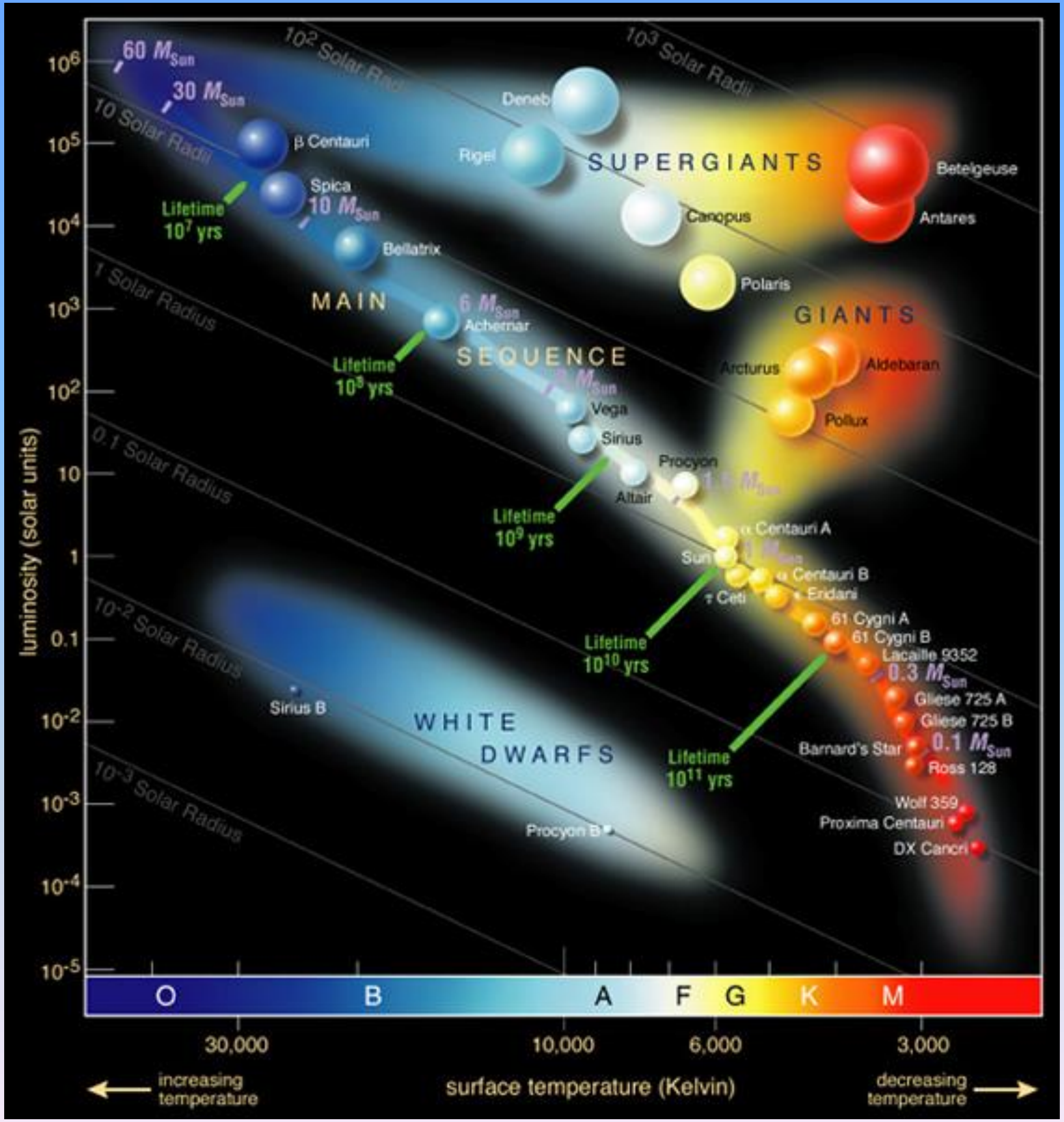
The H-R Diagram

- Establishes the relationship between a star’s surface temperature and its luminosity.
  - Ejner Hertzsprung of Denmark
  - Henry N. Russell of the United States

3. The H-R Diagram

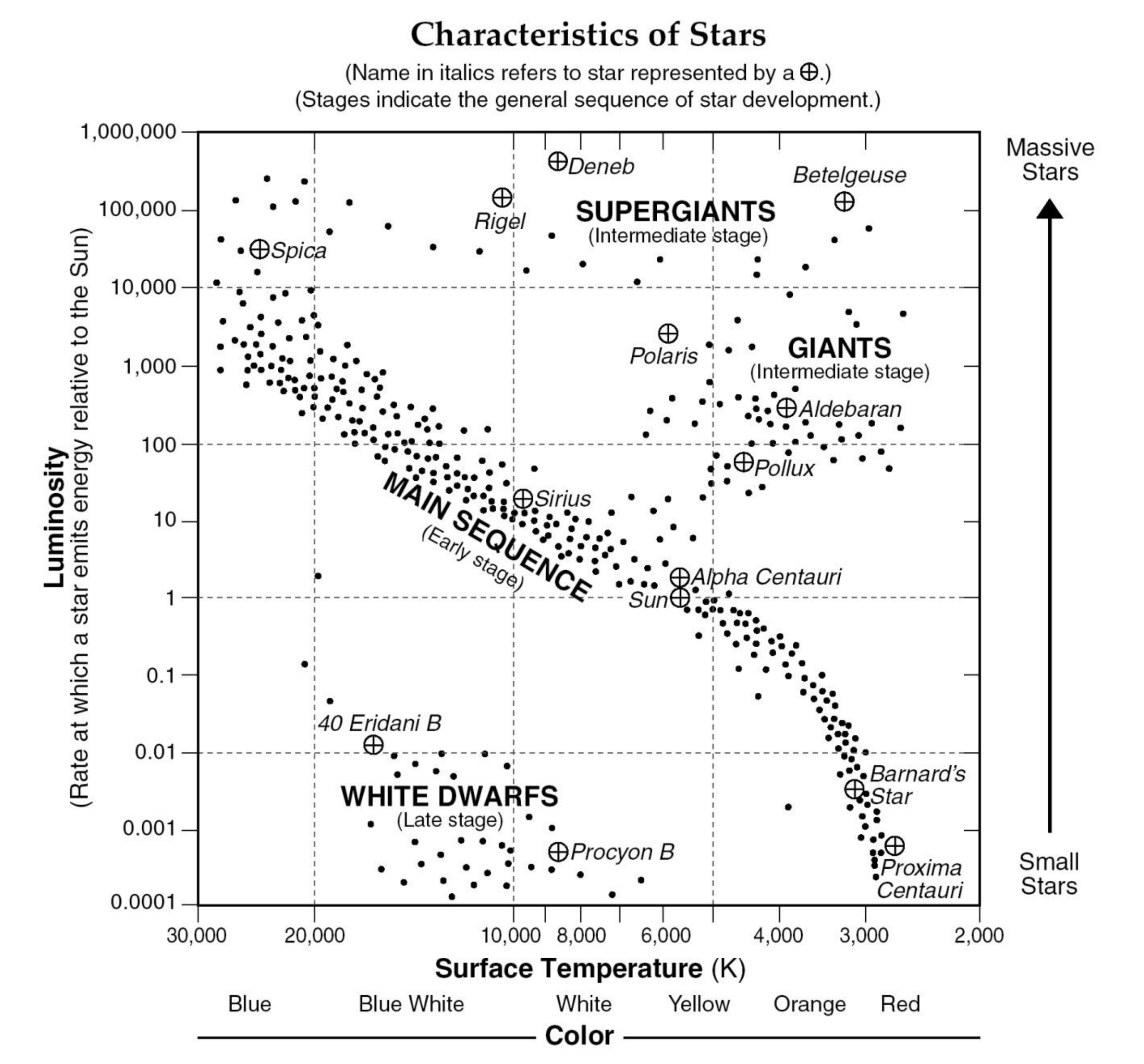
b. Stars of a known distance have been plotted according to their spectral class (as determined by the ___temperature_______ and _luminosity__) and their absolute magnitude.

The H-R Diagram

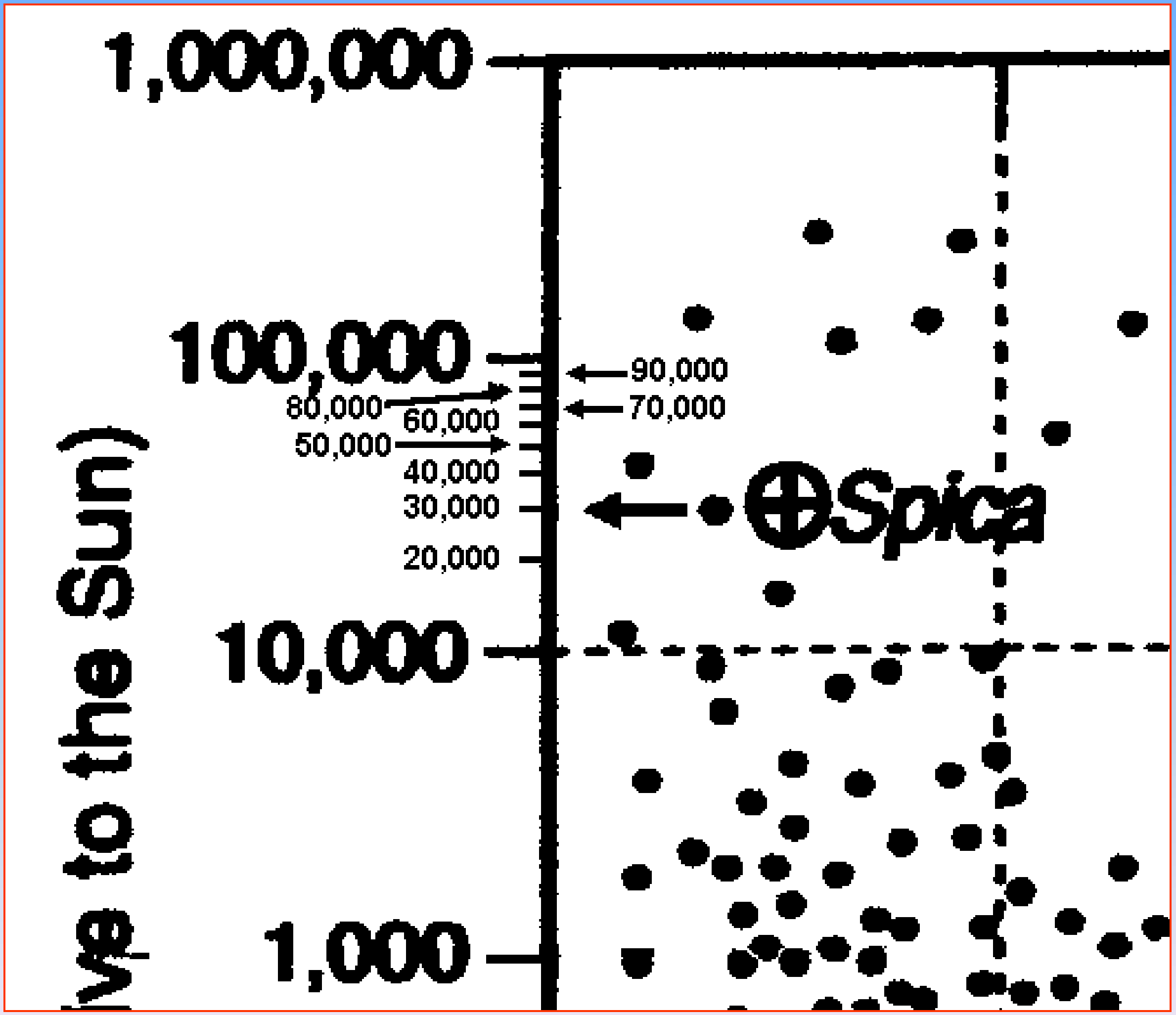


The H-R Diagram:

The Earth Science Reference Tables Version

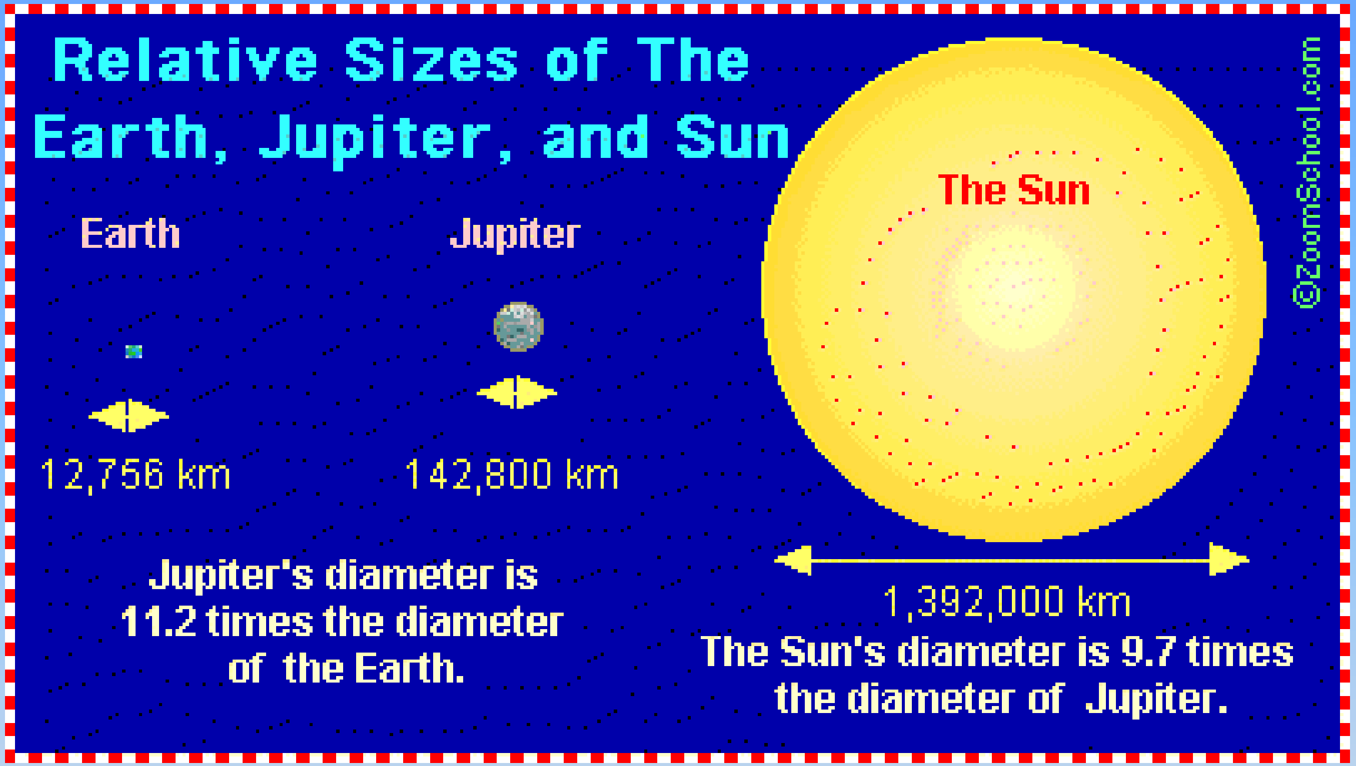


Reading a Non-Linear (Logarithmic) Scale



4. Our Sun

Our Sun



a. *Properties of the Sun*

(1) Size: __109____ times Earth's diameter (1.38 x 10^6 km)

(2) Volume: Could hold more than _____1,300,000_____ Earth's.

Properties of the Sun

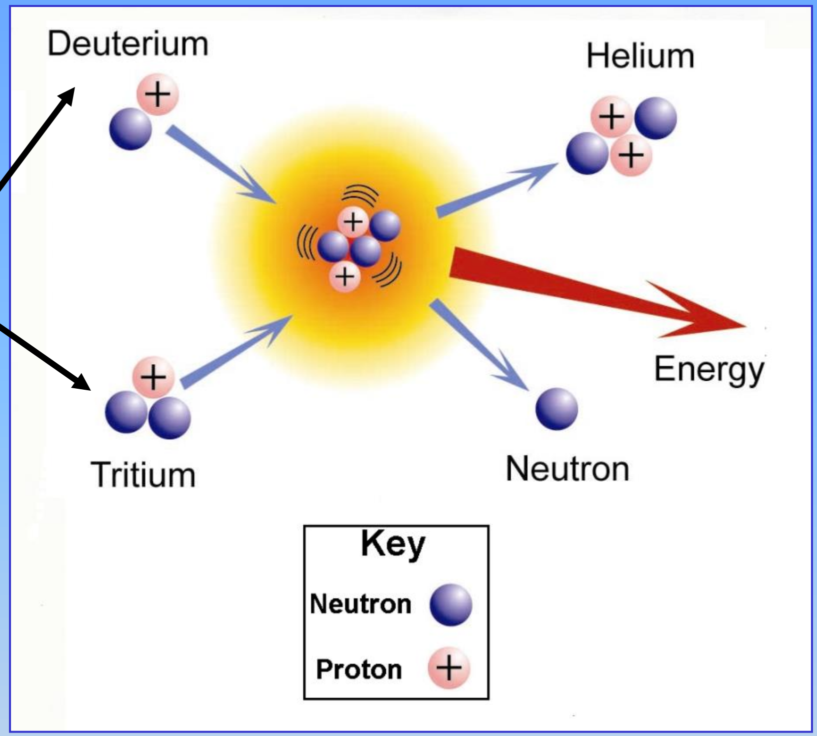
(3) Temperature:

(a) ____**Surface**____________ temperature is about 5,550^o Celsius (~10,000^o Fahrenheit).

(b) ____**Interior**____________ temperature may be as high as 15,000,000^o Celsius

b. *The Source of the Sun's Energy*

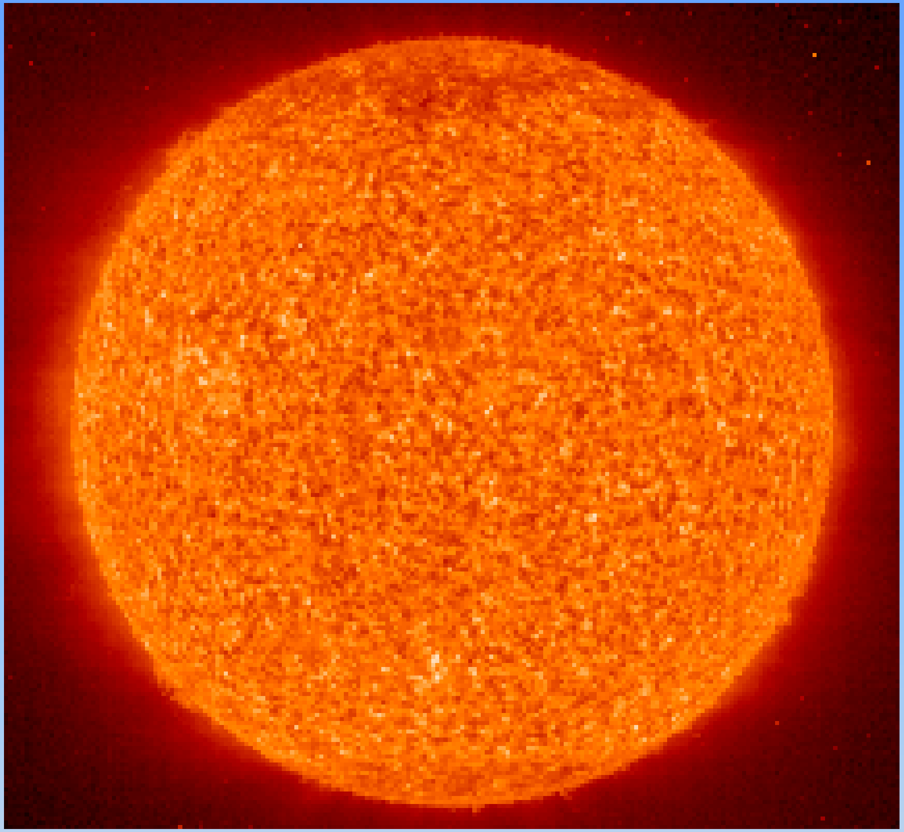
Isotopes of hydrogen



(1) **Fusion** of light elements into heavier elements.

(2) **Hydrogen** converts to **Helium**

(a) Four **Hydrogen** (H) nuclei (each with a mass of about 4.030 mass units) join to form a **Helium** (He) nucleus with a mass of only about 4.003 energy units.



(b) The mass that seems to have been lost is converted into **Energy**________, which is radiated into space.

(c) Estimates indicate that about 4 million metric tons of matter are converted into energy every second but because the Sun is so massive, this process can continue for another five billion years!

c. The Sun's Atmosphere

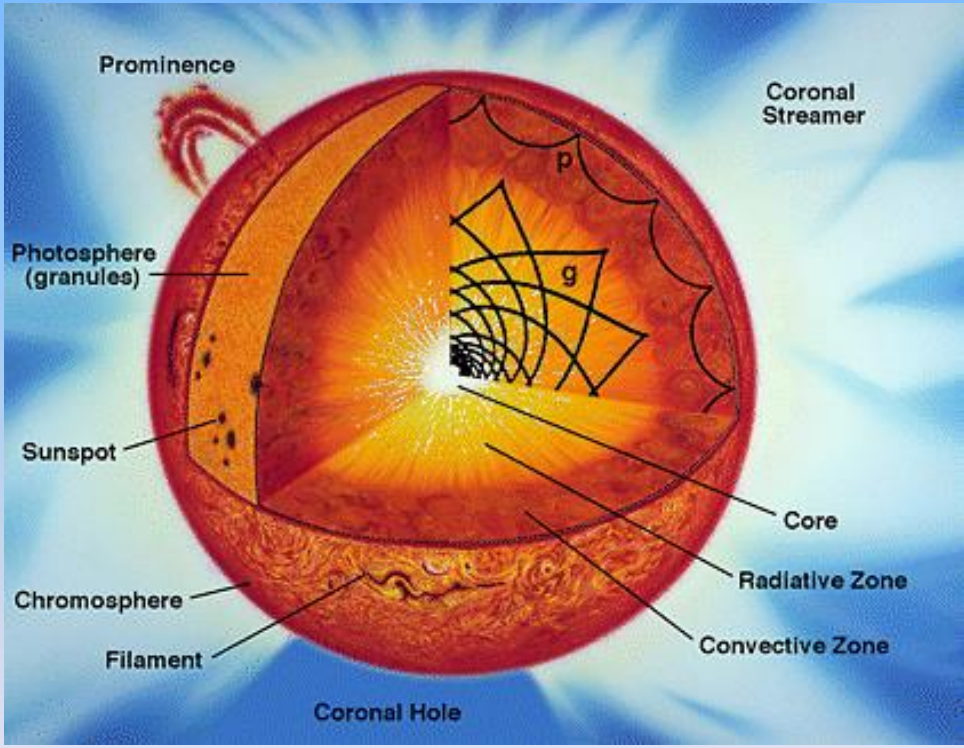
(1) Photosphere

(a) Bright yellow **surface**

(b) 400 km thick

(c) Made of millions of *granules* (individual cells). Granules are wide (about 1500 km across), have a bright center, dark edges, and are the tops of columns of gases that are rising in the center and sinking at the edges. Granules last 8 minutes.

(d) This is the lower denser part of the Sun's atmosphere.



(2) The Outer, Less Dense Atmosphere

(a) Only seen during solar eclipses

(b) **Chromosphere**

(i) Lower part of the atmosphere

(ii) Colored red by glowing hydrogen

(ii) Extends thousands of kilometers above the photosphere

(c) The Corona

(i) Has so little gas that on Earth it would be considered a vacuum.

(ii) Surrounds the Sun to a height of more than one million kilometers.

(iii) During a solar eclipse it is seen as a faint, pearly light.

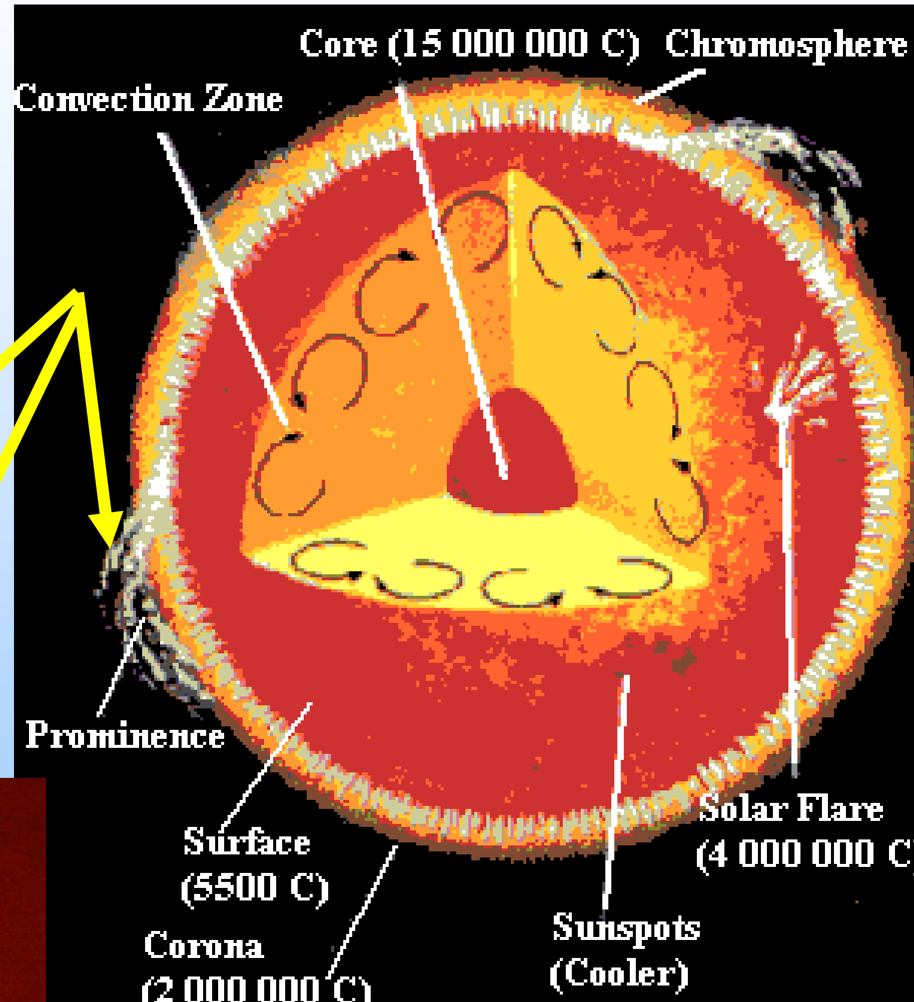
(3) Prominences

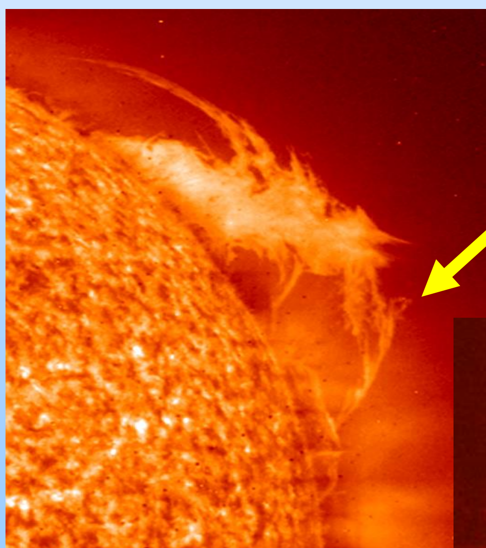
Huge curtains of gas >100,000 km long - Relatively cool

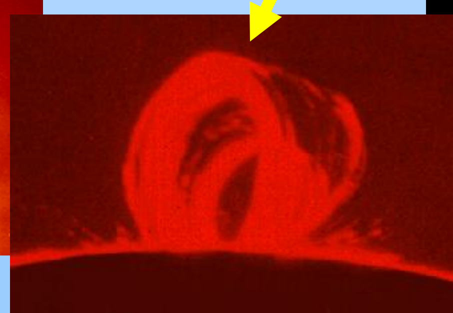
(a) Huge, red, flame-like arches of material that occur in the corona.

(b) Appear like flames but the light is caused by changes in the cooler, denser parts of the corona.

(c) Prominences may last for hours and can extend millions of kilometers about the photosphere







(4) Sunspots

(a) Dark spots on the photosphere

(b) Size may be greater than Earth's diameter.

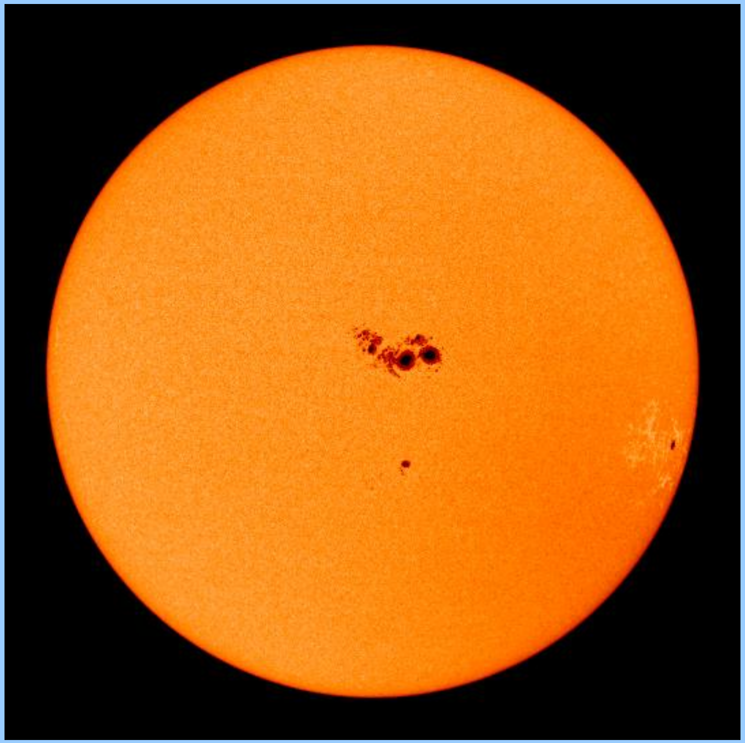
(c) Lifetime varies from a few hours to a few months.

(d) Have a dark center.

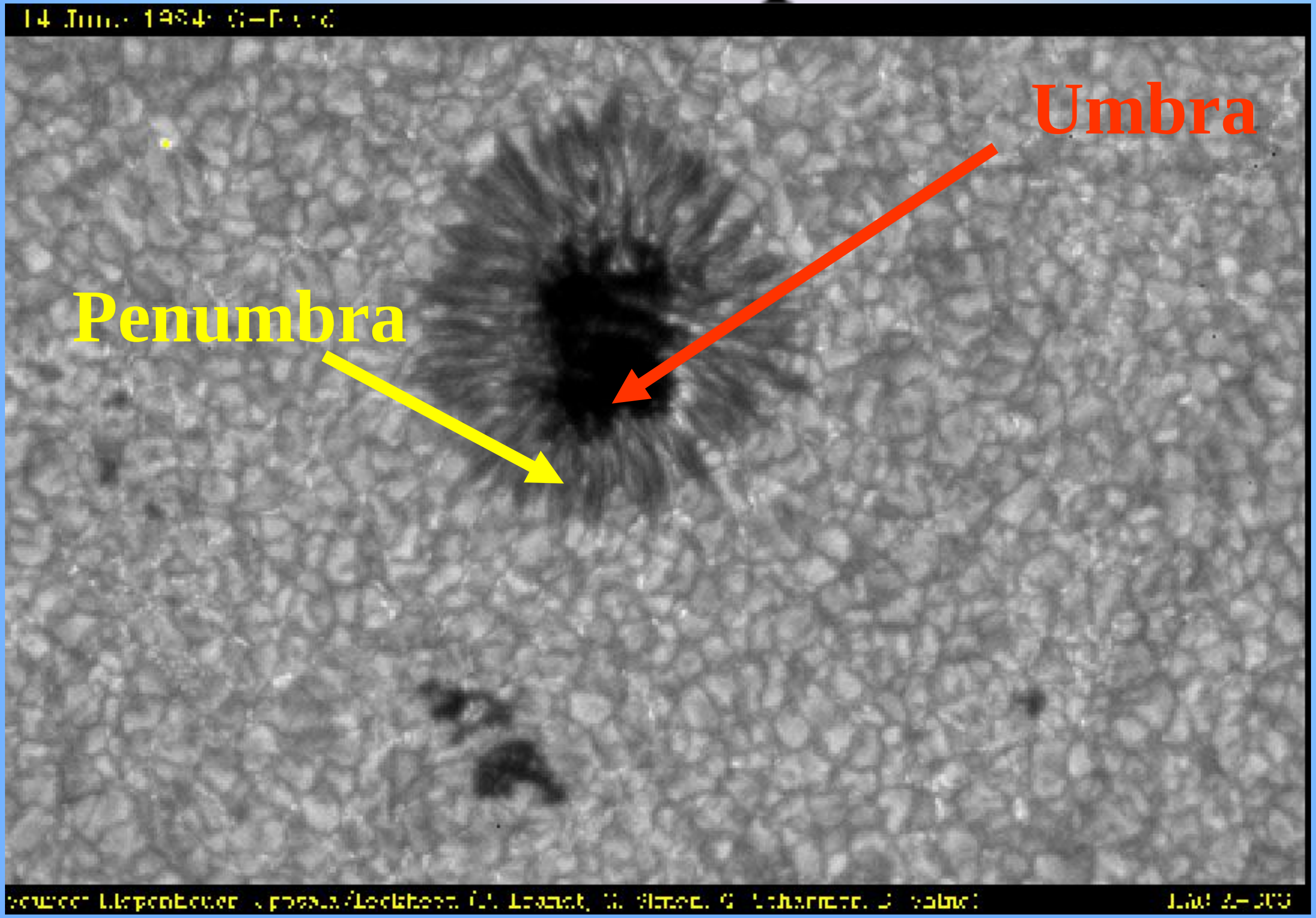
(e) Occur in pairs. One is a north magnetic pole and the other is a south pole.

(f) Because of the concentration of magnetic forces, gases in a sunspot may be as much as 1,500^{o} C cooler than the surrounding photosphere.

(g) Due to the Sun's rotation (25 days at the equator and 27 days near the poles) sunspots move from left to right across it's surface.



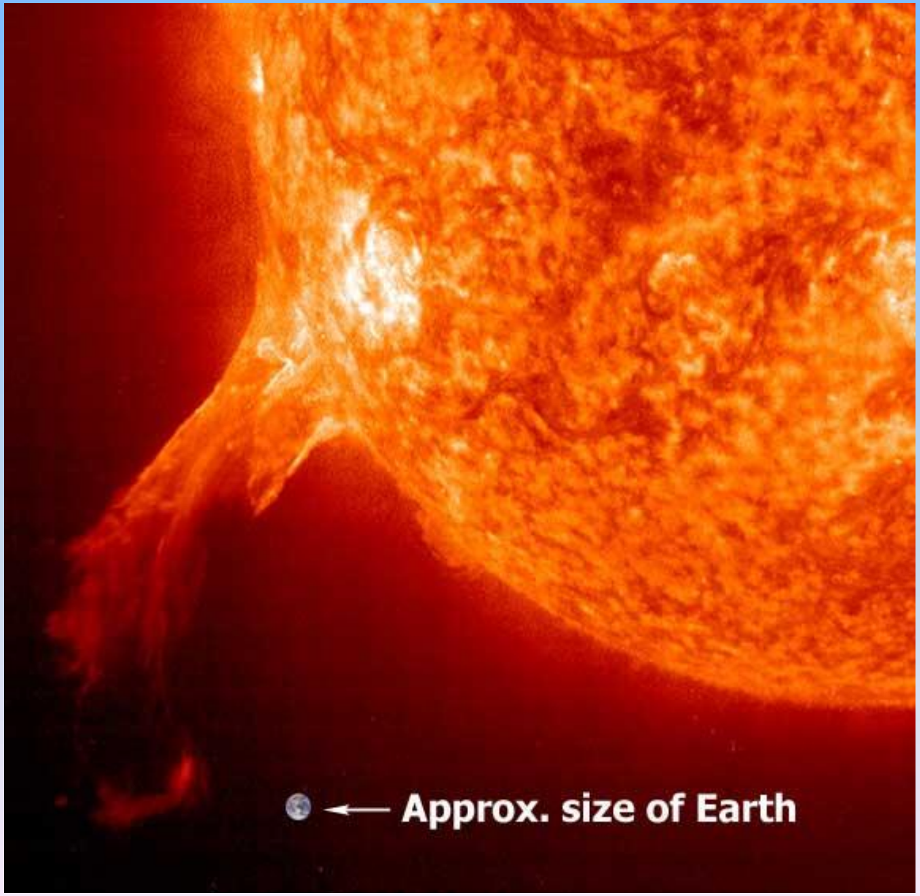
Sunspots



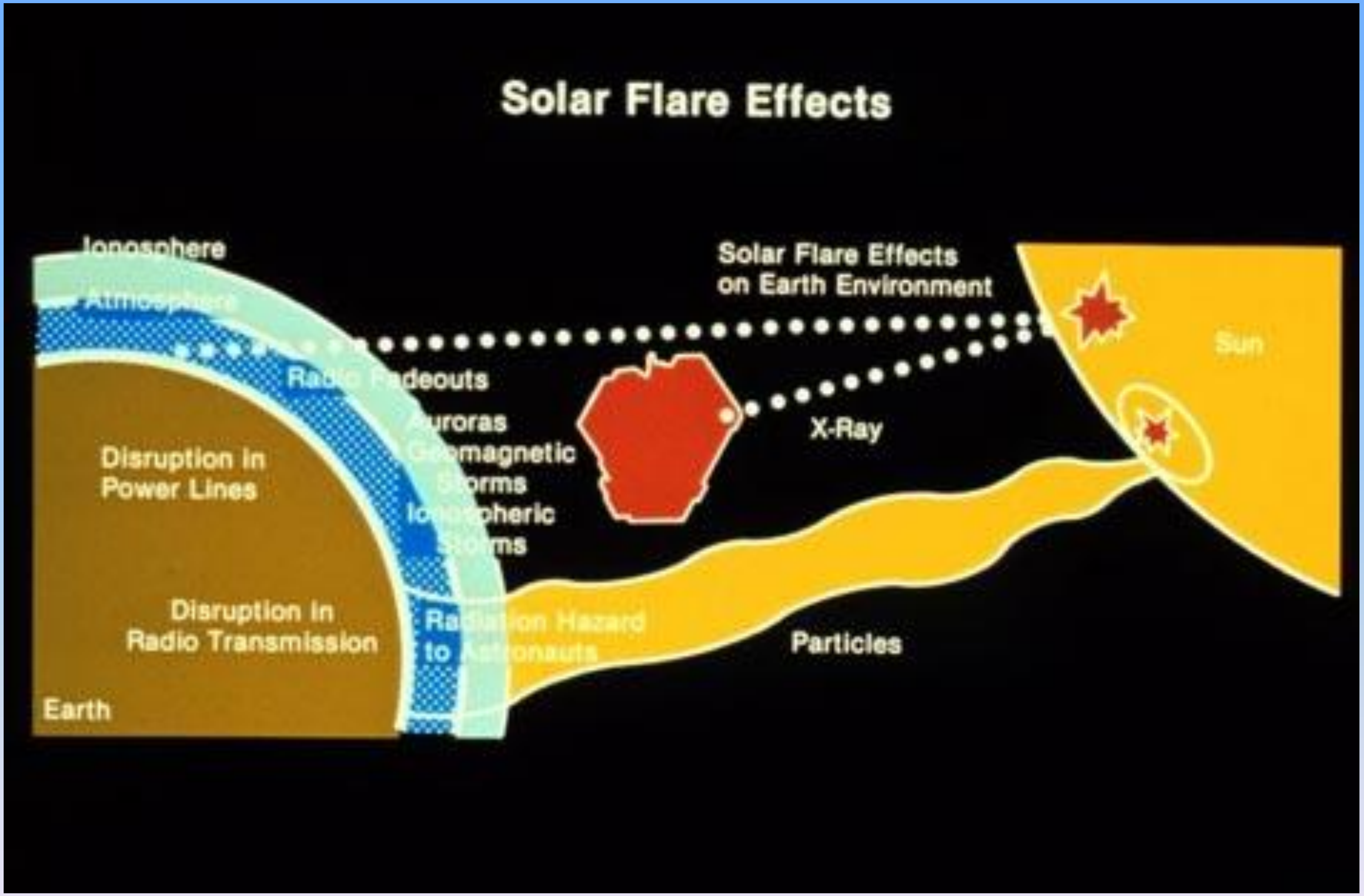
(h) ___Sunspot Cycle___: The number of sunspots varies over an _11_-year cycle

Solar Flares

- Occur near sunspots
- Particles ejected from the sun



Solar Flares



5. Stellar Spectra

a. The Electromagnetic Spectrum

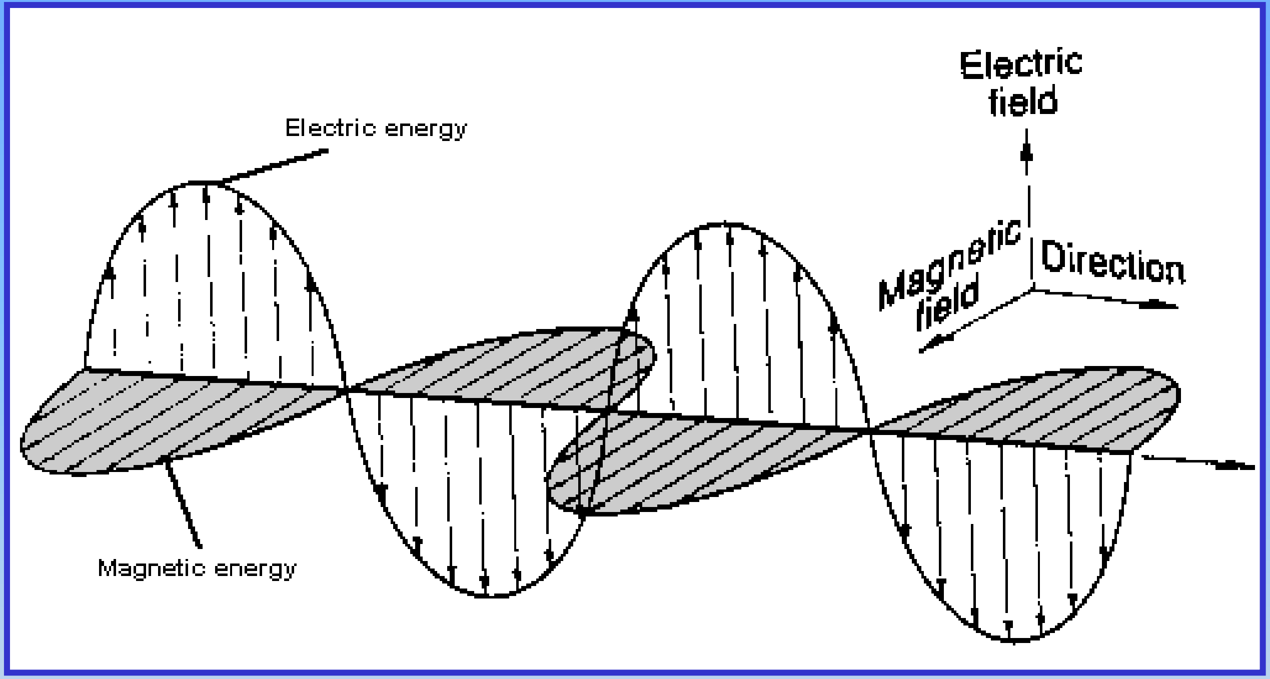
(1) Radiation__________________:

(a) Travels out in all directions from its source.

(b) Does not need a medium through which to travel.

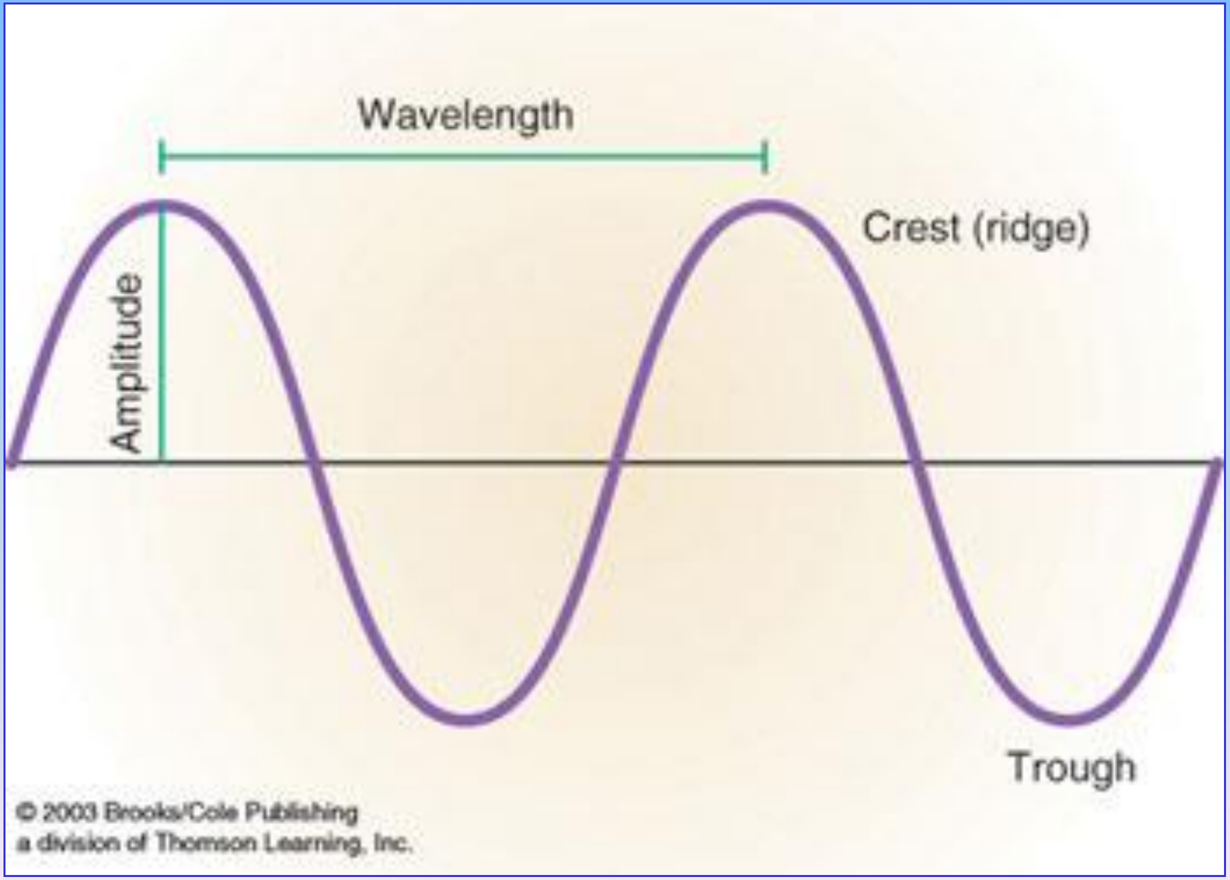
(2) Electromagnetic energy travels through space at the speed of light______________.

How does EM radiation travel through space which has no matter (a vacuum)?

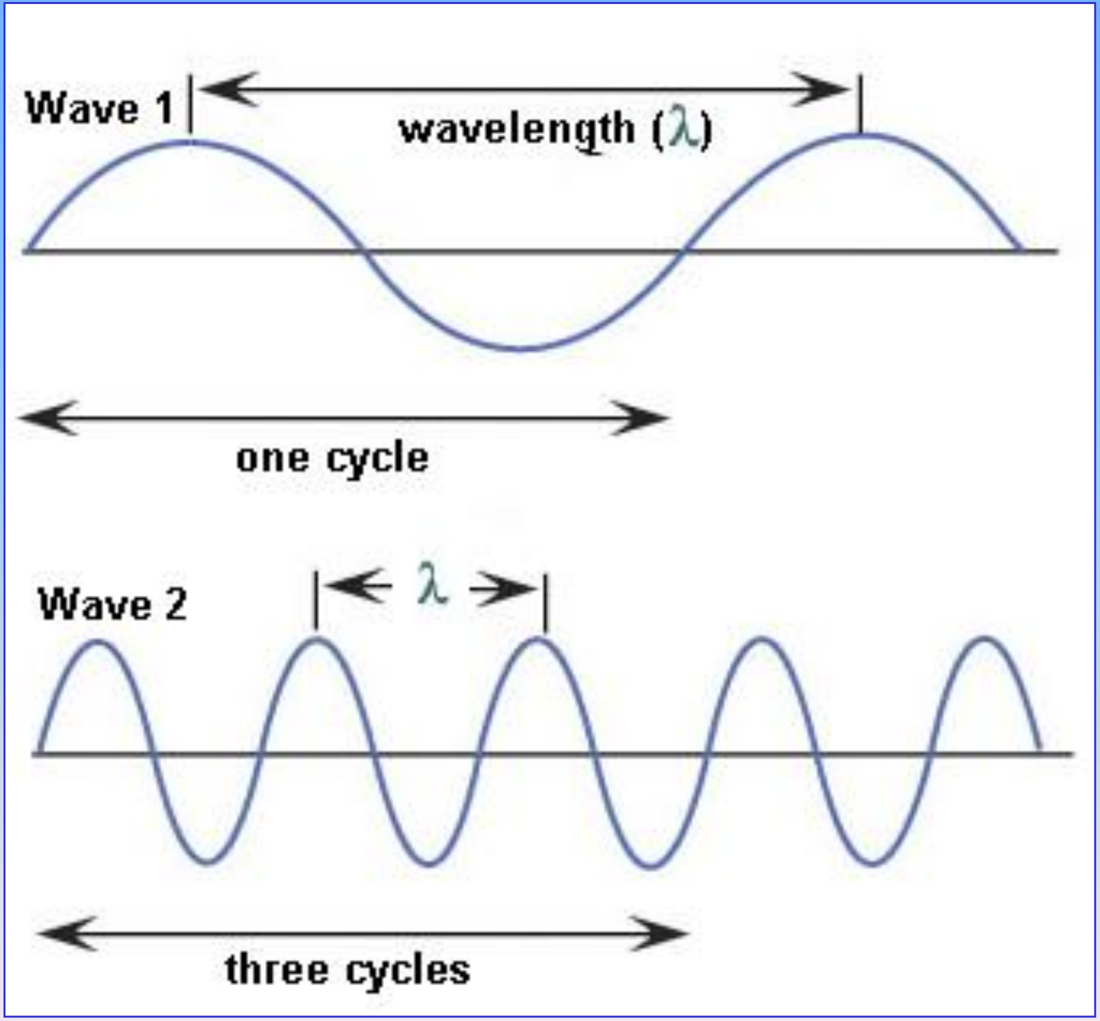


- It is a wave made of a mixture of **electric** and **magnetic** energy .
- Small changes in an electric field create a magnetic field next to it. This in turn creates a new electric field, which then creates a new magnetic field and so on.
- The wave carries itself along by constantly changing its electric energy to magnetic energy and visa versa.

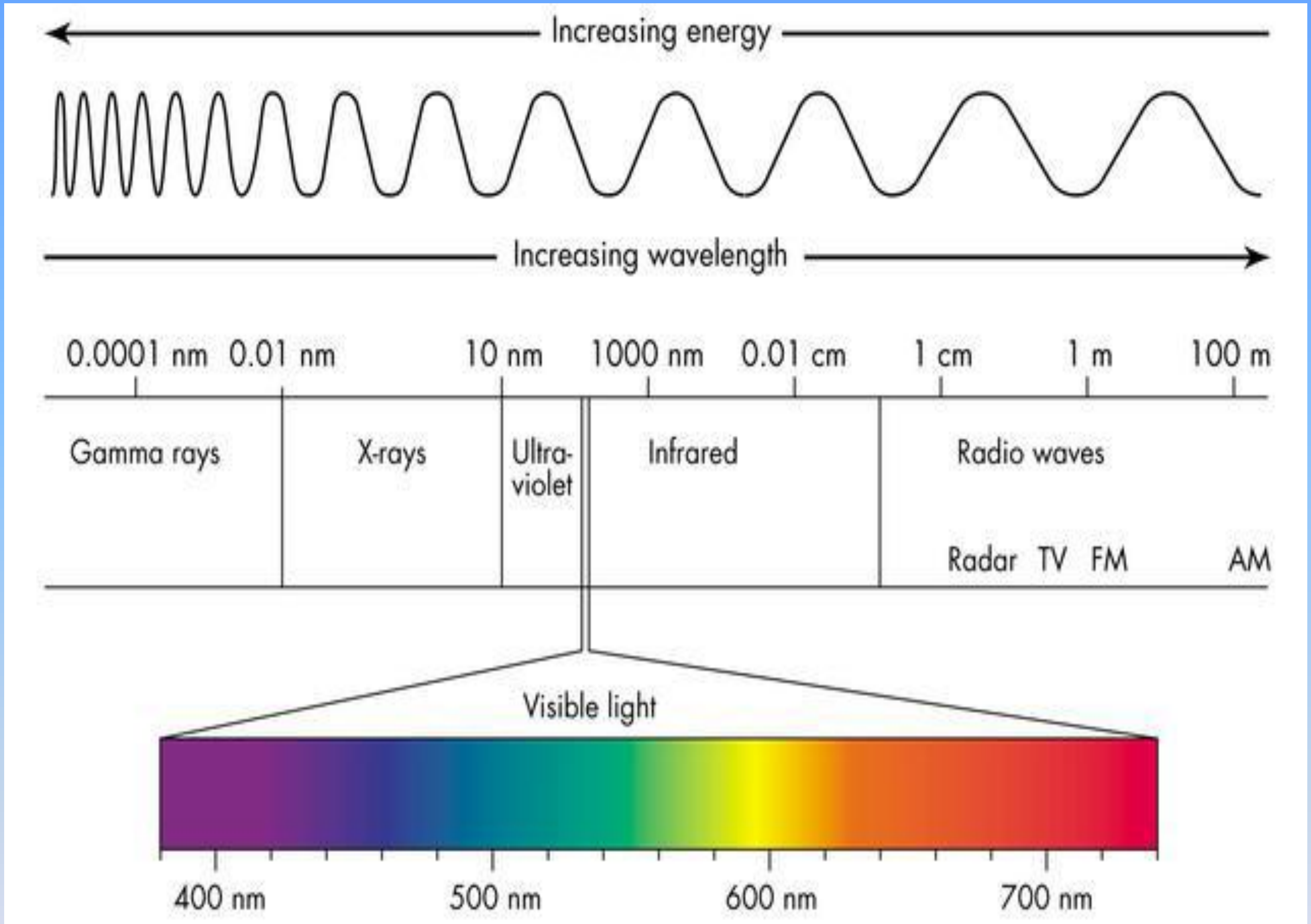
3. Electromagnetic energy is defined by ________**wavelength**________ which affects it's frequency.



Wavelength and Frequency

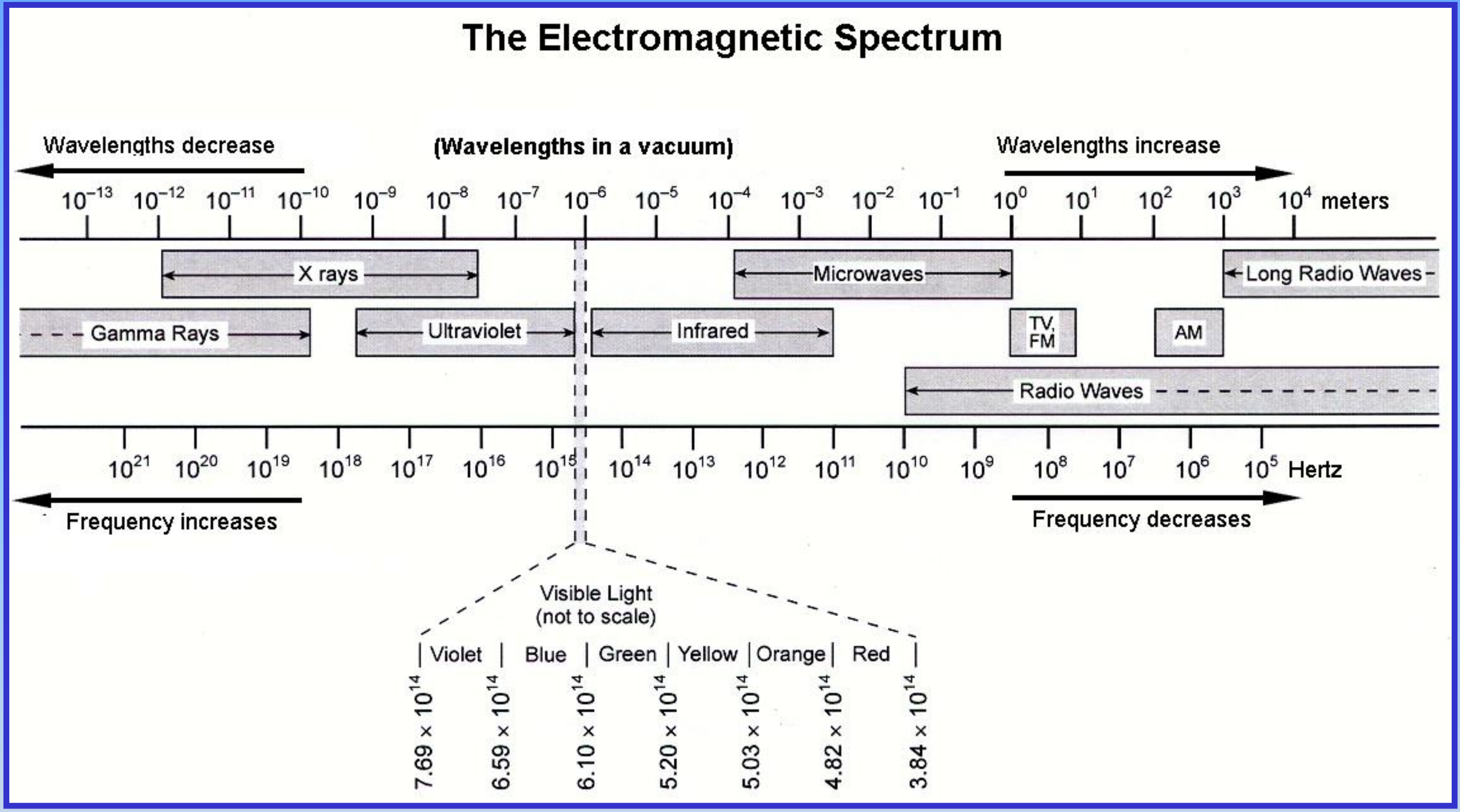


The Electromagnetic Spectrum

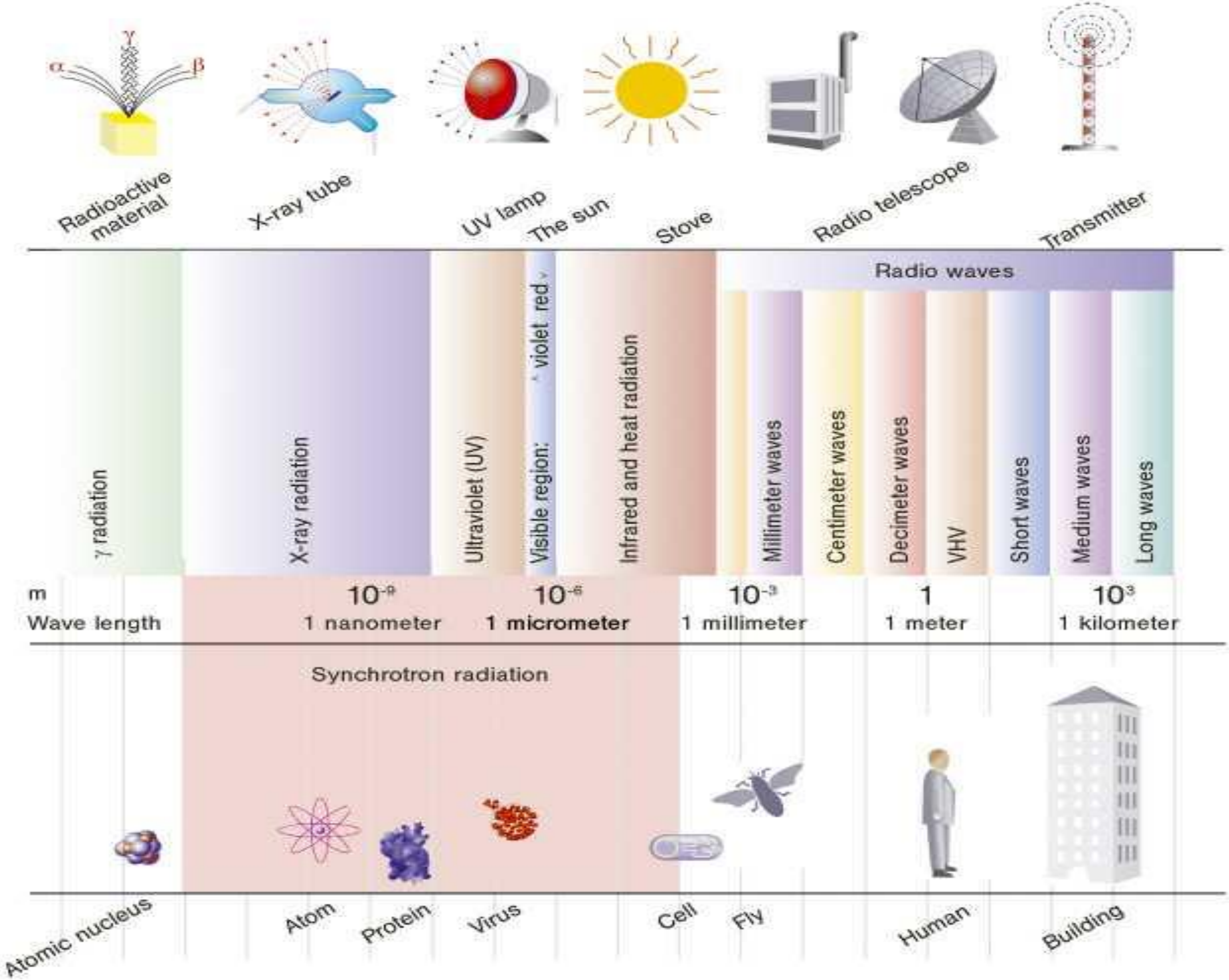


- You are probably familiar with this type of EM Spectrum chart. It's similar to what is in many high school textbooks.
- This is actually a simplified version.

Some wavelengths "overlap."

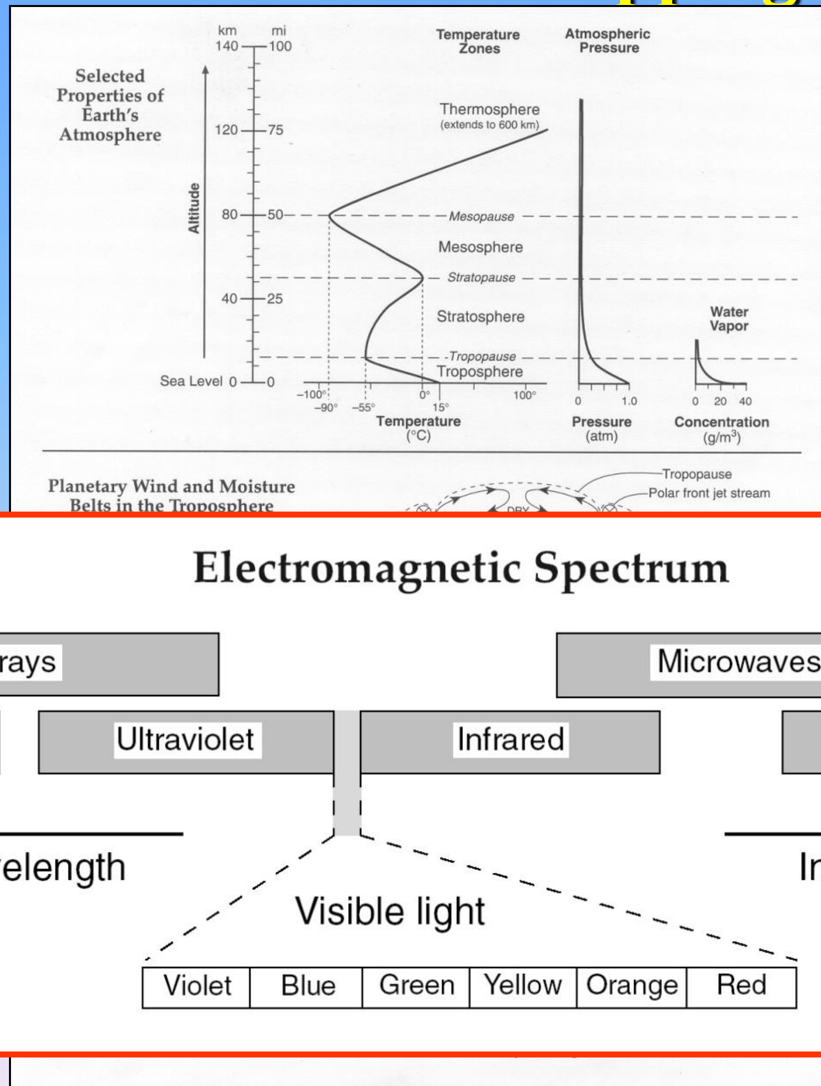


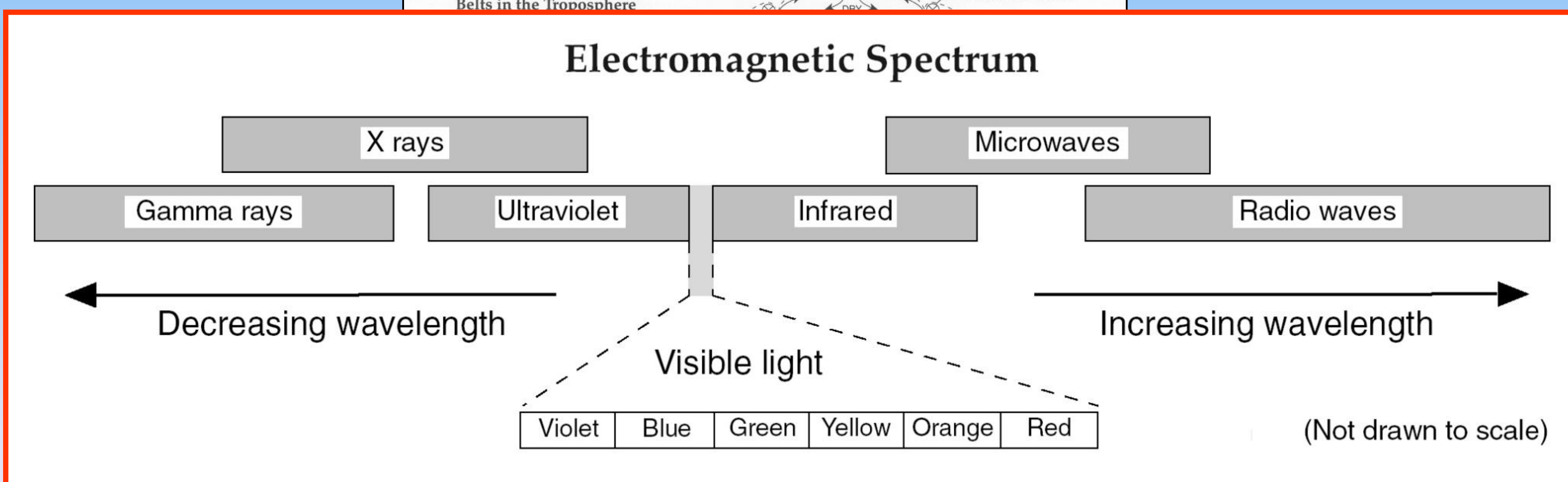
- The electromagnetic spectrum is continuous.
  - There are no gaps between different wavelengths.
  - This means that there is no sharp boundary between where one type ends and another begins.
- Different kinds of radiation gradually change from one to another as their properties change.
  - This results in an overlap at the boundaries.
  - The name used may depend on the source of the radiation. Likewise, microwaves overlap infrared radiation and radio waves.



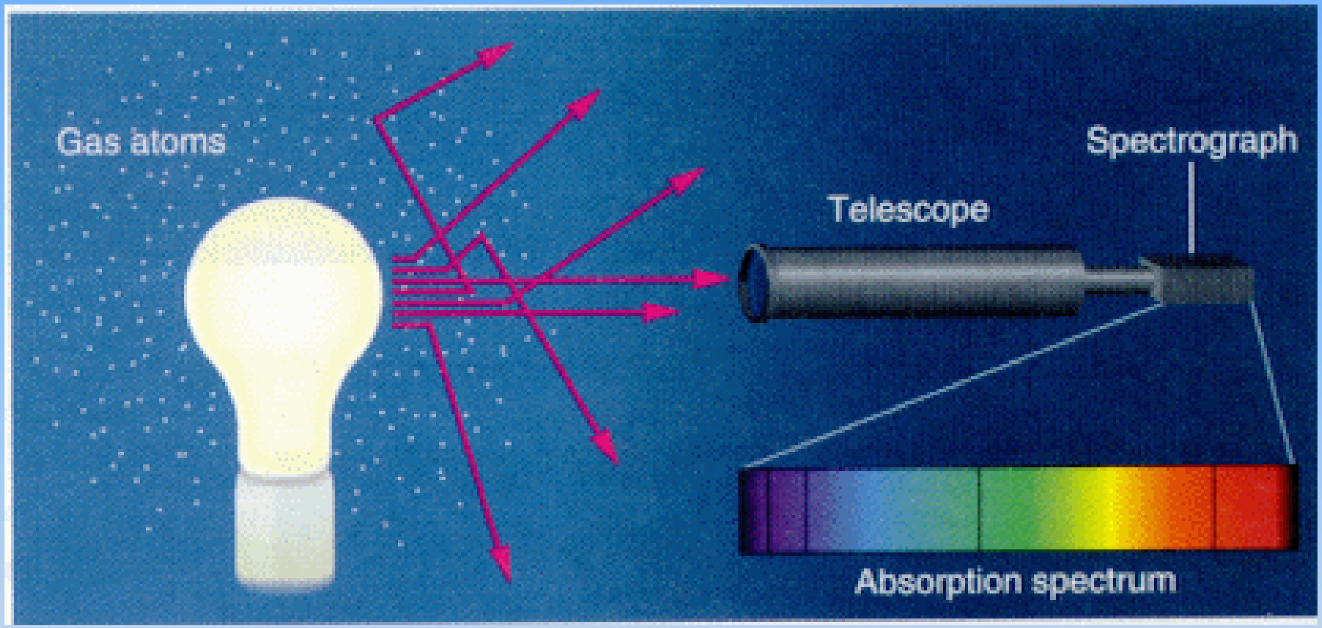
α
γ
β
Radioactive material
X-ray tube
UV lamp
The sun
Stove
Radio telescope
Transmitter
Radio waves
γ radiation
X-ray radiation
Ultraviolet (UV)
Visible region: violet red
Infrared and heat radiation
Millimeter waves
Centimeter waves
Decimeter waves
VHV
Short waves
Medium waves
Long waves
m
Wave length
10^-9
1 nanometer
10^-6
1 micrometer
10^-3
1 millimeter
1
1 meter
10^3
1 kilometer
Synchrotron radiation
Atomic nucleus
Atom
Protein
Virus
Cell
Fly
Human
Building

The Earth Science Reference Tables version is simplified but has the overlapping wavelengths





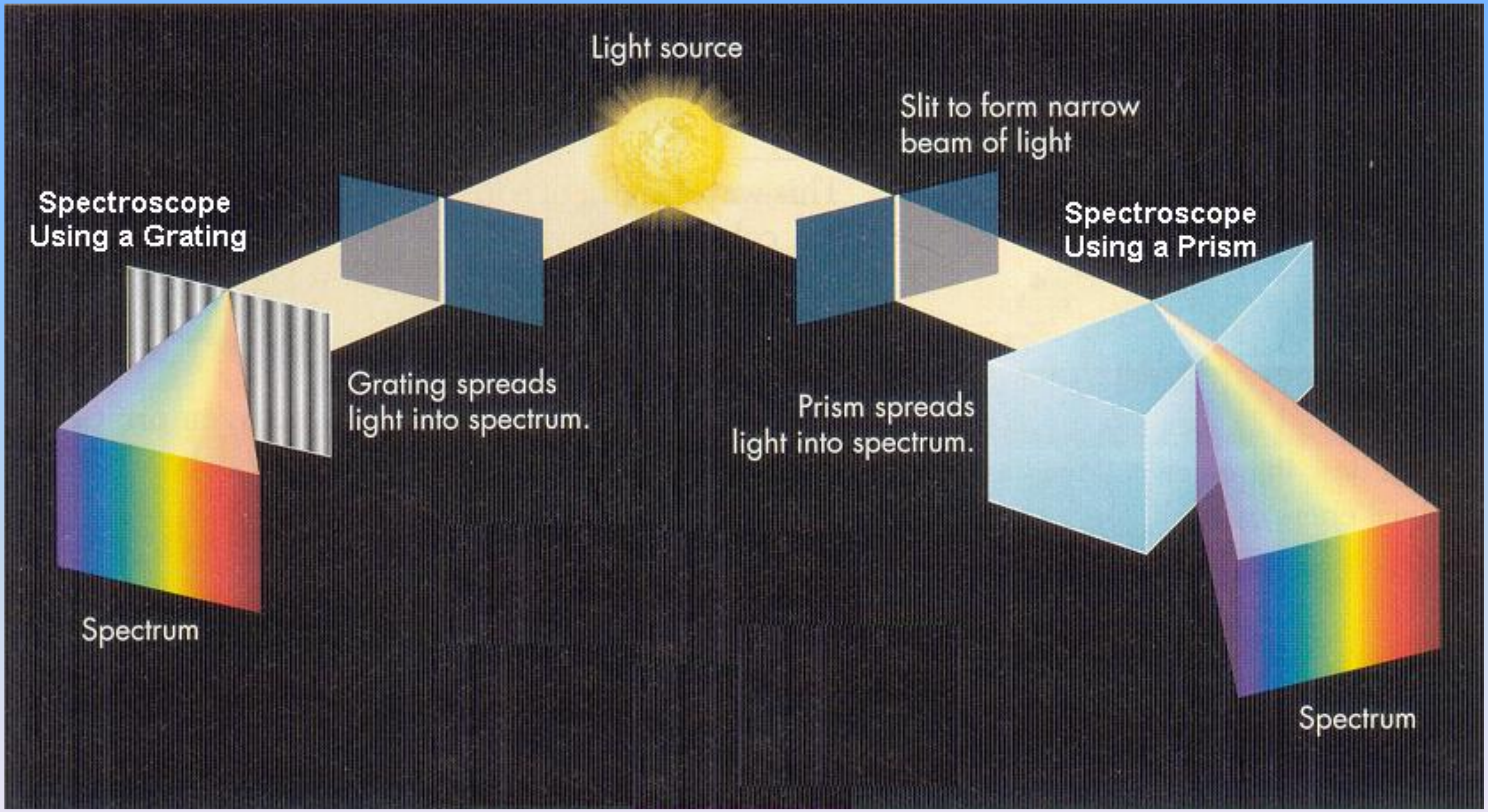
b. *Spectral Analysis*



(1) Separates light into different wavelengths

(2) ____Spectroscope____: Replaces the eyepiece of a telescope with a photographic plate

Spectroscopes

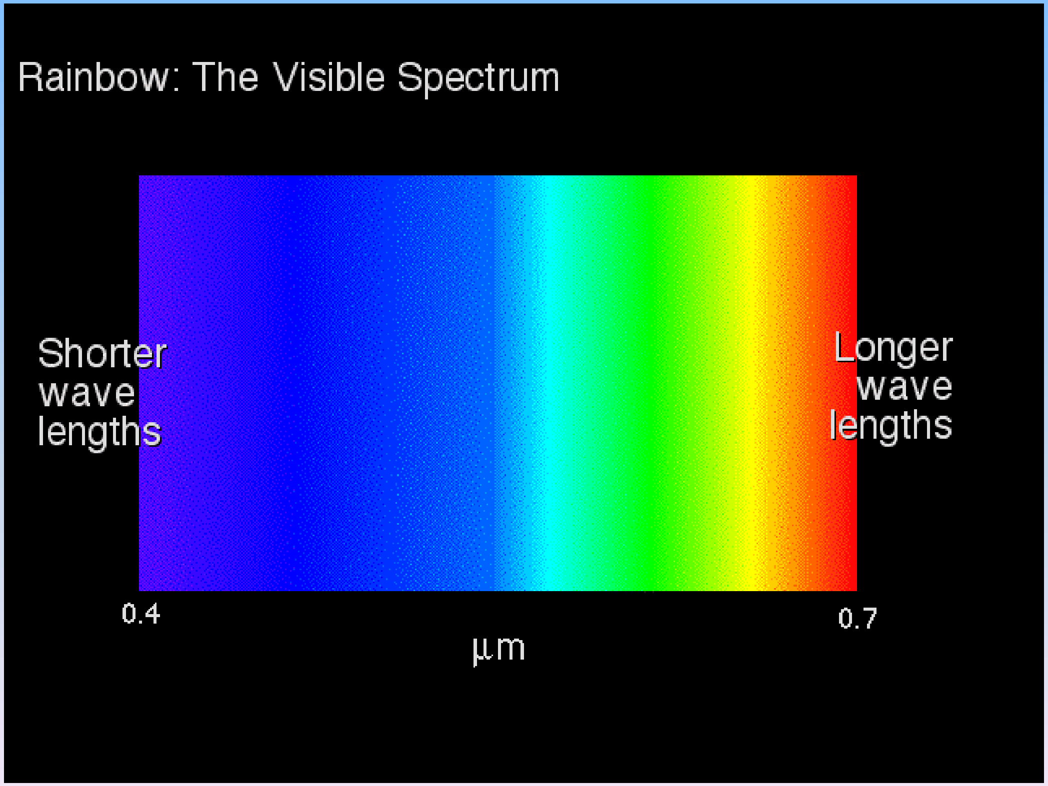


(3) Types of Observable Spectra

(a) ___Continuous______ Spectrum

i) Unbroken band of colors

ii) Indicates that the source is emitting light of all visible wavelengths.

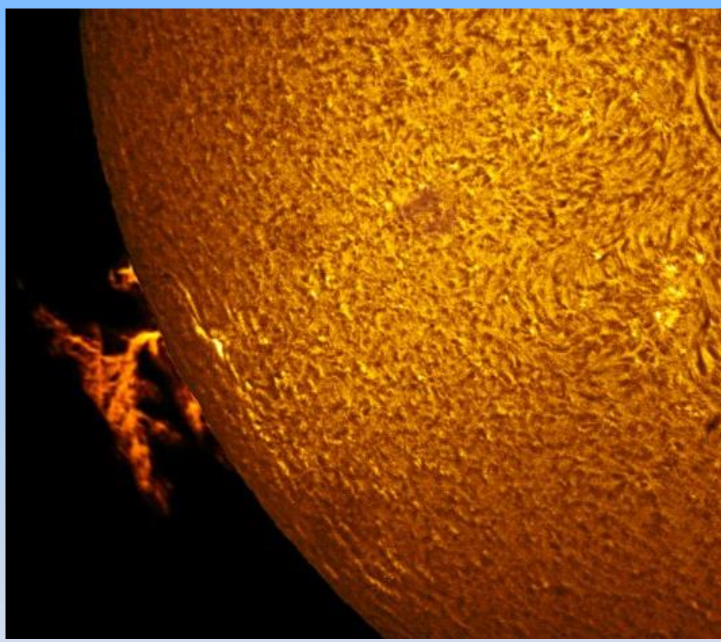


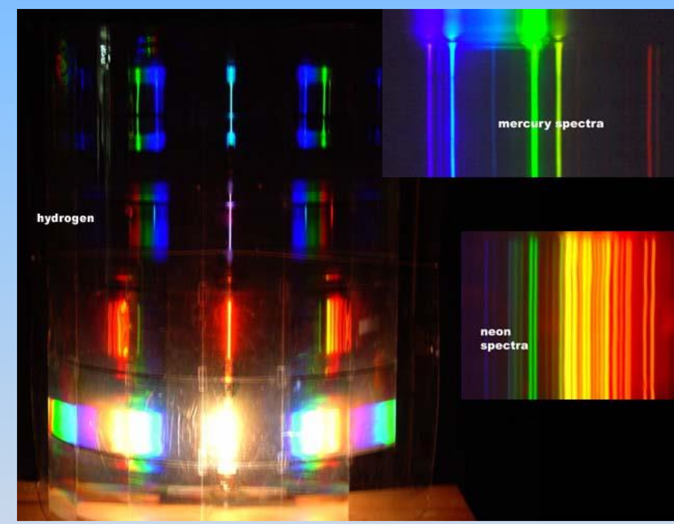
iii) Three types of materials emit visible spectra

a) Glowing __solids__

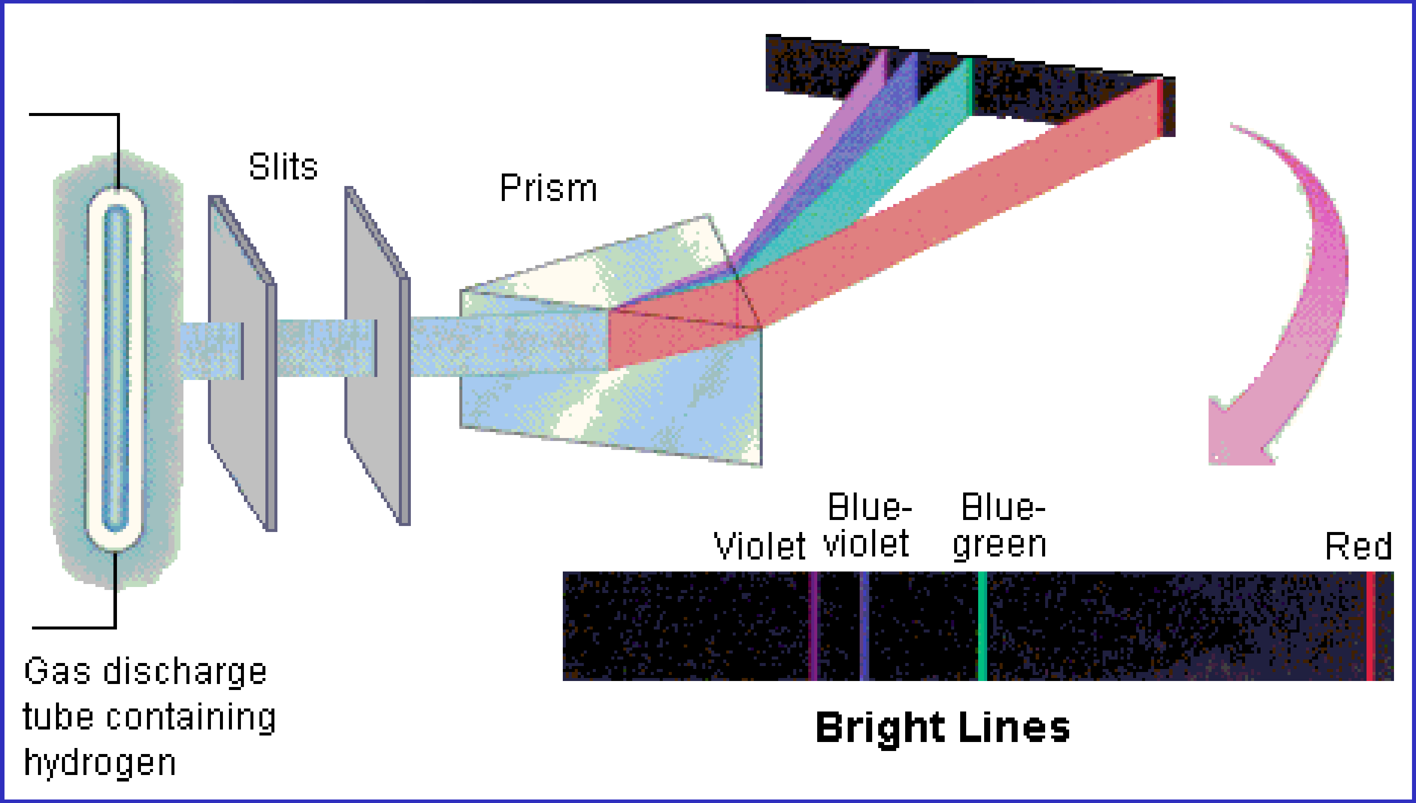
b) Glowing **liquids**

c) Hot compressed ___gases___ (as in a star)





(b) Bright Line Spectrum

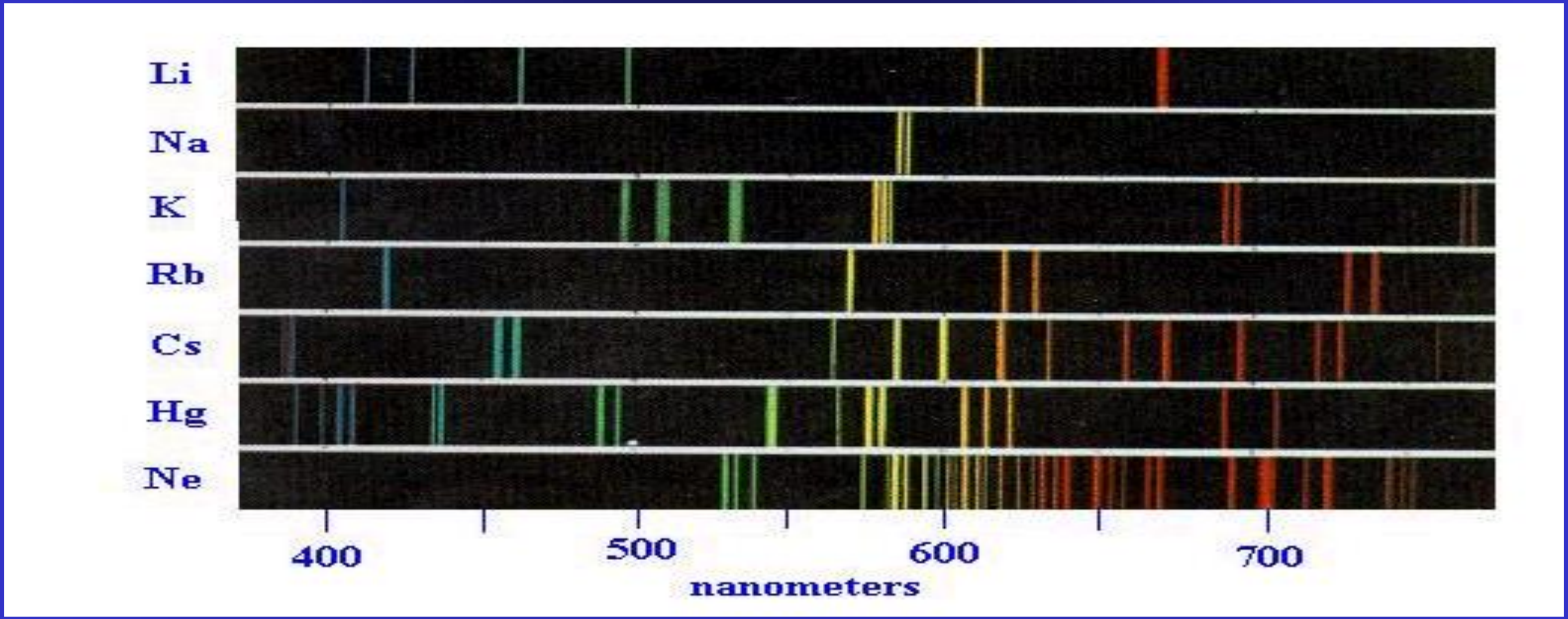


i) Called an *emission spectrum*

ii) **Light of only certain wavelengths is present.**

iii) Originates from chemical elements when in a glowing gas or vapor state.

Emission Spectrum



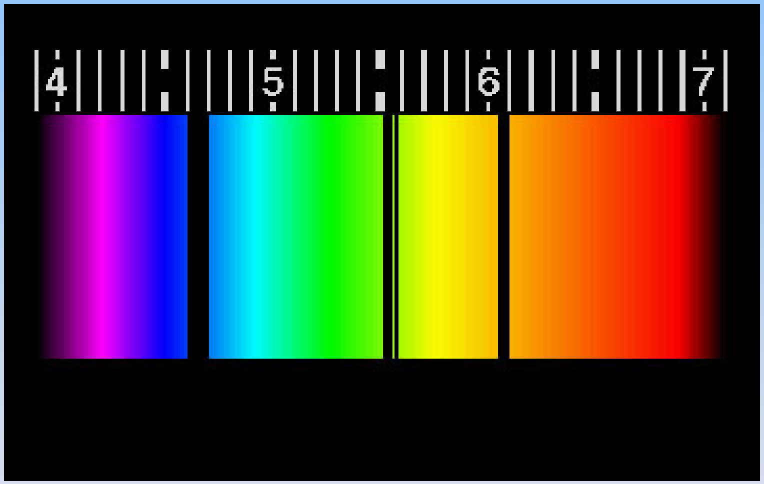
Spectral Analysis

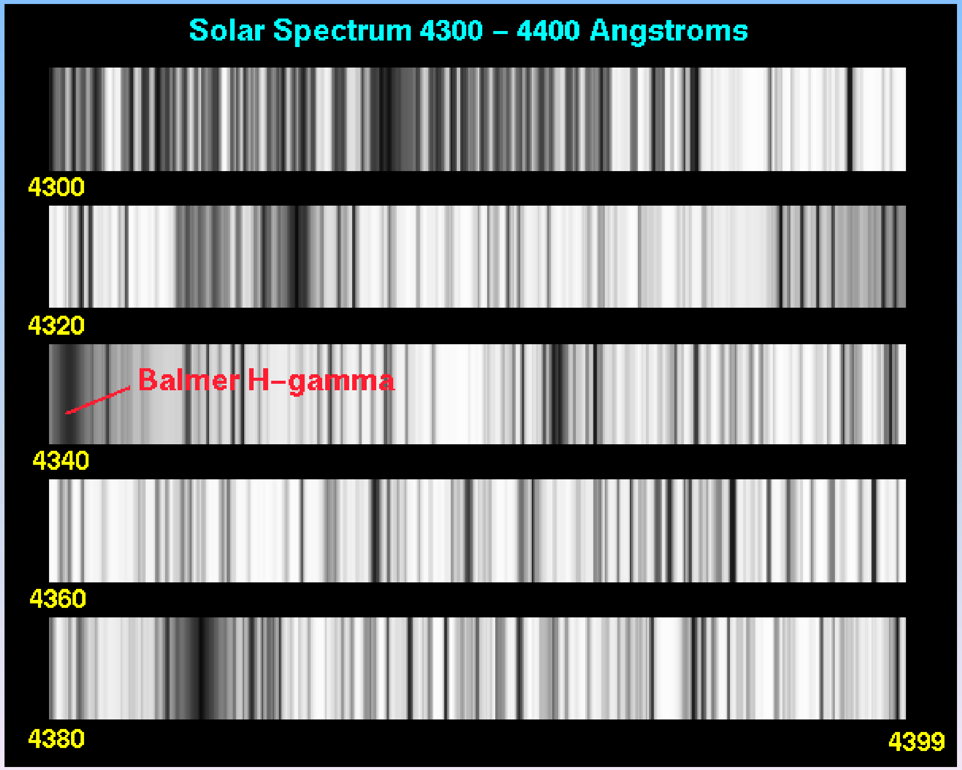
iv) Each **element** has its own unique bright line spectrum.

(c) Absorption Spectrum

i) Called a **dark line** spectrum

ii) Continuous spectrum with dark lines created by selective absorption of light.



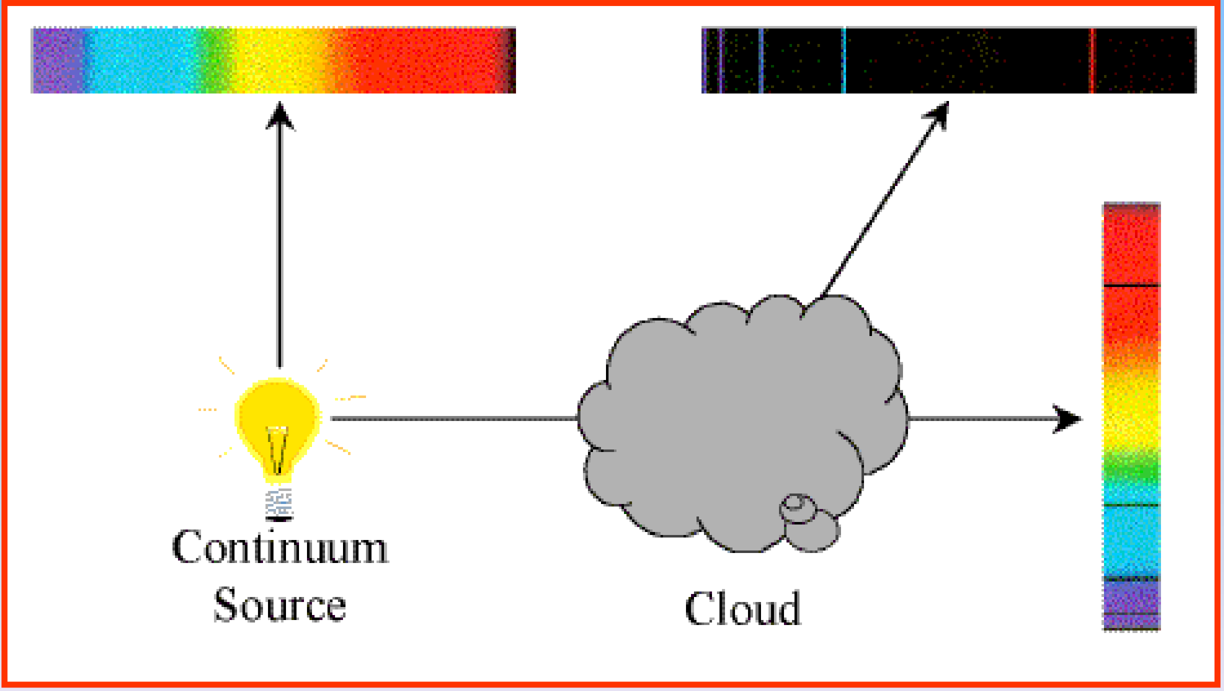


Absorption Spectrum Continued . . .

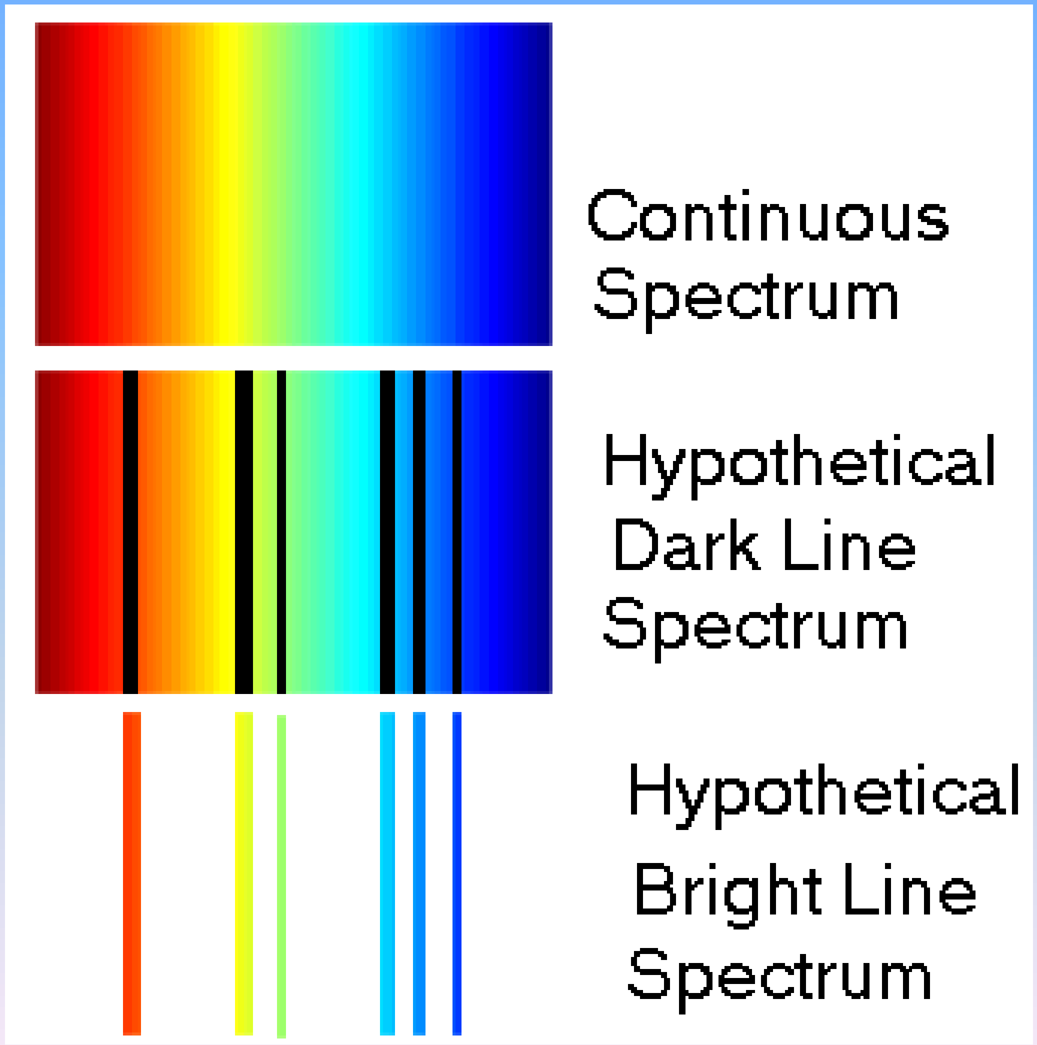
iii) Lines coincide with __**bright**__ lines of the element's bright line spectrum.

iv) Produced when __**cooler**__ gases lie between the source and the spectrograph. The cooler gas absorbs the same wavelength it would emit when heated.

- Atmospheres of stars are much cooler than their interiors.
- Most stars have absorption spectra.
- The Sun's absorption spectrum has 67 elements.

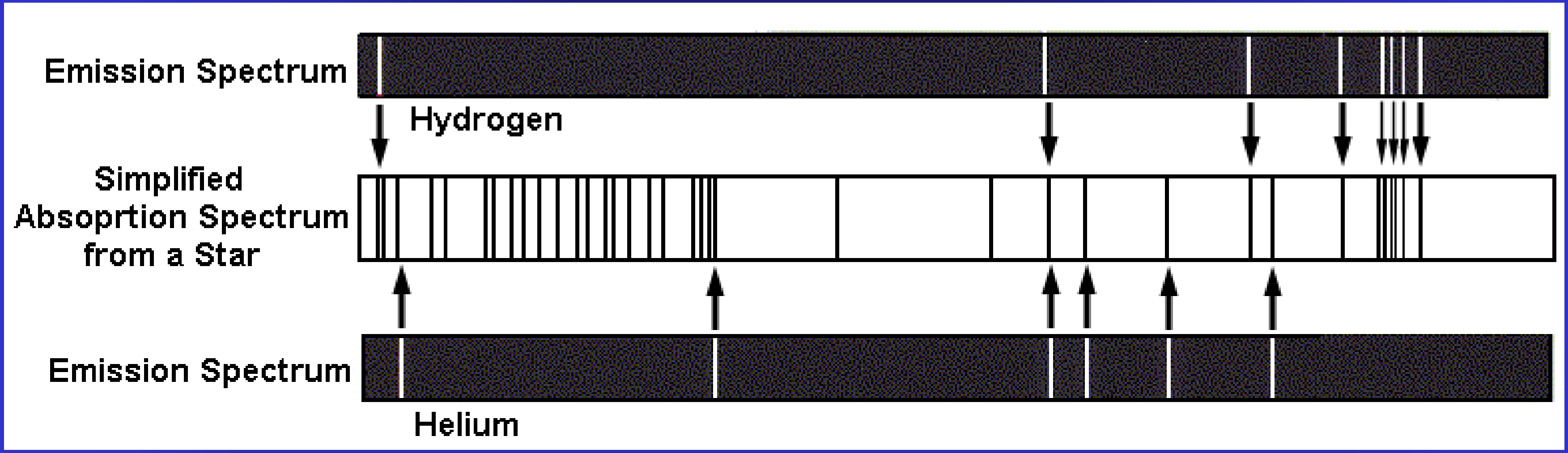


Summary



Continuous Spectrum
Hypothetical Dark Line Spectrum
Hypothetical Bright Line Spectrum

Using a Stellar Spectrum to find the Composition of a Star

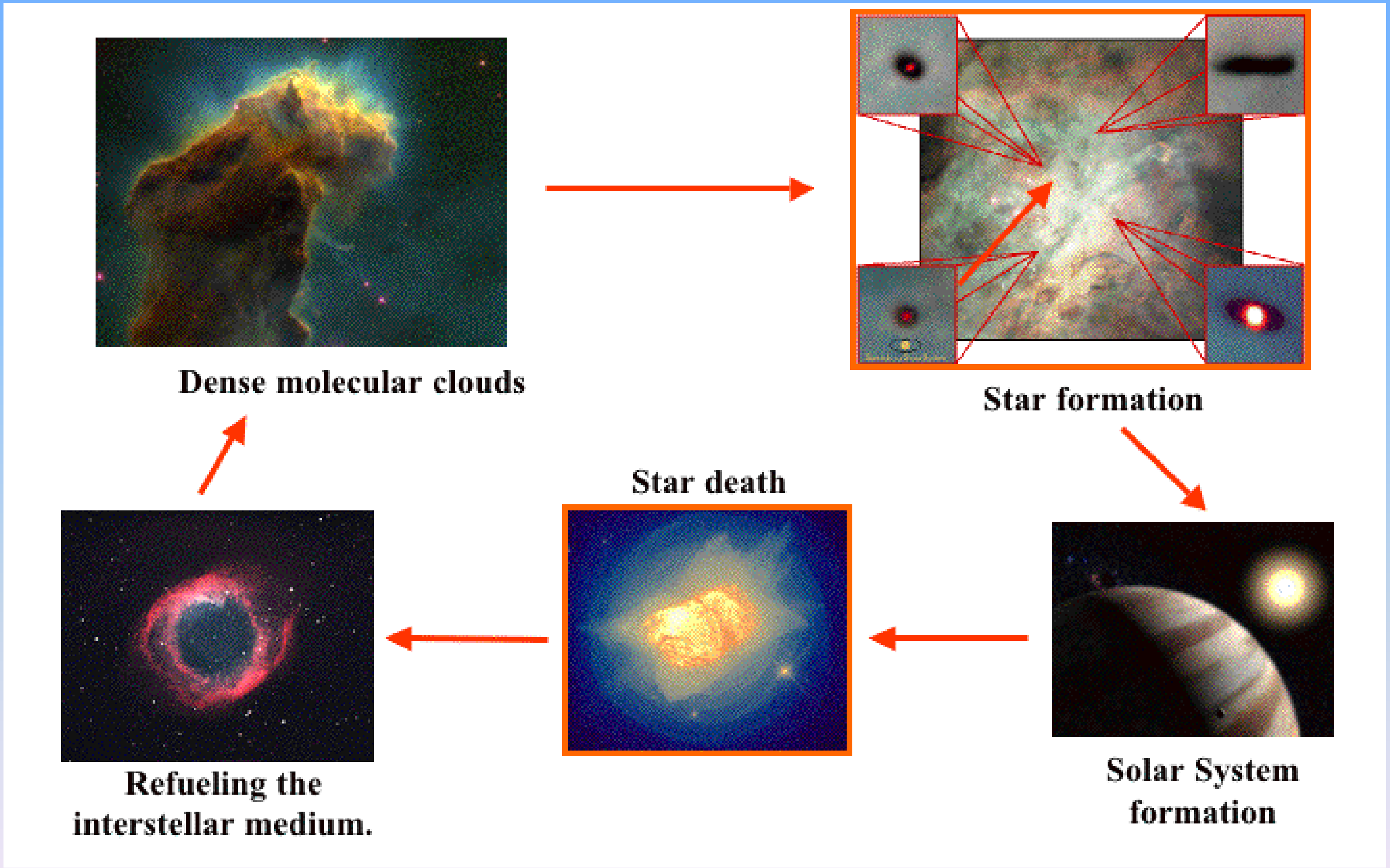


vi. Inferring the Atmosphere of a Planet

a) Planets shine due to __**reflected**______ light.

b) Dark lines present in the spectrum of the planet that are not present in the spectrum of the Sun must have originated in the planet's atmosphere.

6. The Life Cycle of a Star



a. Nebula

(1) About 99% of the cloud is gas, mostly hydrogen.

(2) The remaining 1% is dust (1/10,000 cm in diameter) consisting of silicon, carbide, graphite, diamond, and minor amounts of nitrogen and other elements.

(3) Average nebula is 25 light years in diameter.

Nebulas – Stellar Nurseries

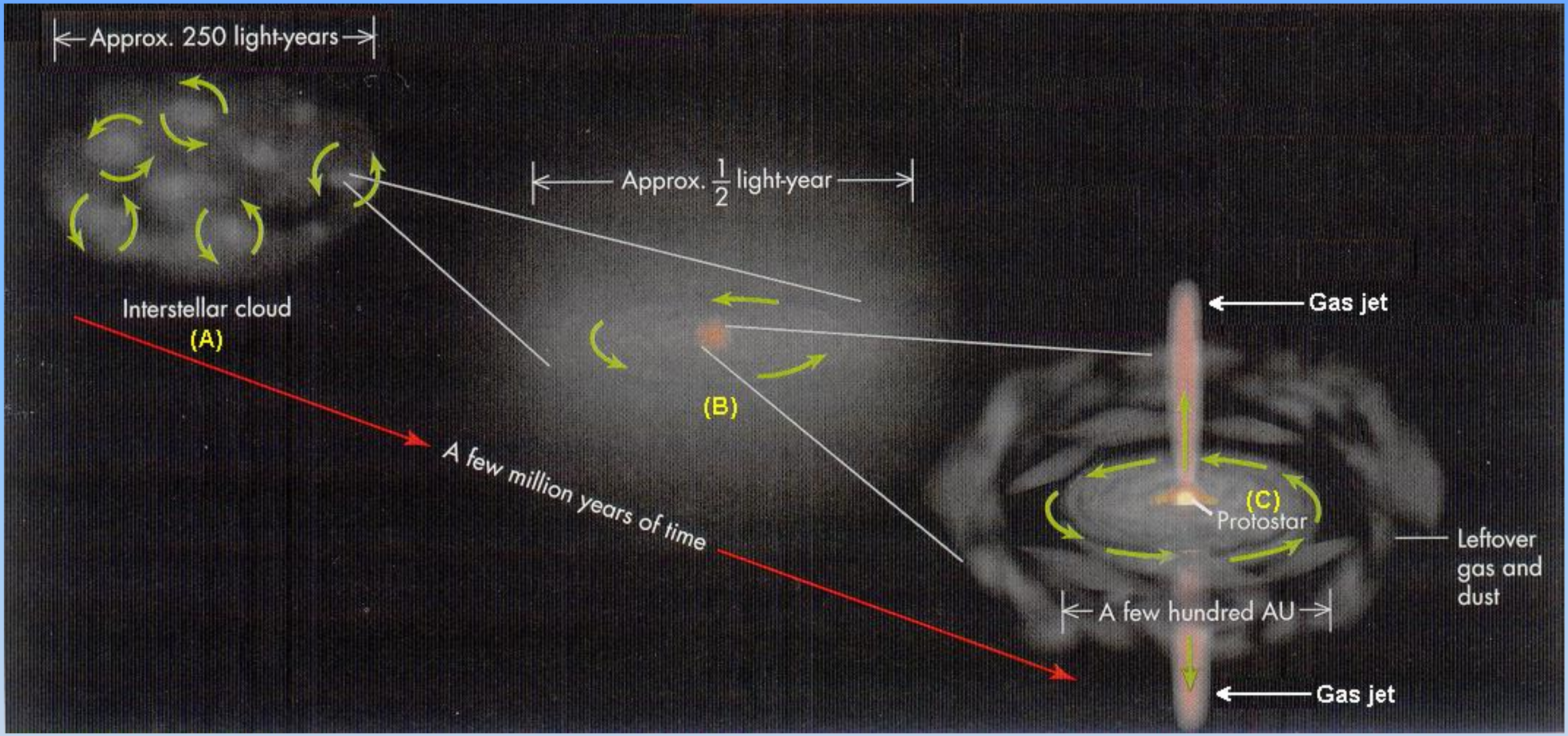
(4) An outside force (e.g., shockwave from a supernova) triggers the force of gravity between atoms of gas and dust and they move towards each other.

(5) Cloud becomes denser.

(6) Temperature increases

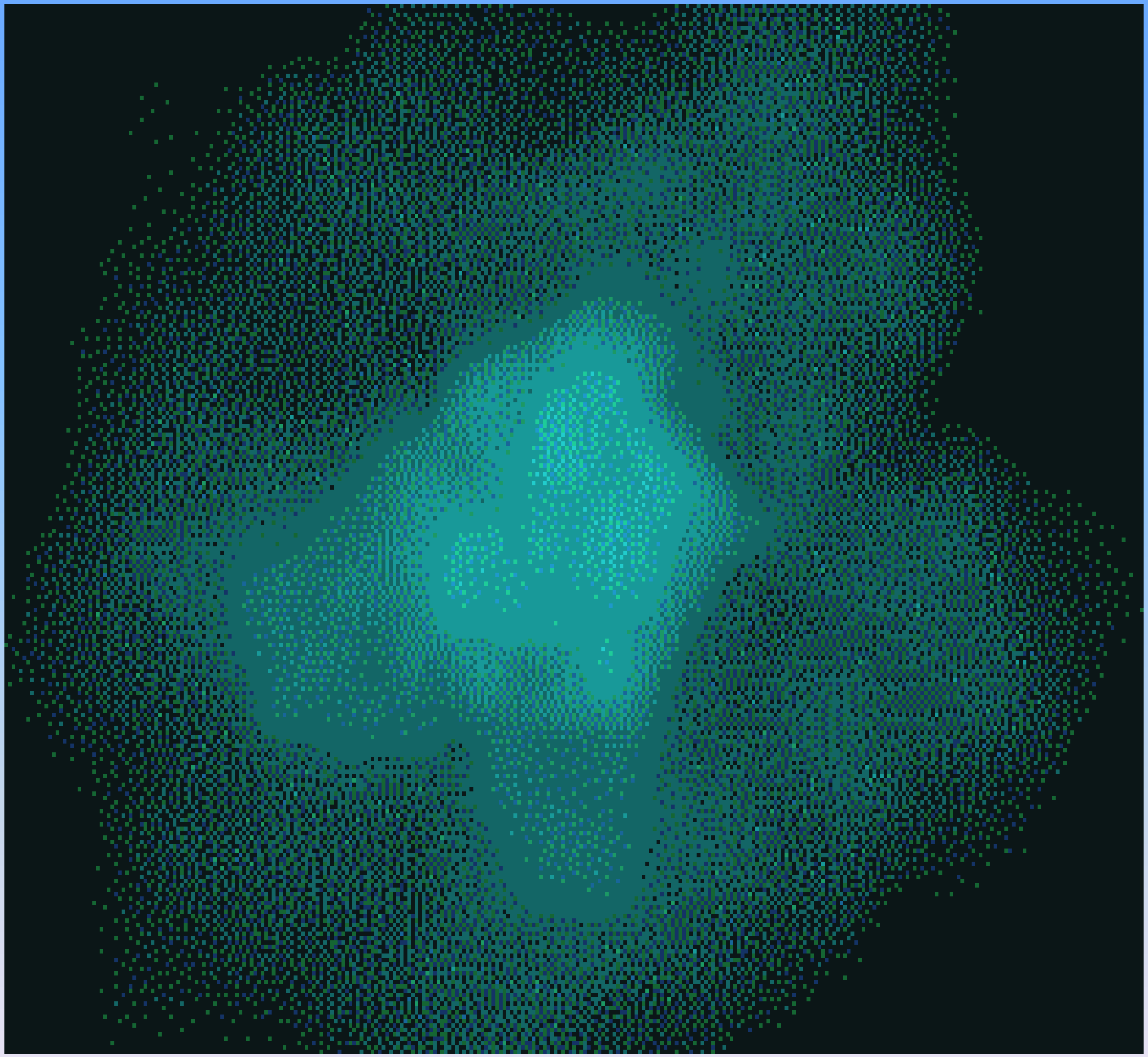
(7) Parts start to glow when the temperature is high enough. It is now a **protostar**________.

Protostar Formation

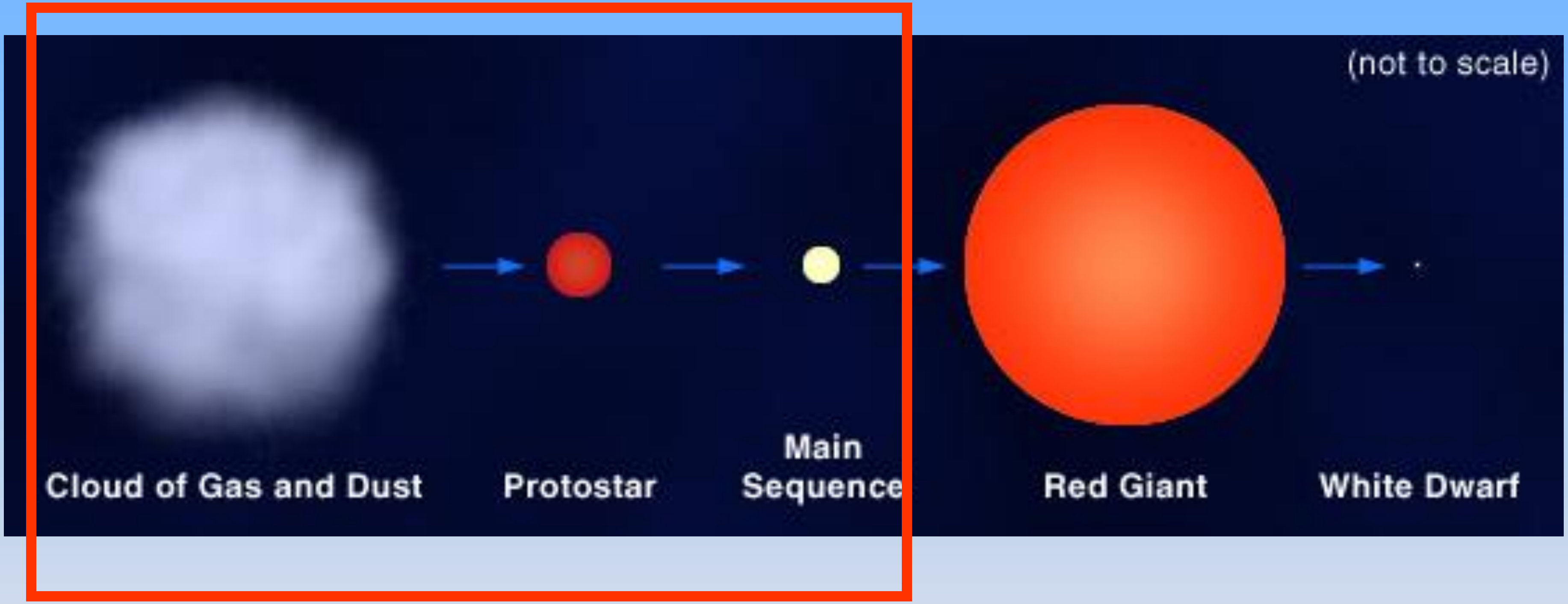


b. Continued contraction increases the density of the protostar.

c. Fusion begins and the star is born.



The Birth of Sun-Like Star



d. When the release of energy counterbalances the force of gravity the star stops contracting and is said to be in a

Stable State

______________________________.

Blue Stars

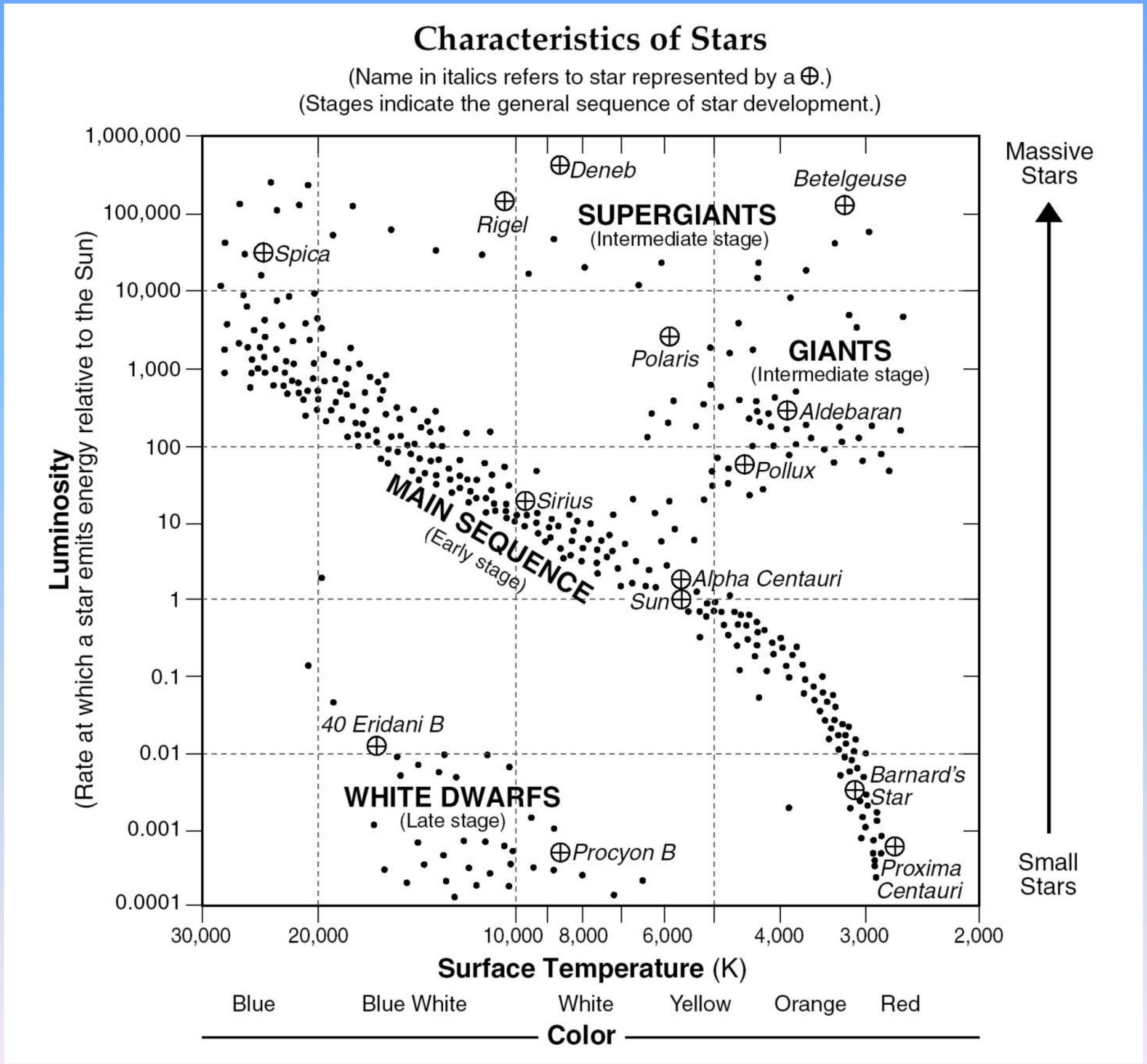
(1) Massive blue stars may reach a stable state in a few hundred thousand years.

Yellow Stars

(2) Less massive yellow stars may take millions of years to reach a stable state.

Stable Low Mass (Sun-Like) Stars

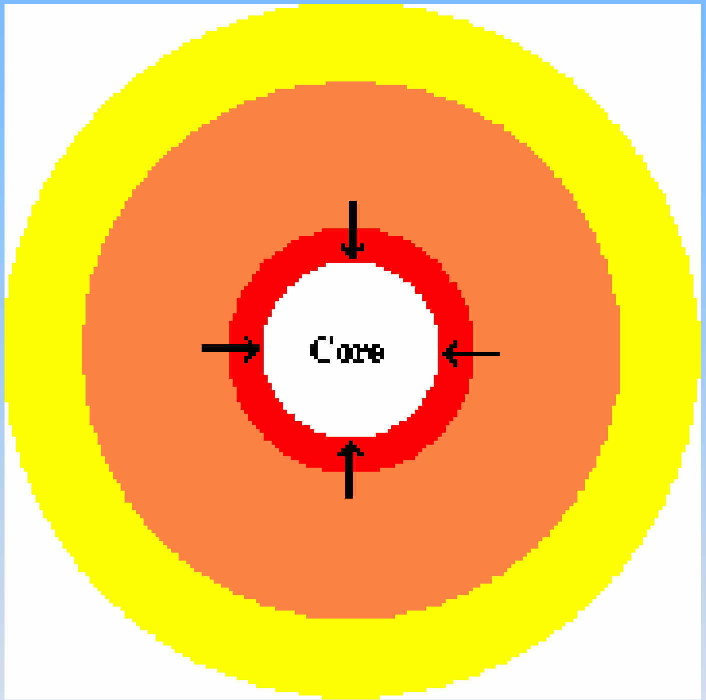
- Stable **<u>Sun-like stars</u>** are found on the main sequence.

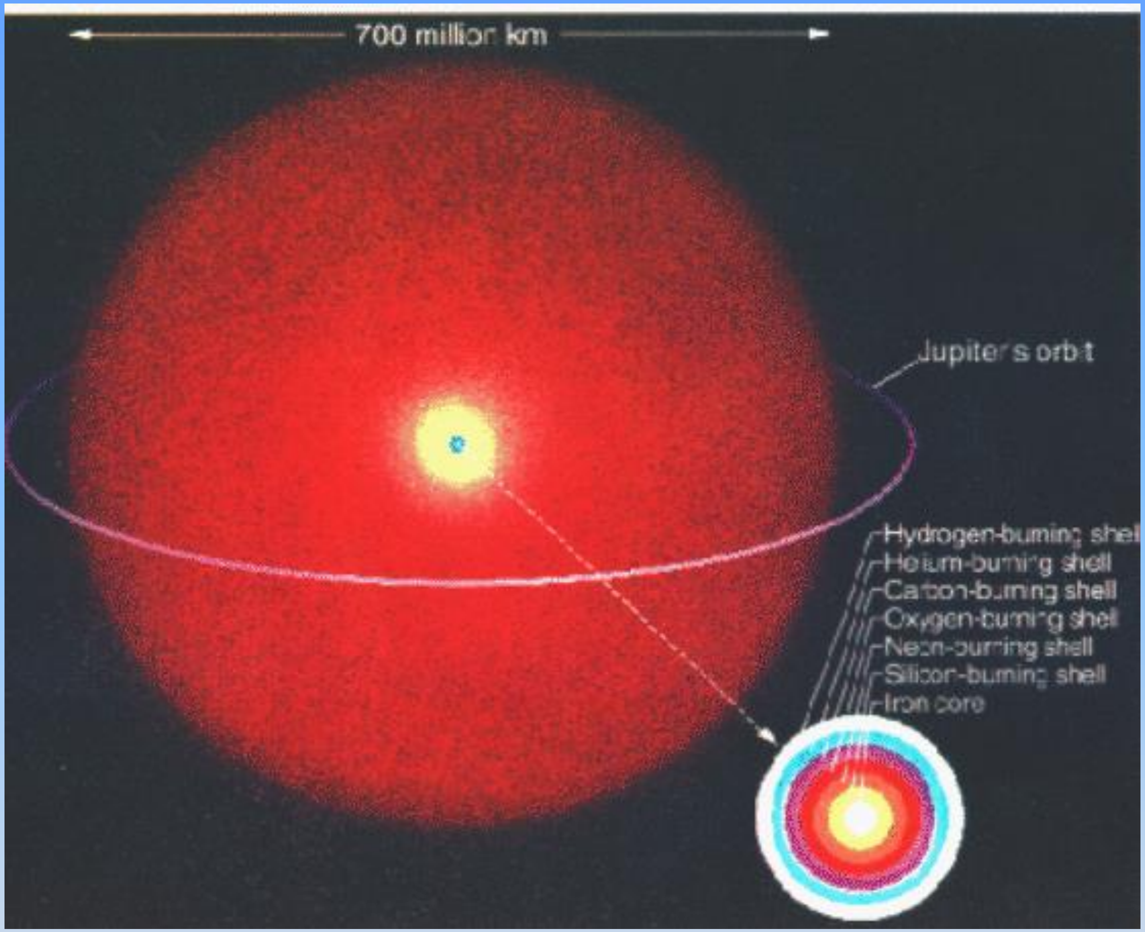


e. Eventually the light nuclei in the core (helium in the case of the Sun) become depleted.

(1) Energy of fusion no longer balances the force of gravity and the core contracts again.

(2) The core heats up and the star's outer layers expand causing the star to radiate more light and become brighter.

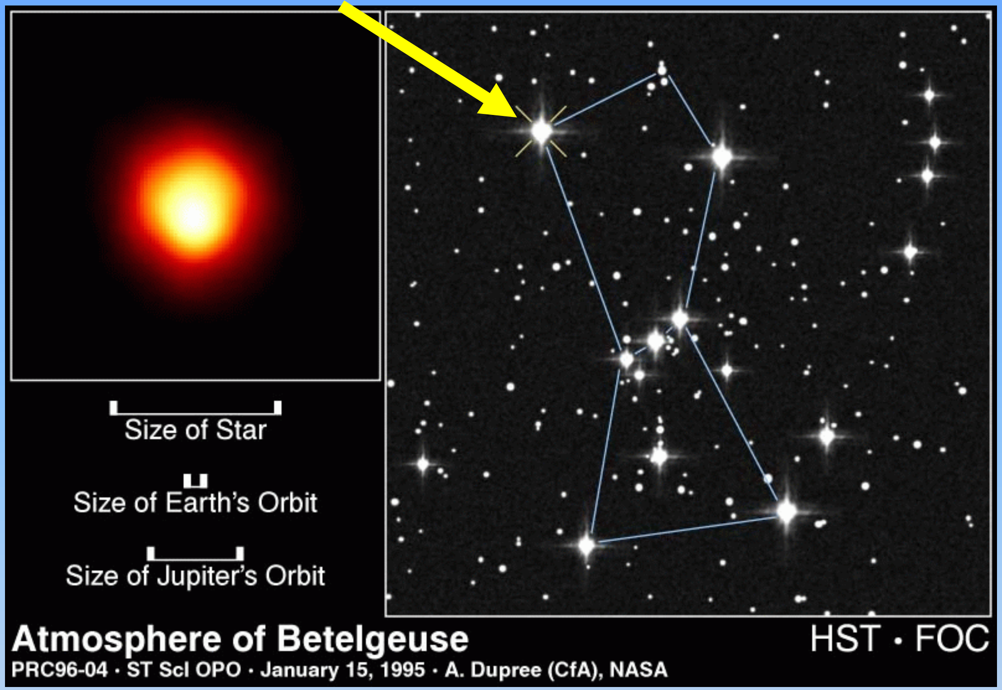




(3) Fusion starts again in the outer layers but the core is now composed of only helium.

(4) The result is the continued expansion of the star and the formation of a red giant or a **supergiant.**

Supergiant Stars Continued . . .



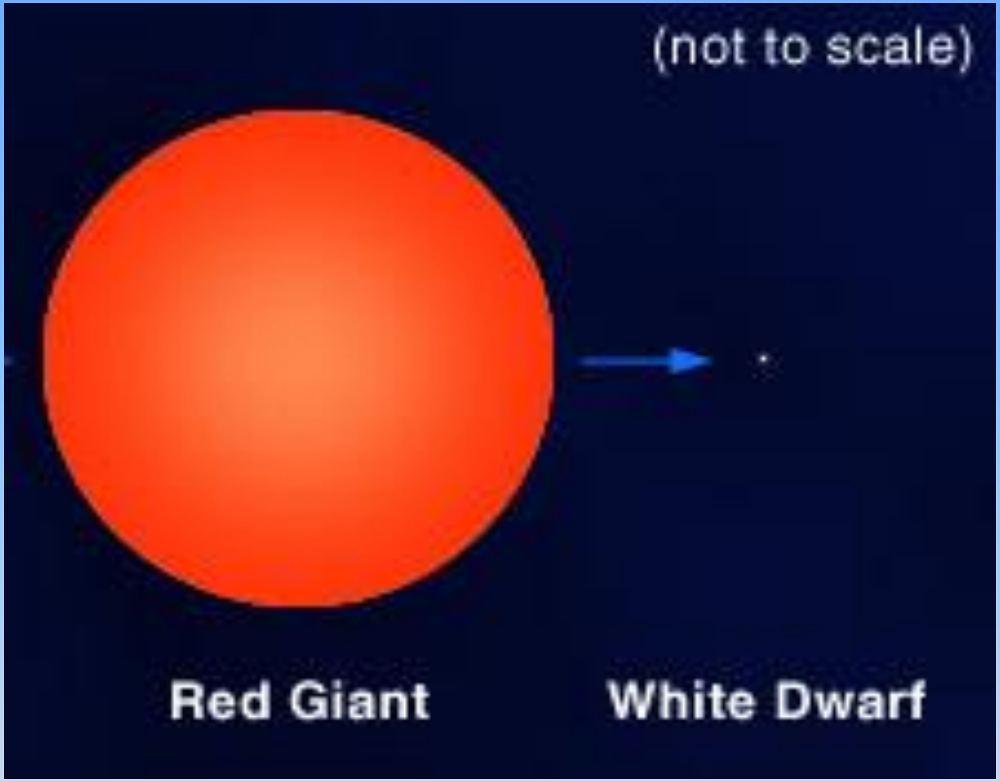
Astronomers estimate that the Sun could be 160 times its present diameter. This will be beyond the position of Earth's orbit (about 1.5 astronomical units).

f. White Dwarf

(1) Final Stage of a star's life

(2) Most fuel is depleted

(3) Weight of outer layers no longer supported by temp. and pressure of the core



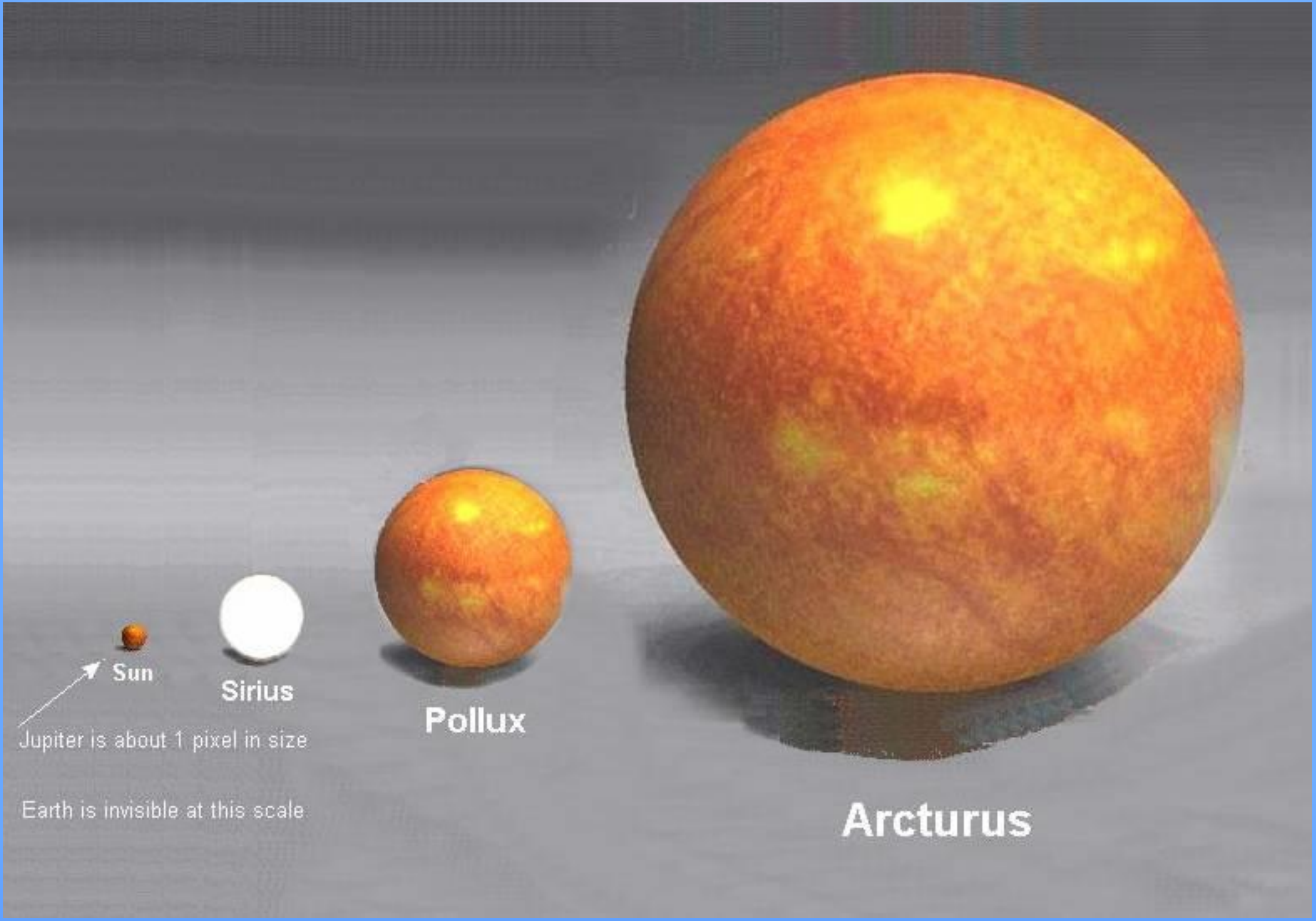
(4) Collapse of the giant squeezes the nuclei of its atoms together and the star becomes a white dwarf that is most likely no larger than Earth.

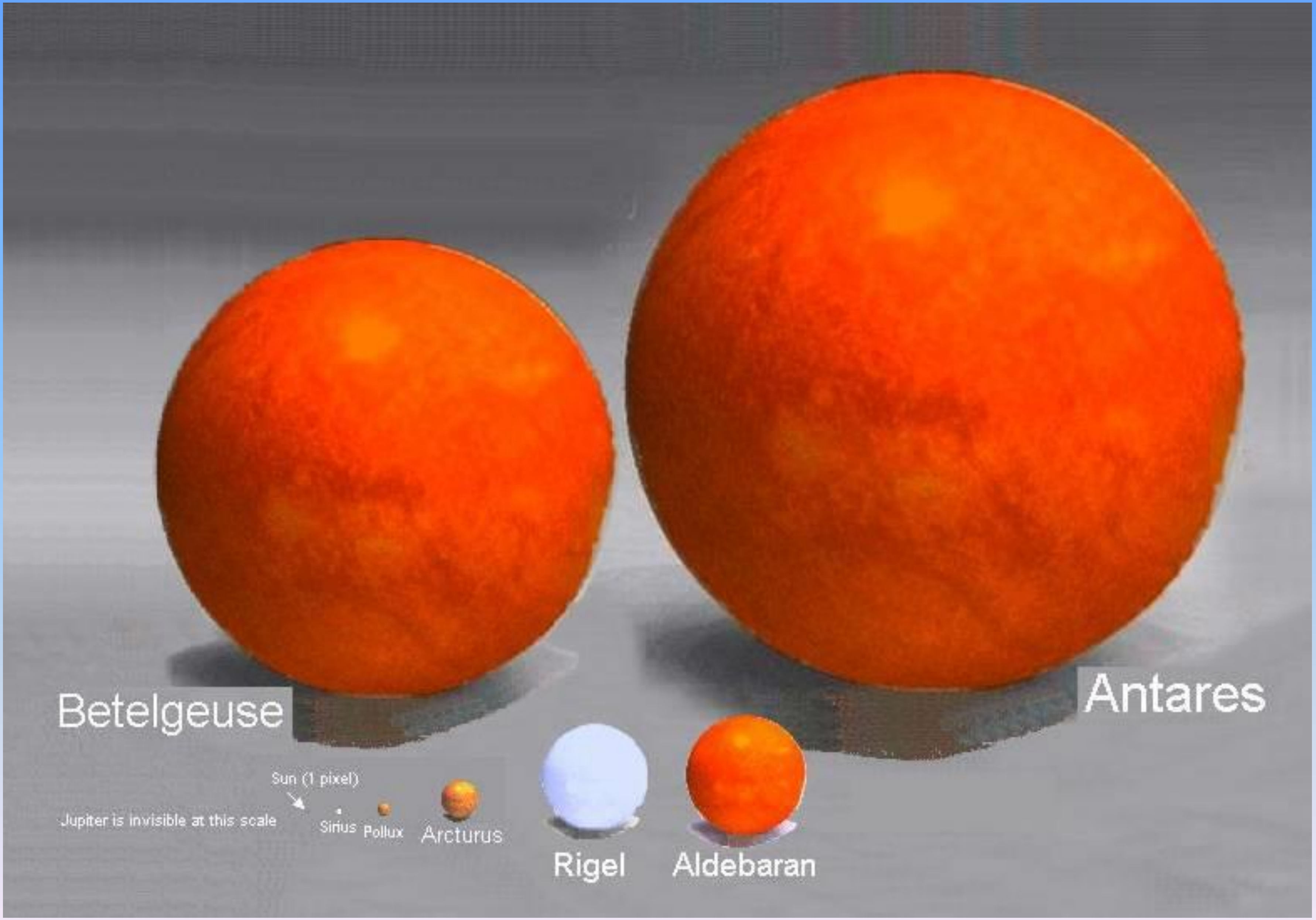
White Dwarf Stars Continued . . .

a

- Made of carbon
- Ultimate fate of the Sun
- Hotter than the Sun
  - Smaller
  - Dimmer

Comparing the Sizes of Stars




Betelgeuse
Antares
Sun (1 pixel)
Jupiter is invisible at this scale
Sirius
Pollux
Arcturus
Rigel
Aldebaran

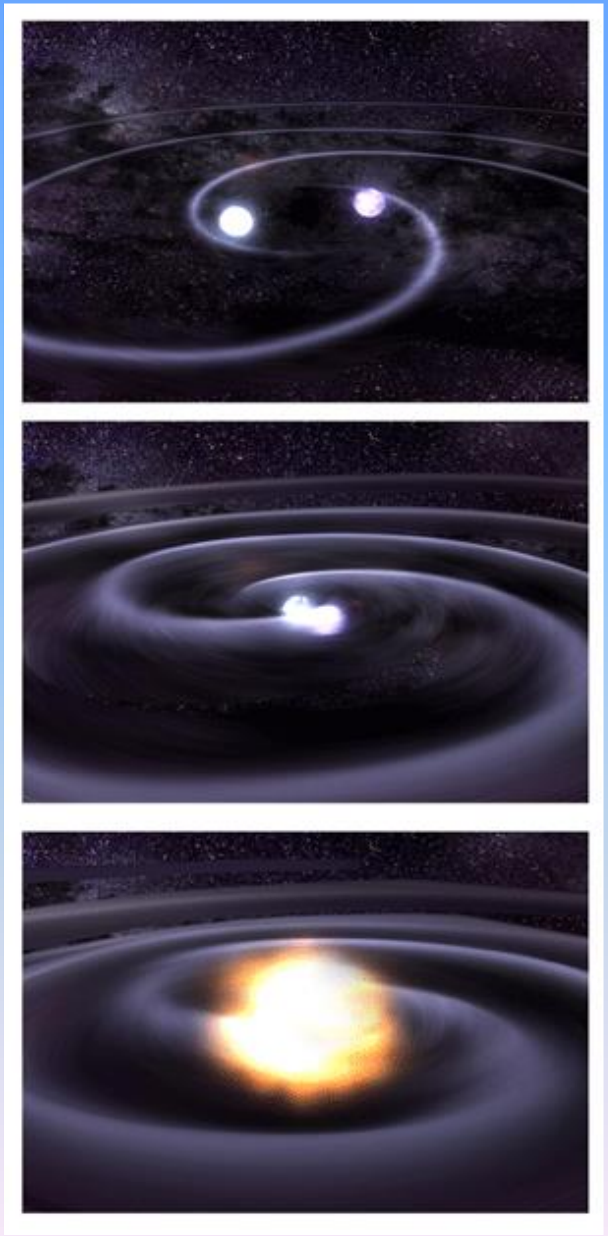
g. Nova

1970 Chevy Nova

Oops . . .

Wrong type of nova

Nova



(1) A white dwarf flares increasing in brightness a hundred to a million times

- Collision with another star may be a cause

h. Supernova

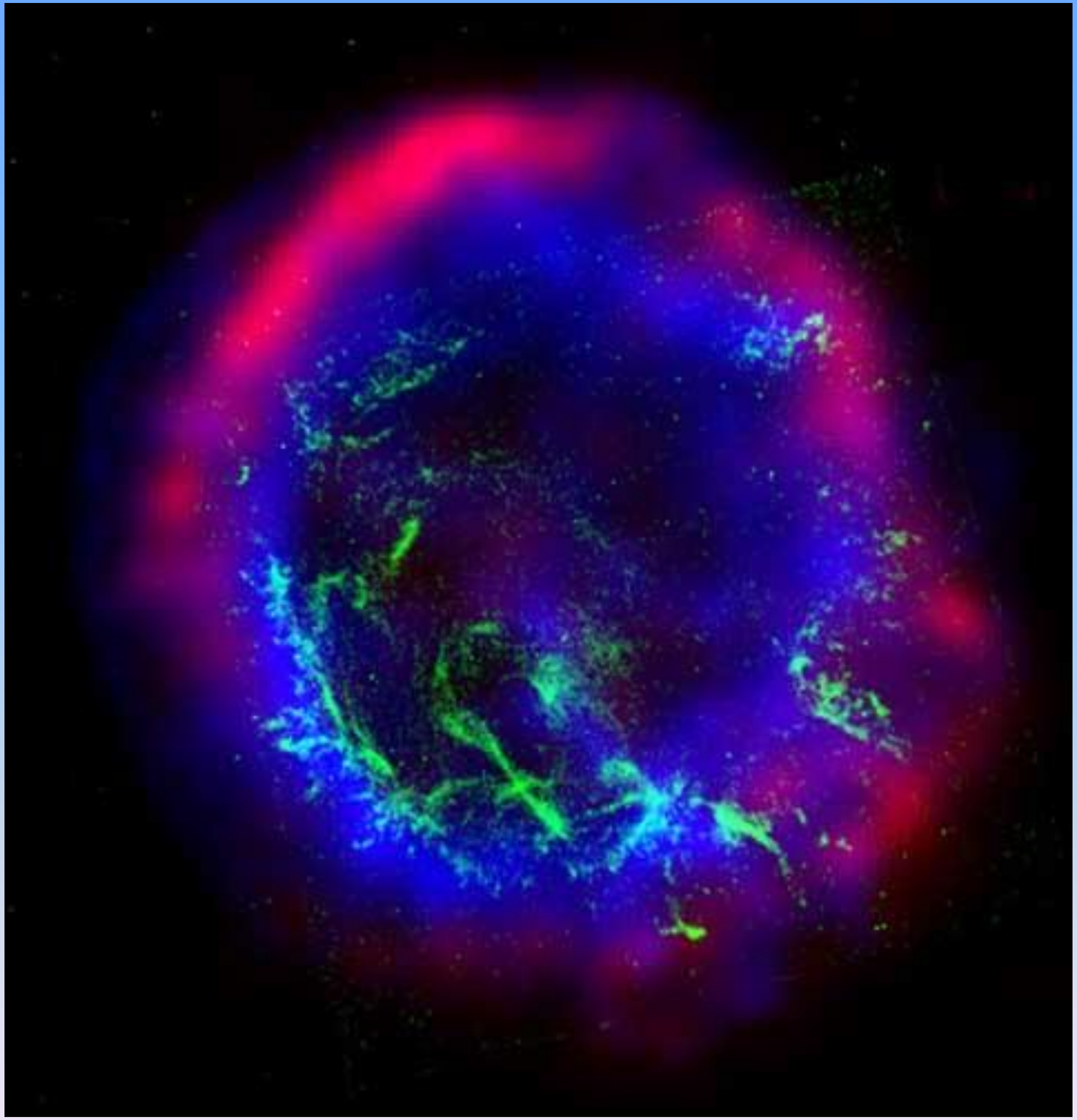
(1) Very massive stars

(2) When the star cools a central iron core collapses.

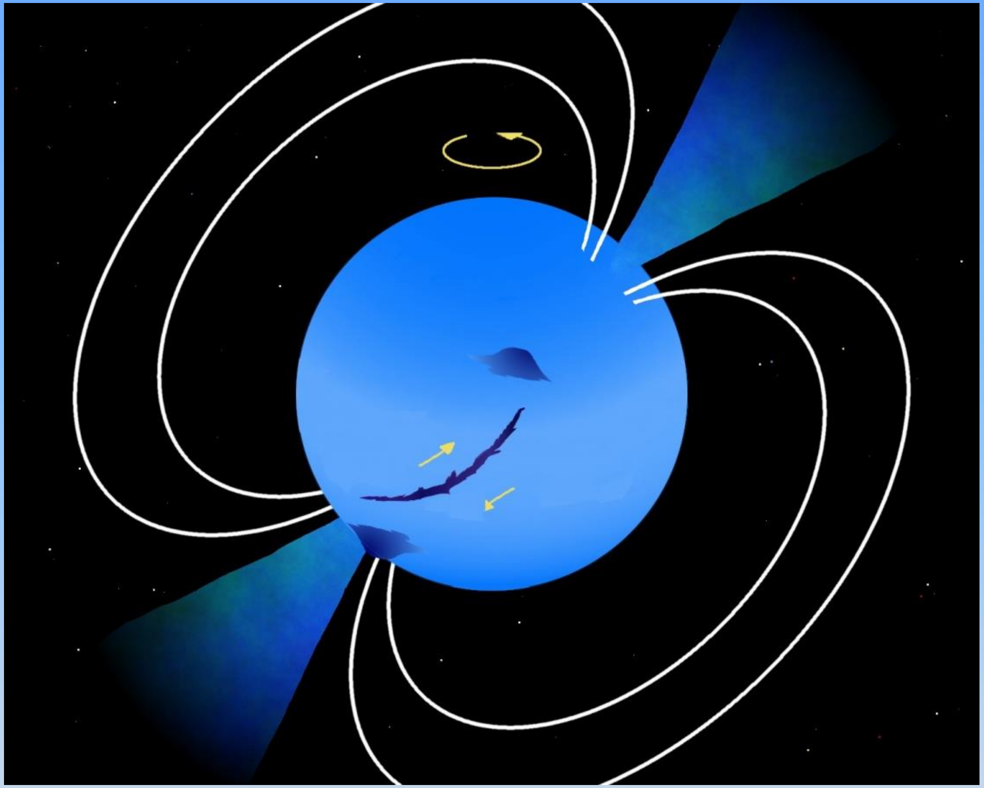
(3) Increased temperature and pressure fuses iron with heavy elements.

- Results in a violent explosion
- Half mass blown away as a great cloud

A Nebula Forms

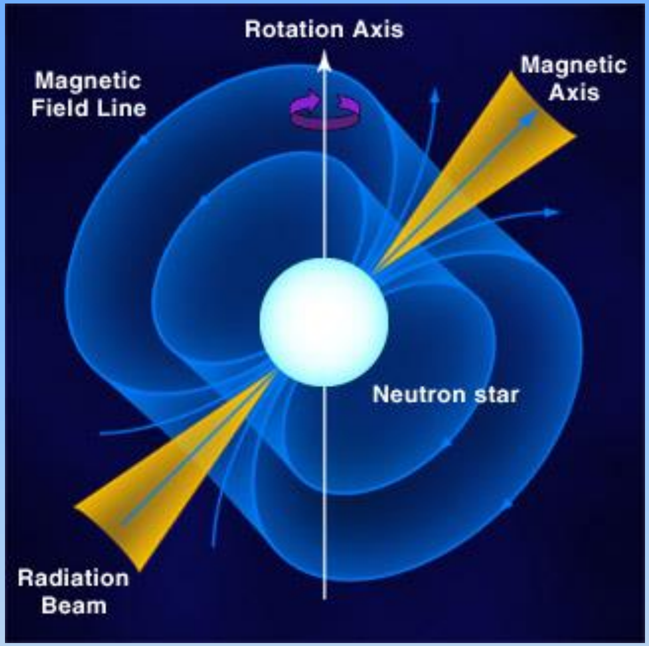


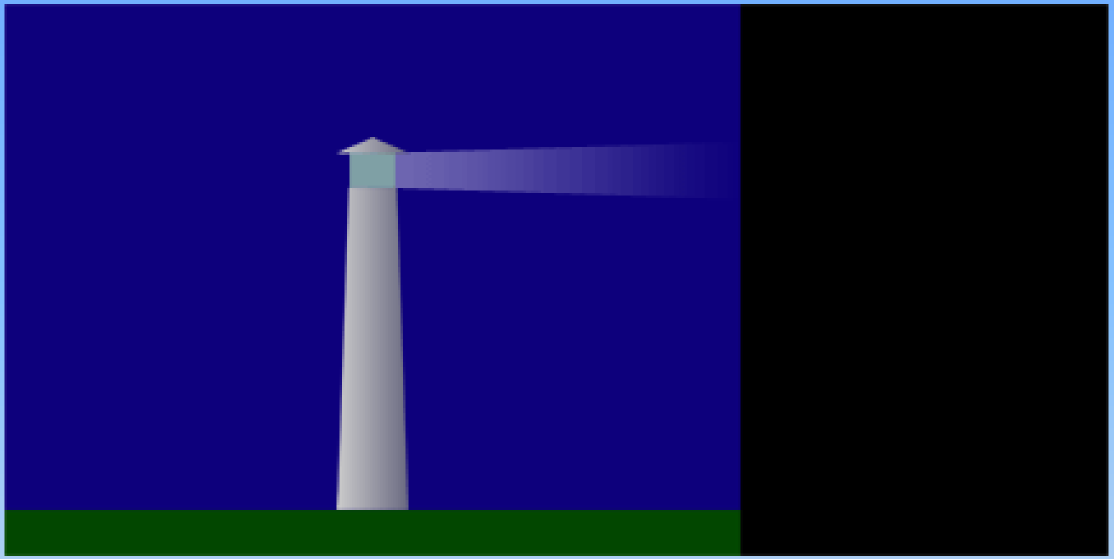
(a) After a supernova



- The mass that remains is called a neutron star
  - Astronomers believe that all atom's electrons are crushed in the nucleus and combine with protons to form neutrons

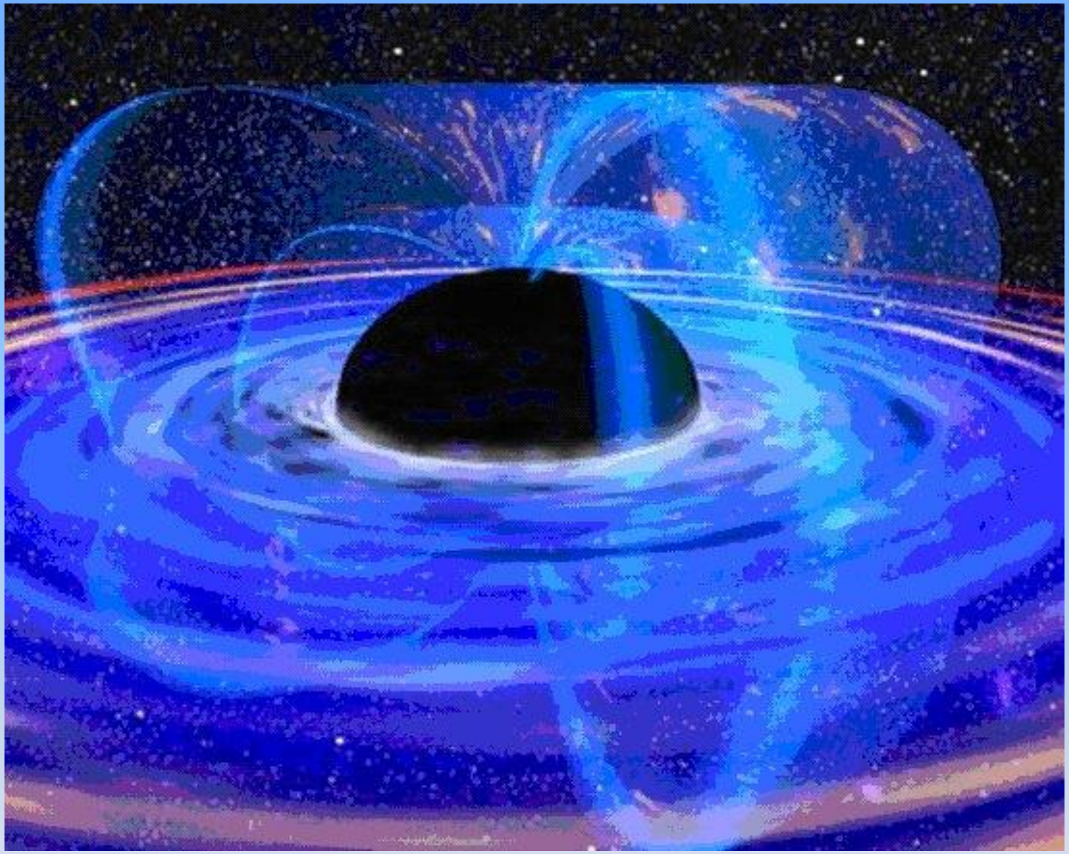
Pulsars





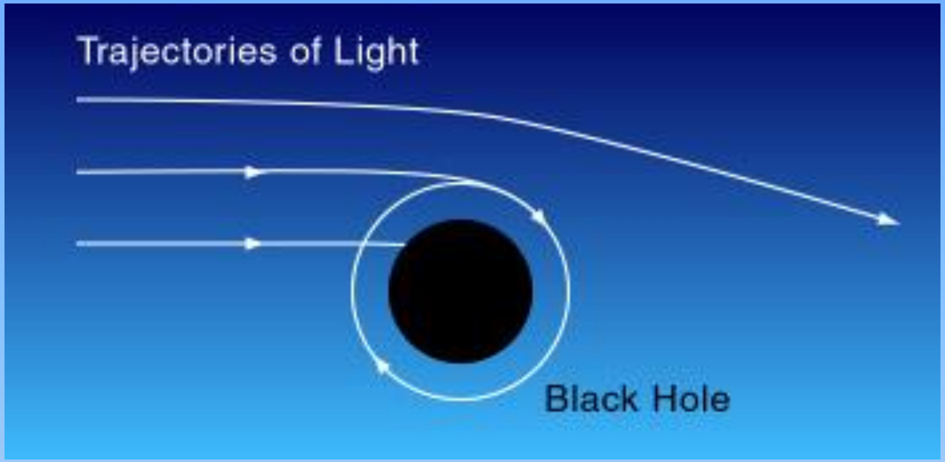
- Usually, the rotational axis of the neutron star does not align with the magnetic axis.
- The radiation beams will sweep around and create the **light house effect**.
- What we observe on Earth will be pulses of radio wave with very stable period.
- This is a **pulsar ---** one can be found at the center of the Crab Nebula

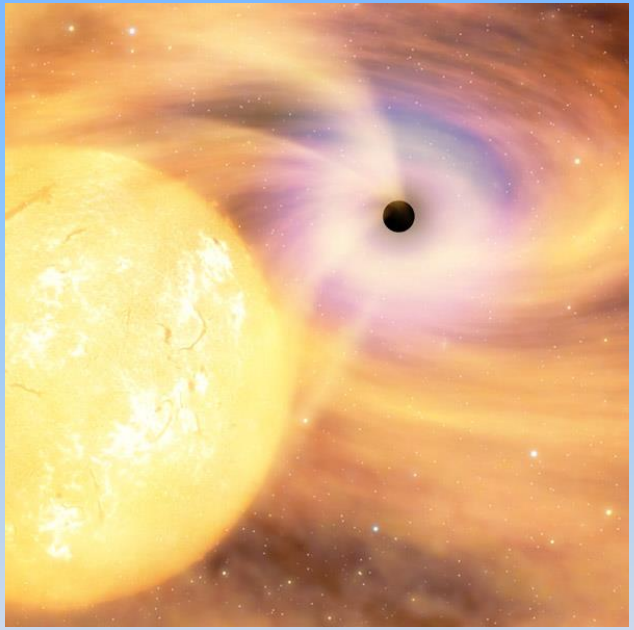
(b) If the star is very massive the star collapses into a very small volume.



- These invisible objects are called ***black holes***.

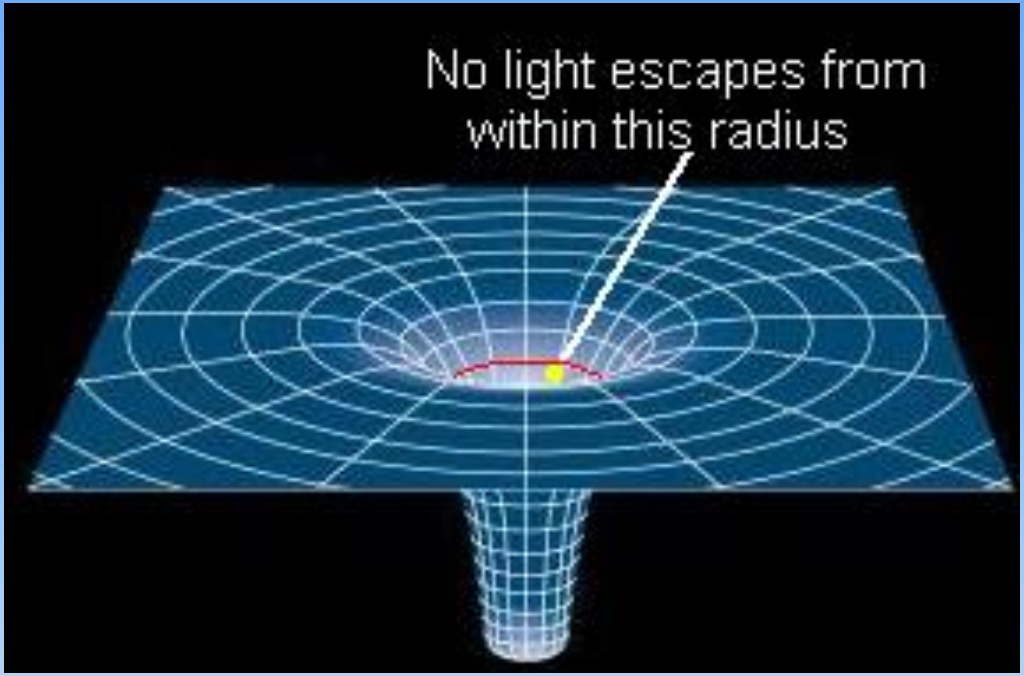
Black Holes Continued . . .



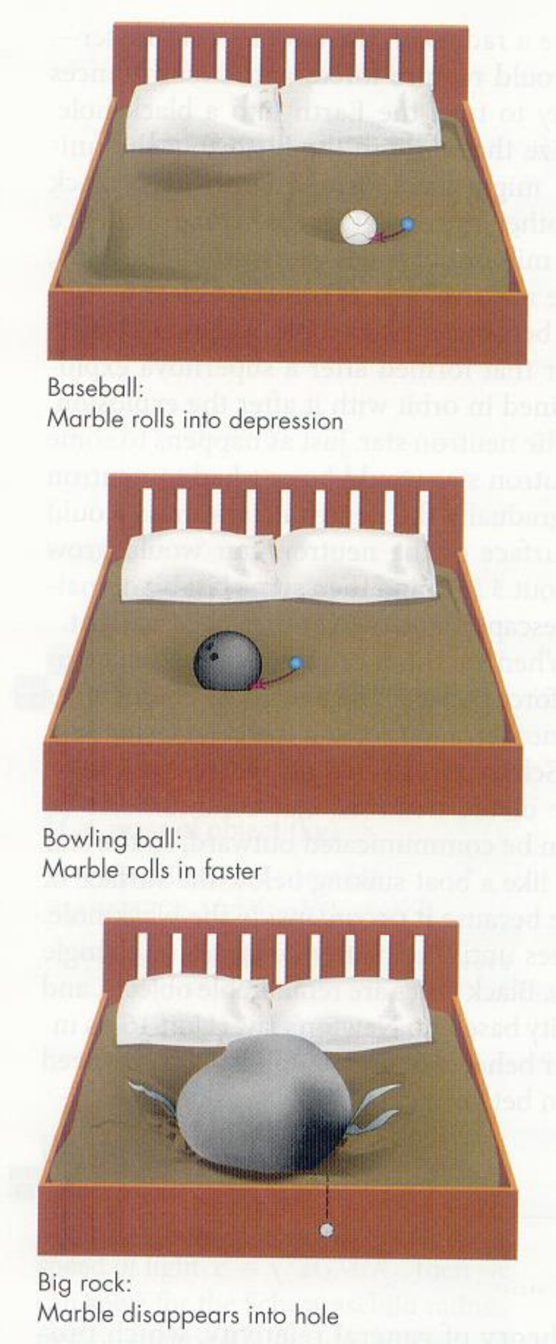


- Gravitational forces are so strong that even light can not escape
- The collapsing object would completely disappear from view.
- It is believed that a black hole will eventually collapse into a single point in space.

Curvature of Space

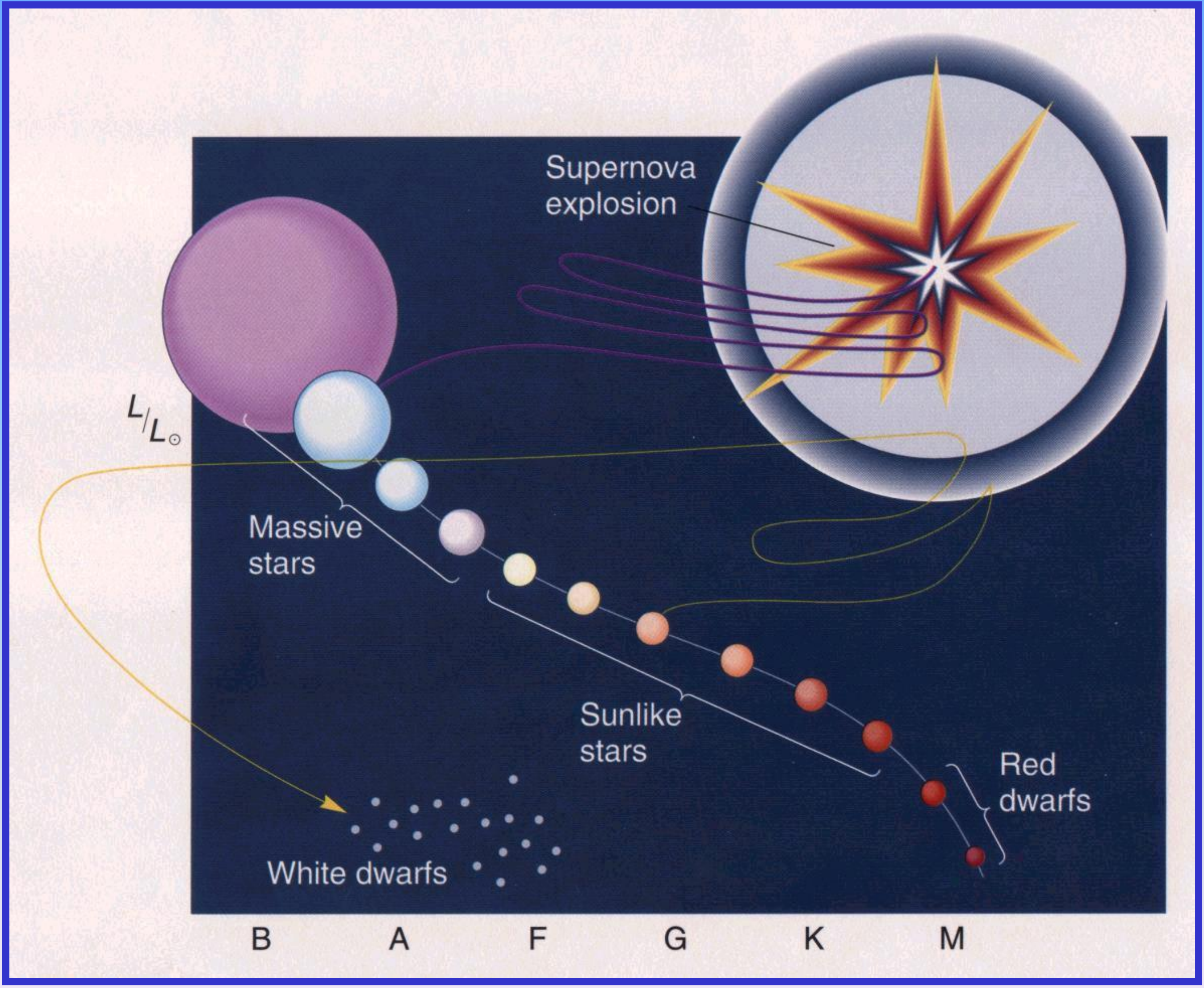


- Astronomers believe that the extreme curvature of space caused by a black hole's huge mass keeps light from escaping.
- Anything that gets closer than a certain distance from the black hole is lost from the universe.

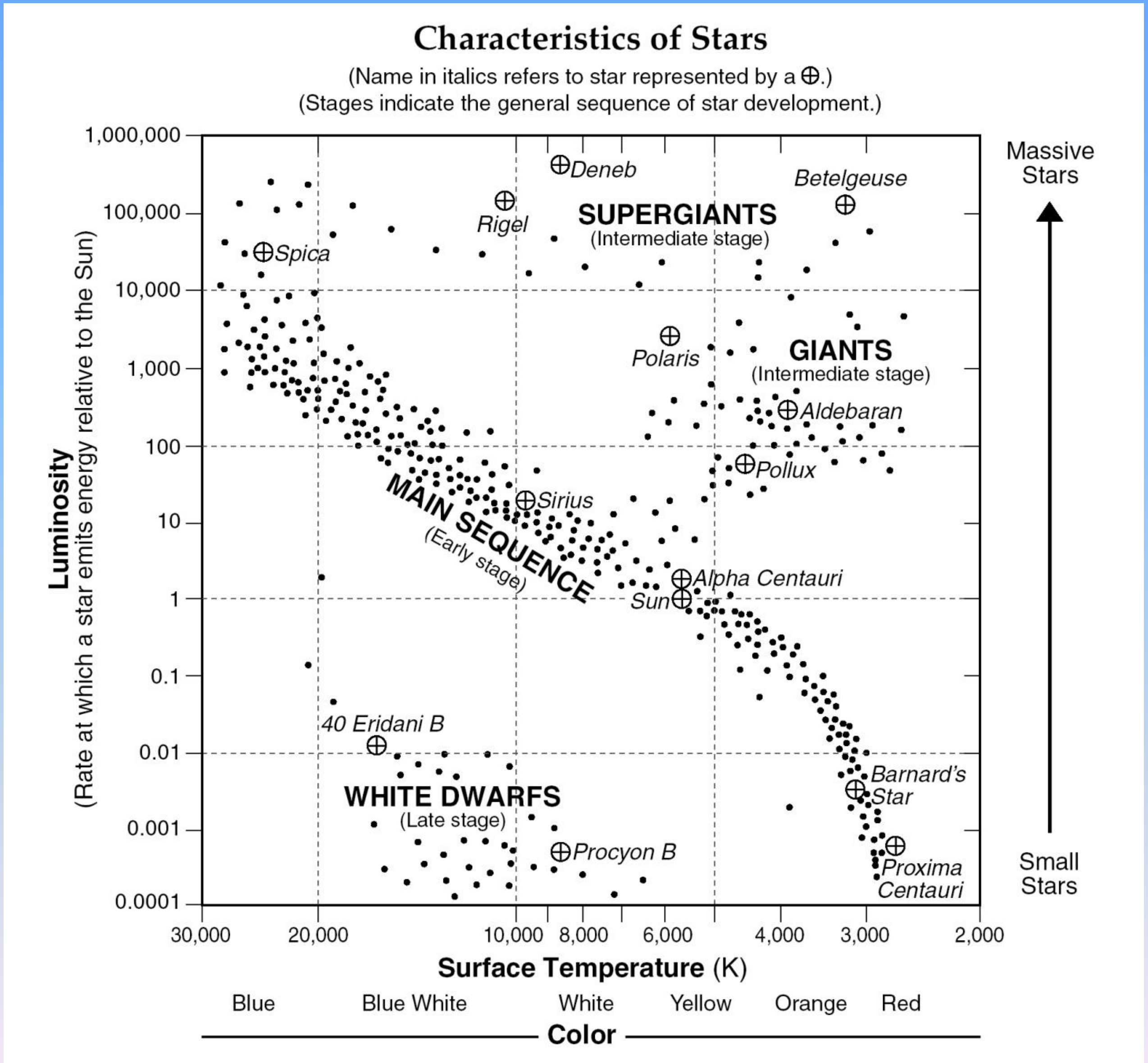


Waterbed Analogy

H-R Diagram: Stellar Demise



The H-R Diagram:



B. Galaxies

Galaxies

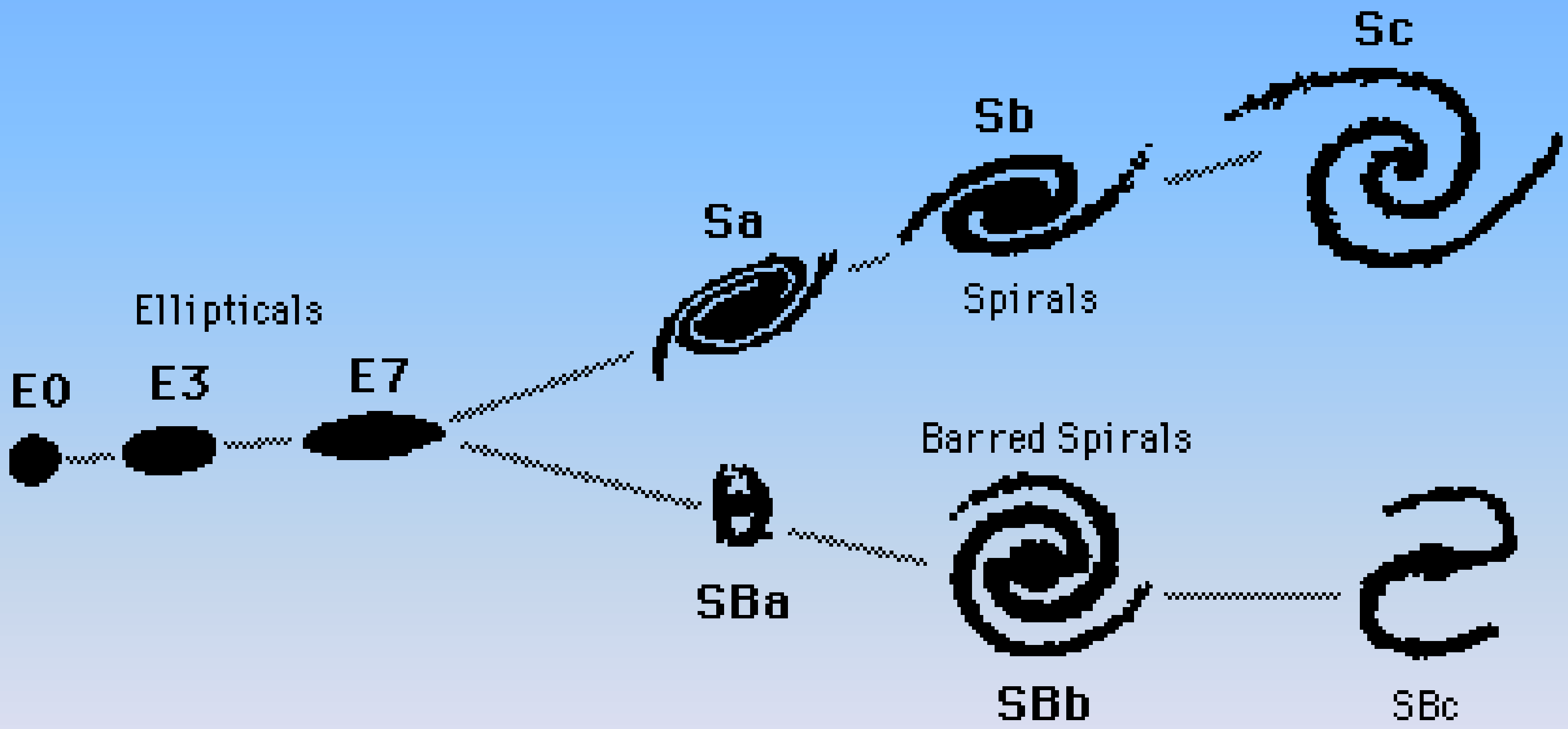
1. A galaxy is a system containing __millions__ or __billions__ of stars.
2. Space contains several __billion__ galaxies.
3. Galaxies glow from the combined light of billions of stars.

4. Classification of Galaxies

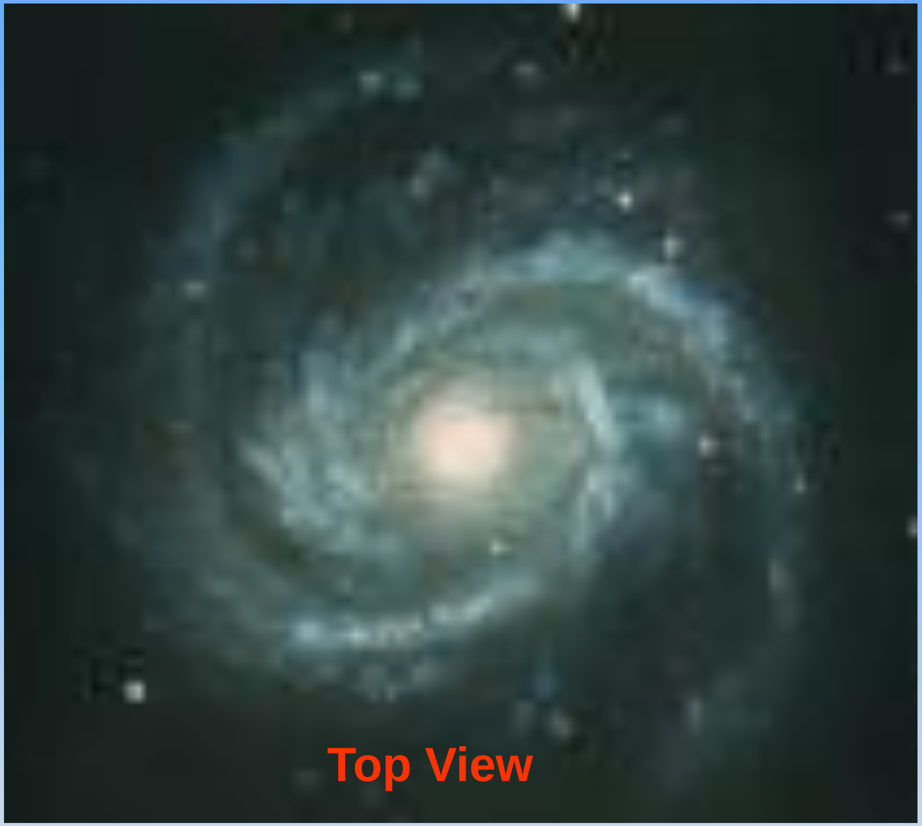
a. Galaxies are classified by__Shape__:

There are three main types:

Hubble Classification



a. Spiral Galaxies

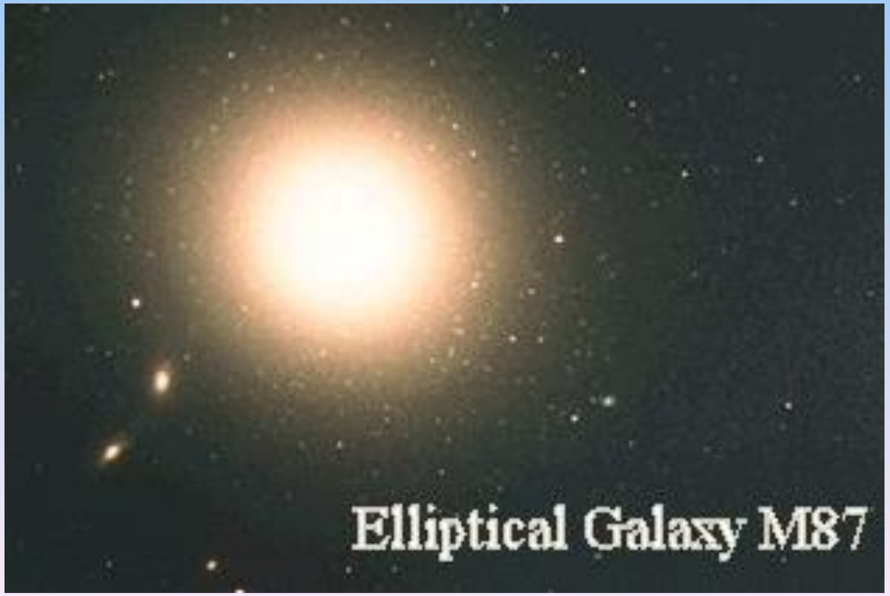


(1) Central lens-shape, bright nucleus surrounded by a flat disk.

(2) Spiral arms (usually two) come out from opposite sides and trail behind as the galaxy rotates.

Barred Spiral Galaxies

b. ___Elliptical Galaxies___



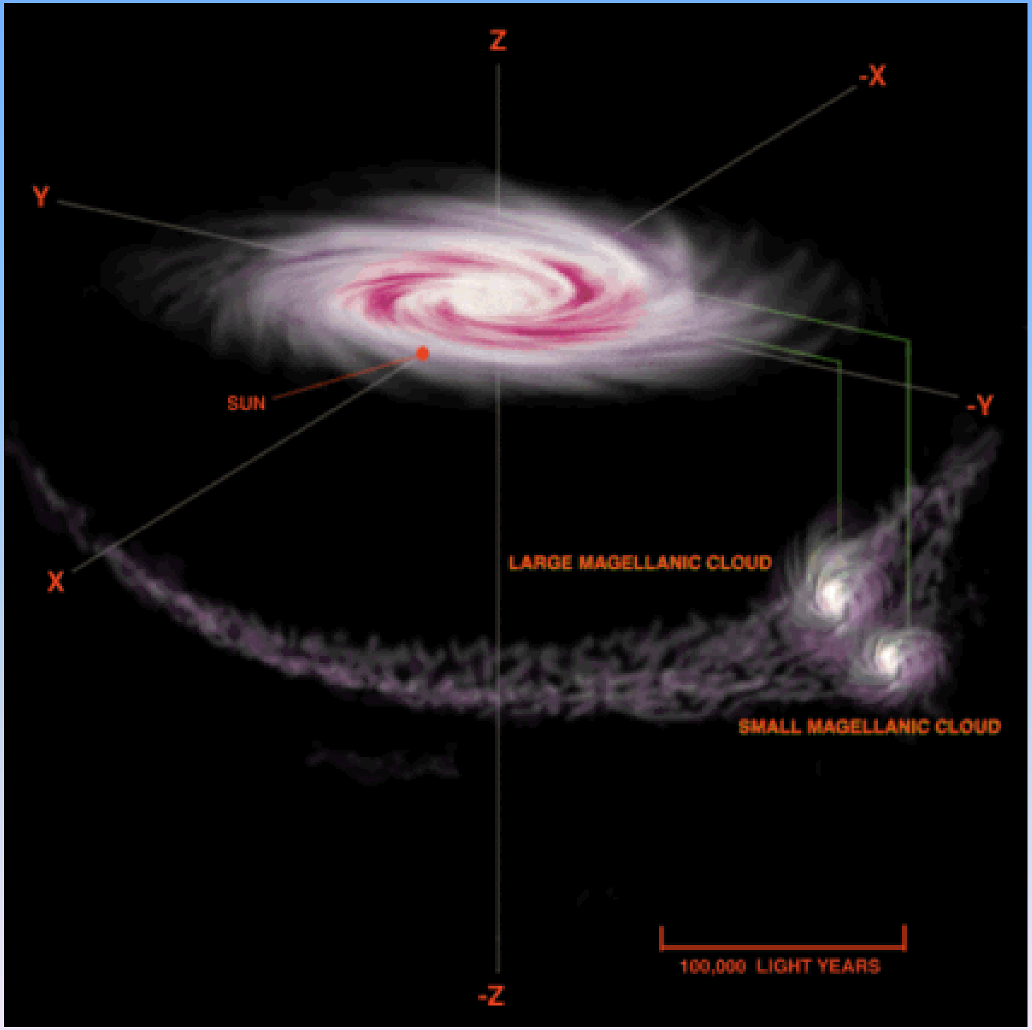
(1) Range from nearly spherical to lens-shaped.
(2) No arms are present.

c. Irregular Galaxies

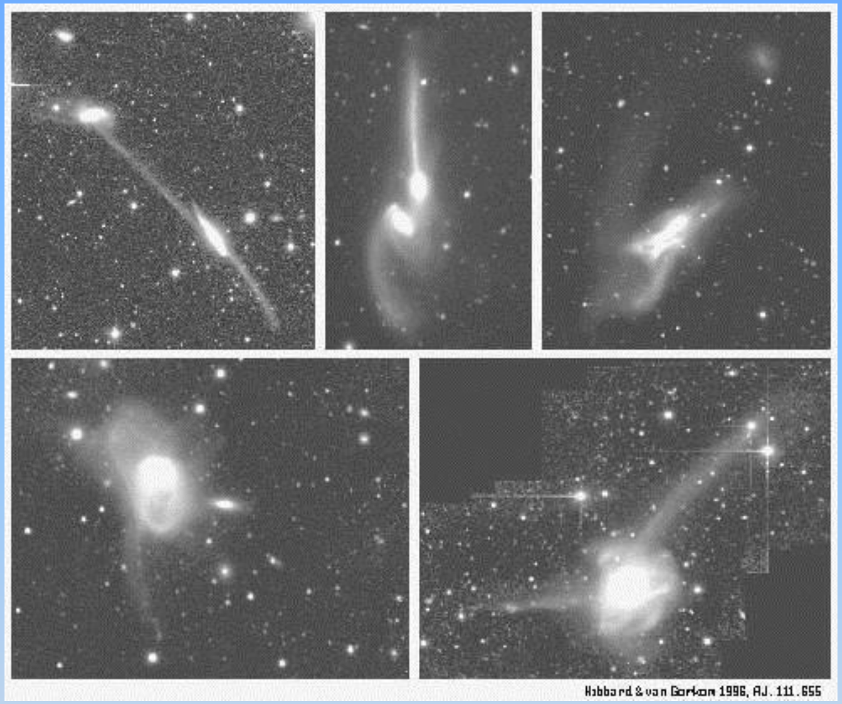
(1) These are smaller, fainter, and less common than other types of galaxies.

(2) Stars are spread unevenly.

Irregular Galaxies – The Magellanic Clouds

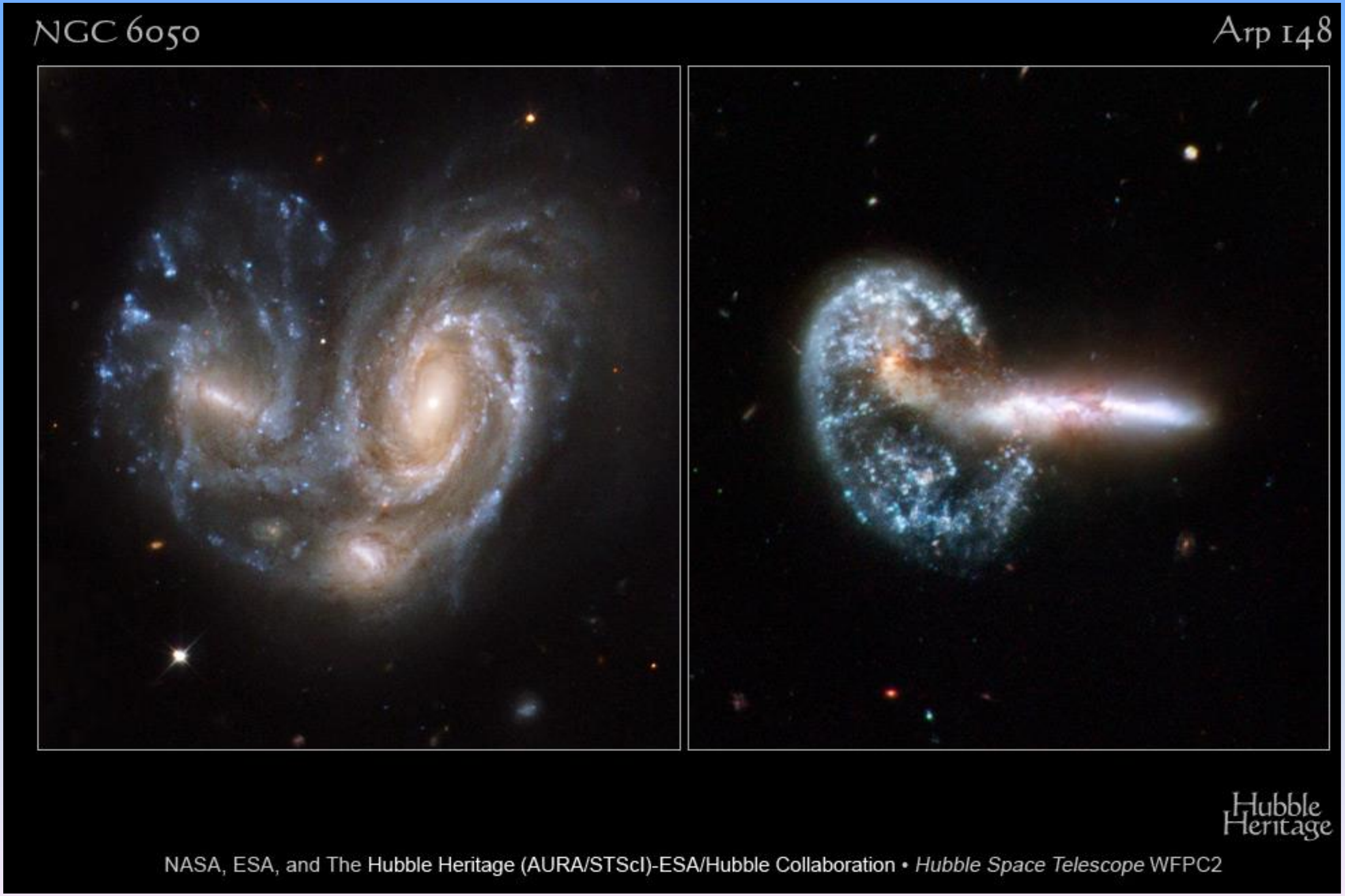


Peculiar Galaxies



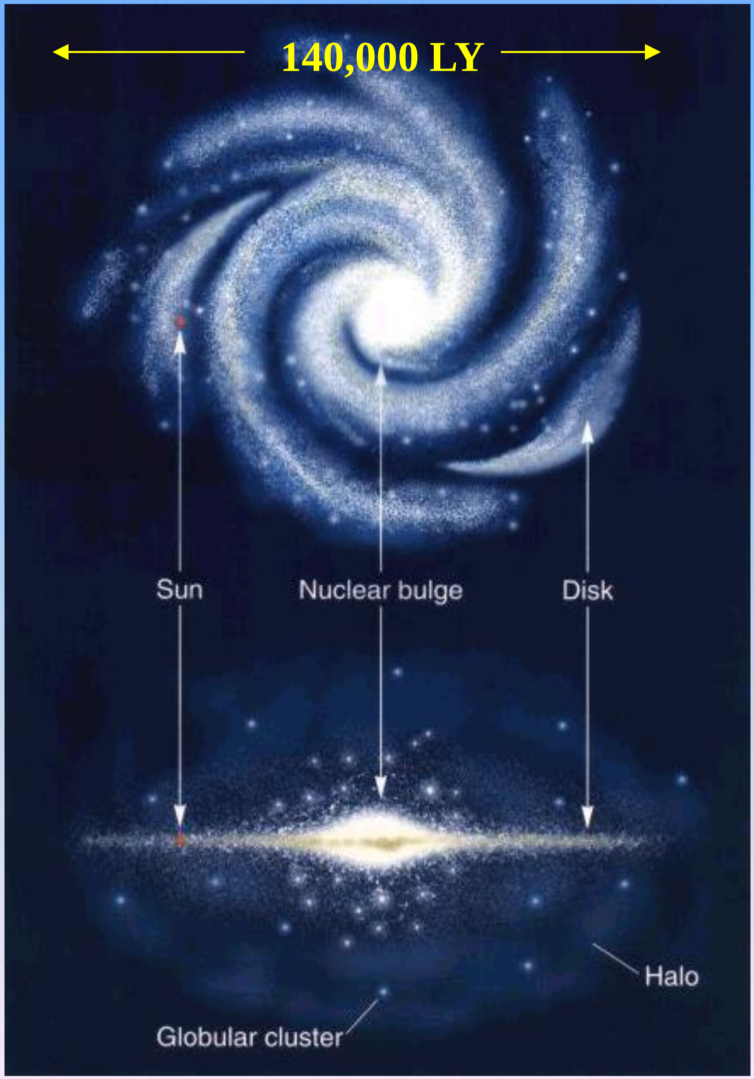
- Galaxies that are abnormal in size, shape, or content.
- May be a result of galactic interactions or merges

Merging Galaxies



5. The Milky Way

a. The Home Galaxy to which the Sun belongs



b. A spiral galaxy
c. Diameter: 140,000 light years
d. Greatest thickness: 20,000 light years.
e. Sun: About 23,000 light years from the galaxy's center. (See Rev. Book *Figure 9-1*, p. 425)
f. Approximately 100 billion stars.
g. Belongs to a small cluster of 40 galaxies know as the Local Group

Why is our home galaxy called the Milky Way?

It’s because when viewed from Earth the collective light from all the stars has an appearance like . . .

The Milky Way

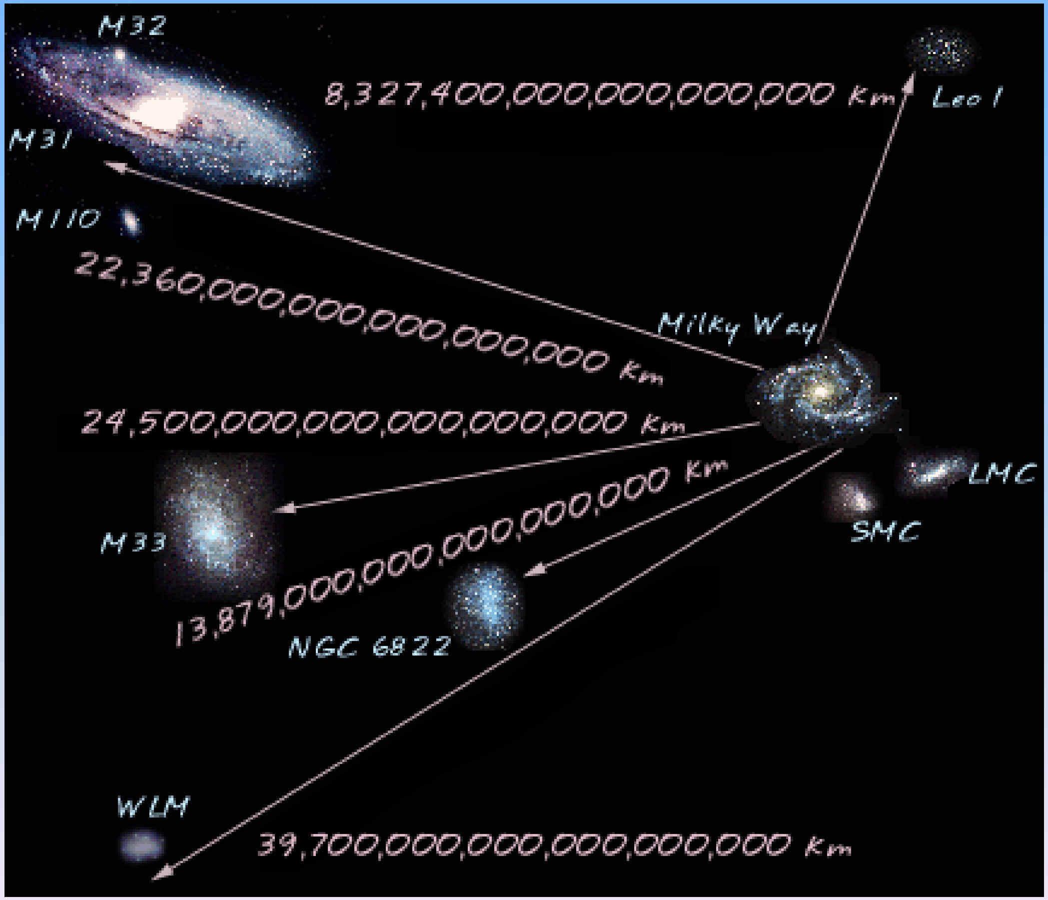
No, it's not because it looks like the candy bar.

The Milky Way

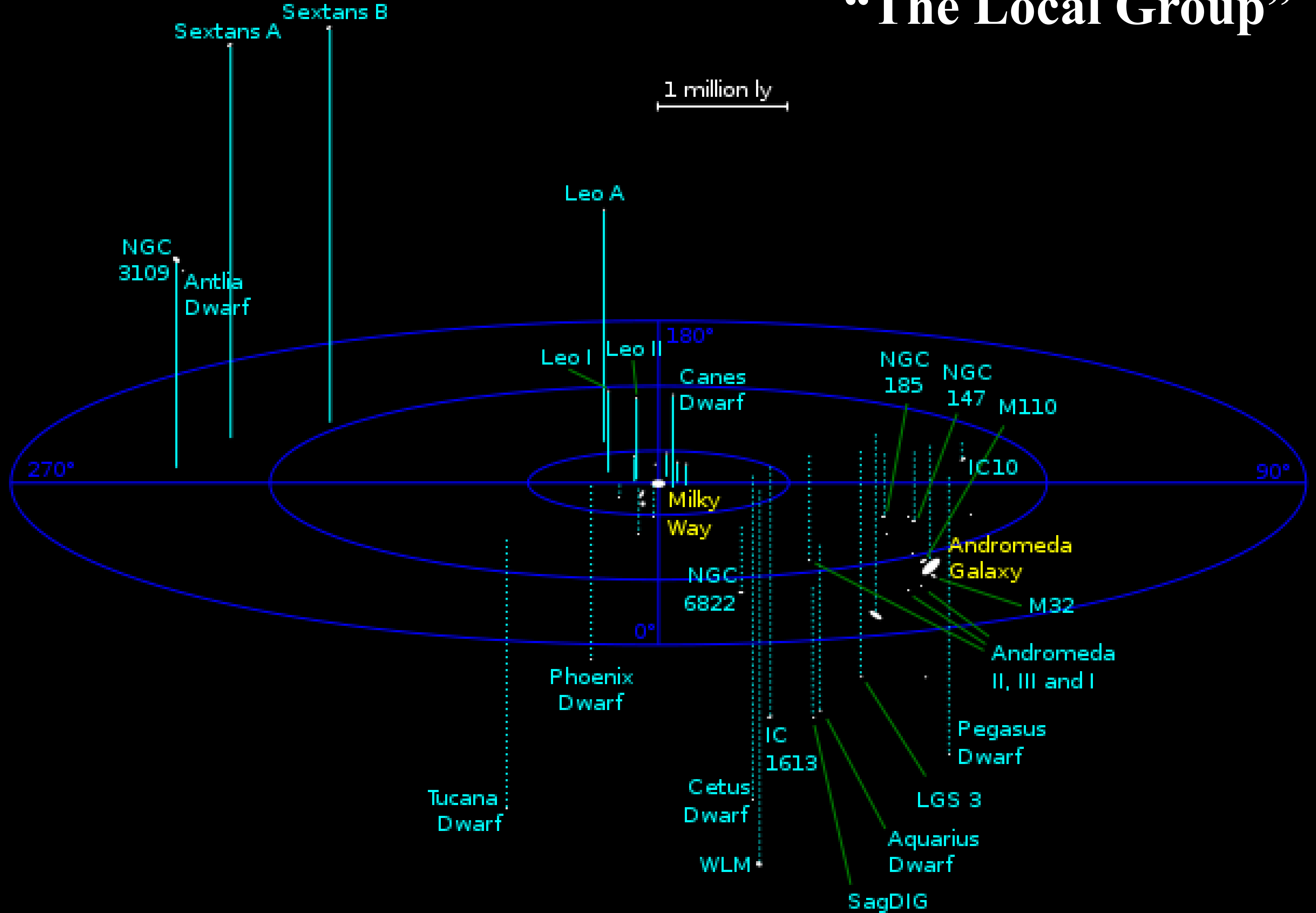
The sky has a milky white appearance.

Local Group of Galaxies

- Small cluster of 40 galaxies
- Milky Way is in the local group



“The Local Group”



C. Finding Distances in the Universe

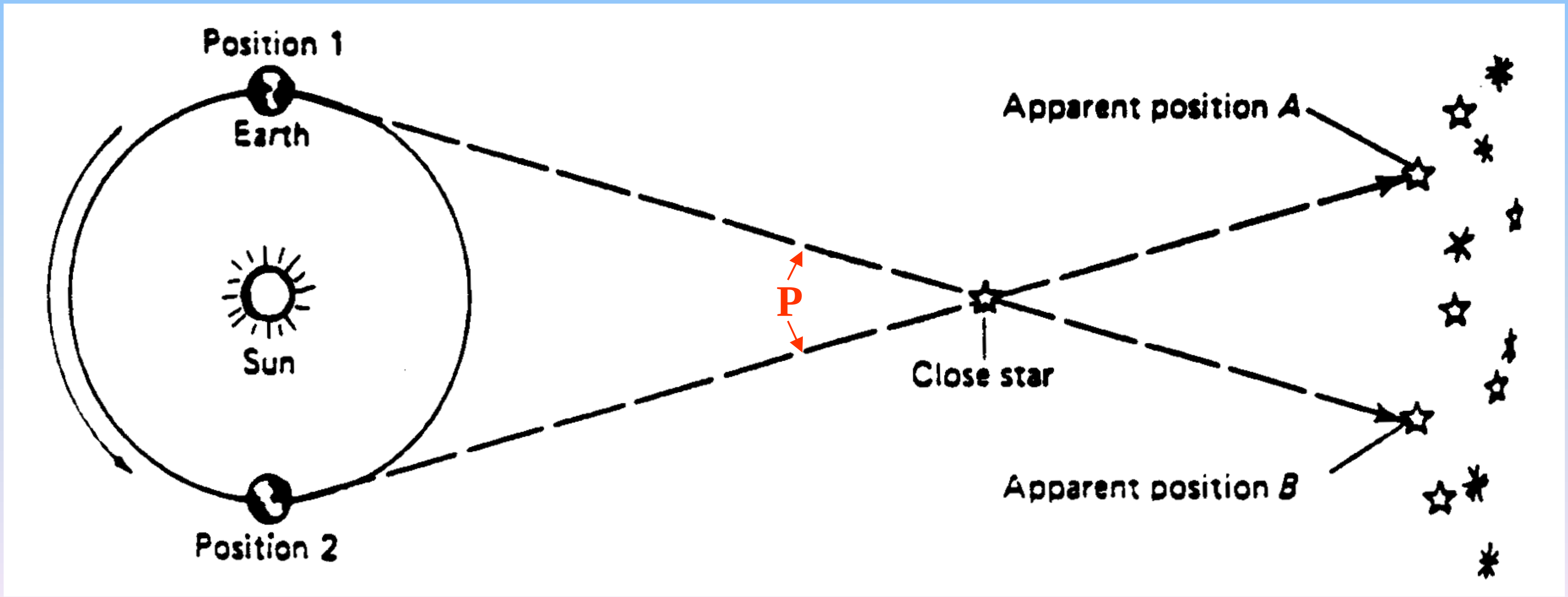
1. *Spectroscopic Distance*
   - Compares apparent magnitude to magnitude
   a. Knowing the spectral class allows its **absolute** magnitude to be determined
   b. Difference between *apparent* magnitude and *absolute* magnitude is a result of the distance of the star from Earth.
   c. Distance is mathematically determined.

2. Stellar Parallax

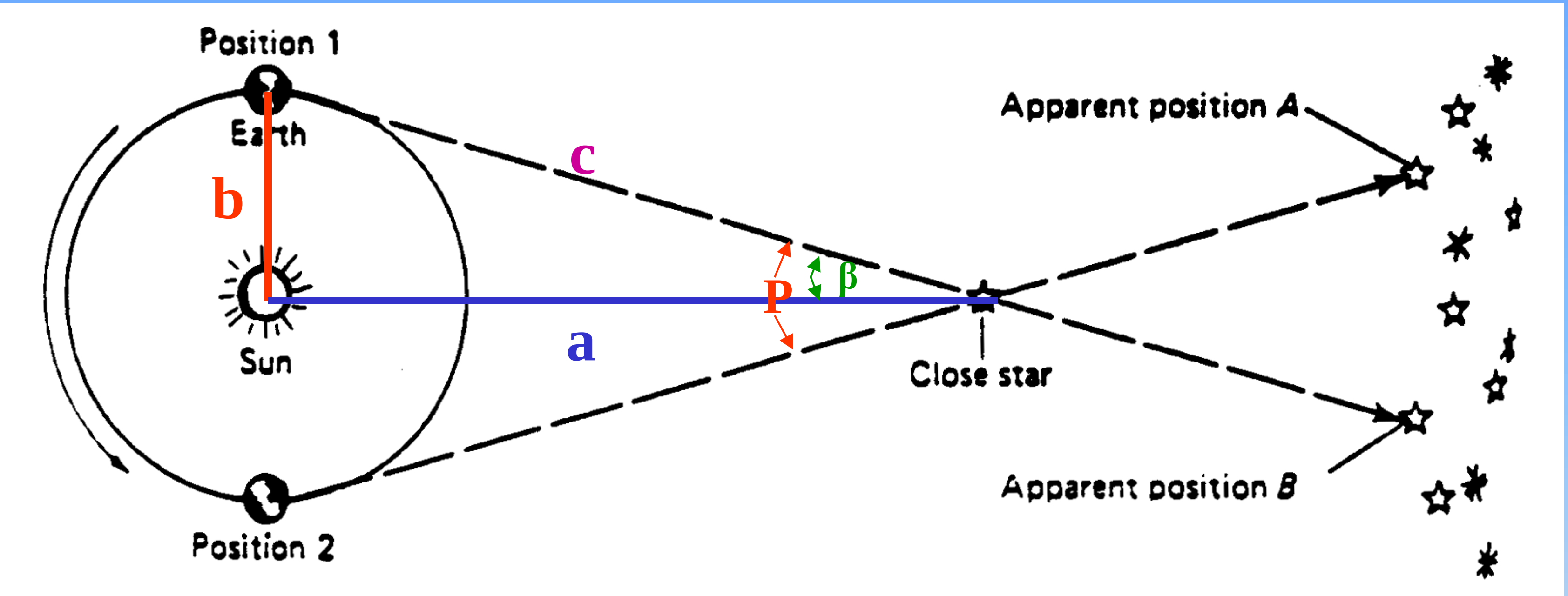
a. Because Earth revolves around the Sun in its orbit, a star that is relatively nearby appears to change position against the background (faraway) stars.

b. The angular separation at two dates (6 months apart) can be measured. This is angle "p" in the diagram shown below.

c. Using the known distance from Earth to the Sun, the distance to the nearby star can be determined geometrically using a right triangle.



Calculating Distance Using Stellar Parallax



b = 1 A.U.

$\angle \beta = \frac{1}{2} \angle P$

a = distance to star

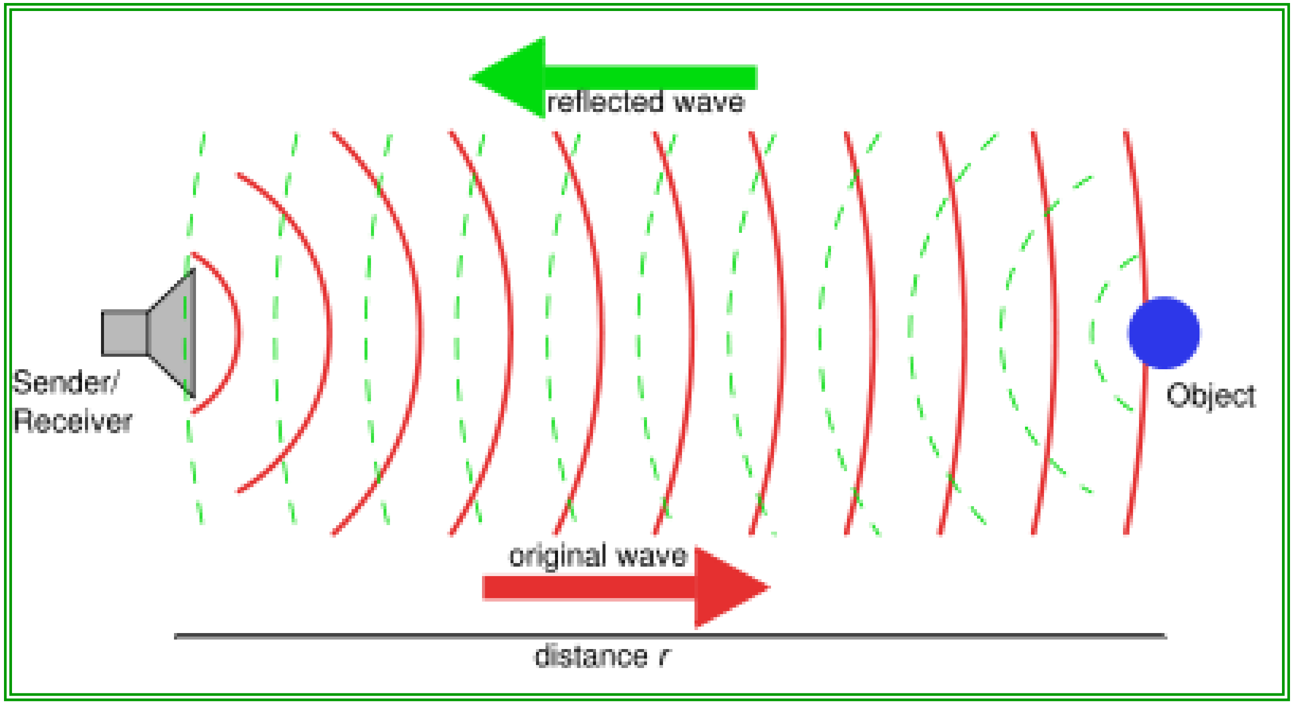
c = hypothenuse

$$\tan \beta = \frac{b}{a}$$

$$a = \frac{b}{\tan \beta}$$

3. Radar

Radio Detection and Ranging



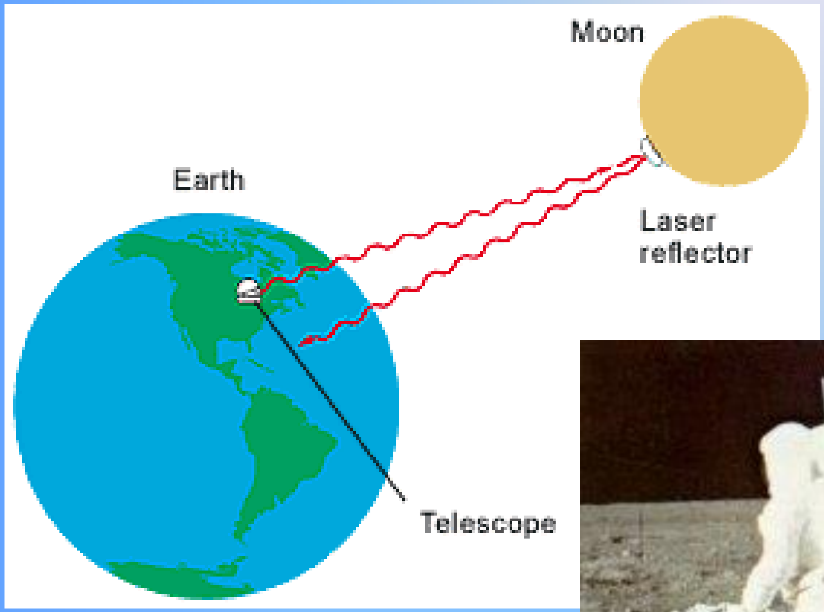
a. A radar pulse is reflected off a solid object such as the moon.

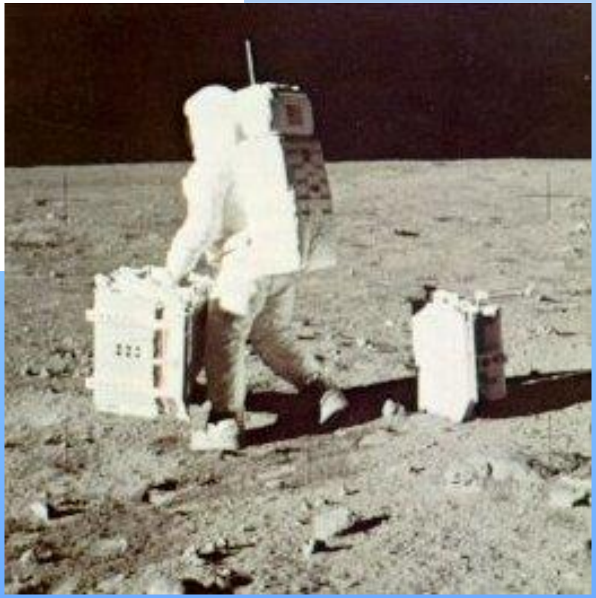
b. The time of the round-trip is measured with high accuracy.

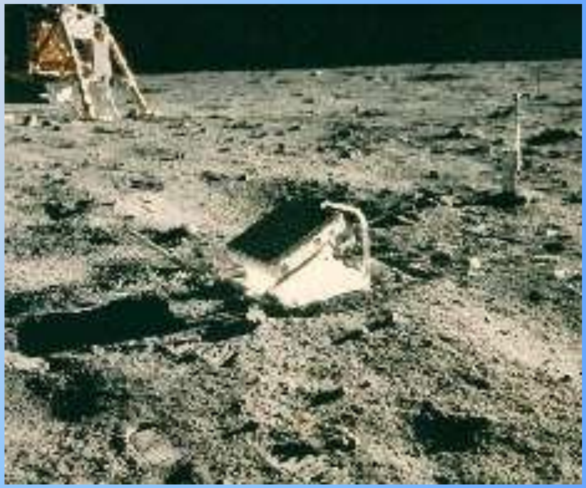
c. Using rate (speed of light) and time the distance can be mathematically determined

4. LASER

Light Amplification by Stimulated Emission of Radiation







Laser reflectors on the Moon

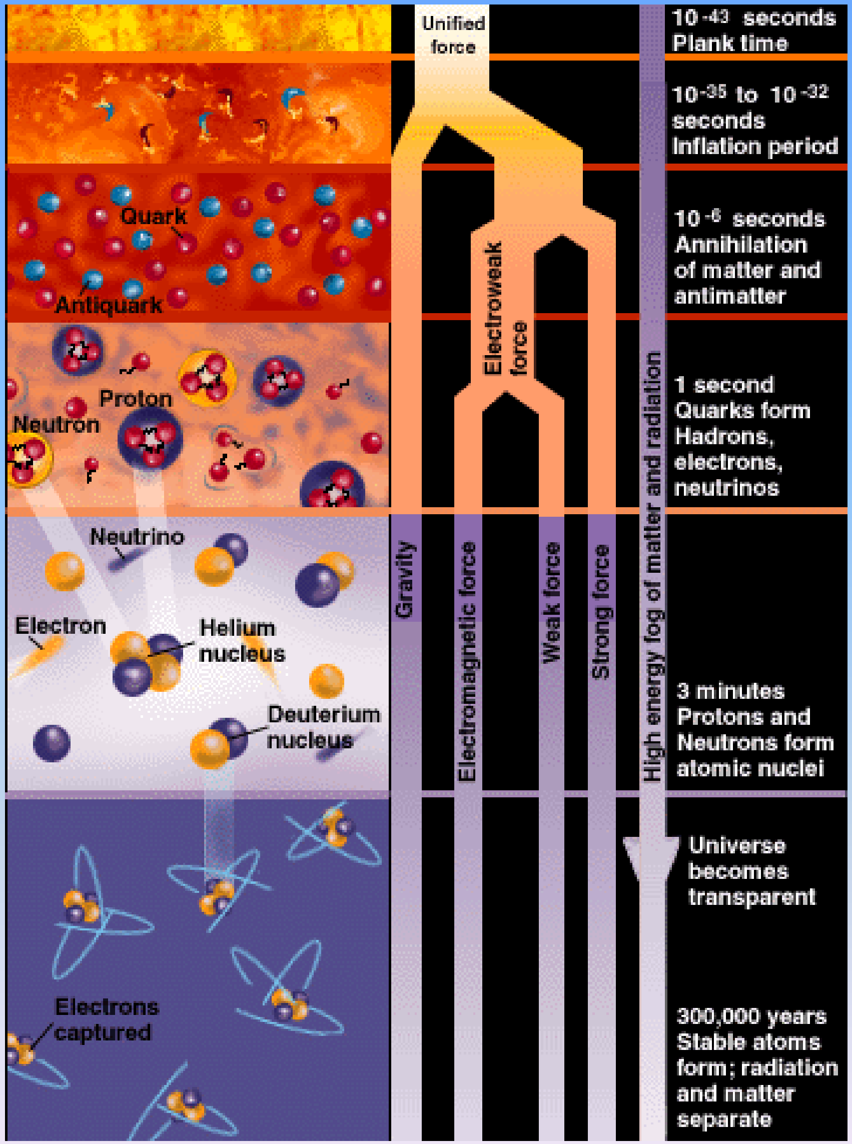
II. Theories on the Origin of the Universe and the Solar System

A. The Big Bang

The Big Bang

1. The entire universe was a very hot dot, smaller than the diameter of an atom.
2. 15 billion years ago (More recent research indicates that the universe is **13.7 billion** years old with only a 1% margin error.)
   a. Expanded faster than the speed of light
   b. Mechanism that initiated the event is still being researched.

The Big Bang



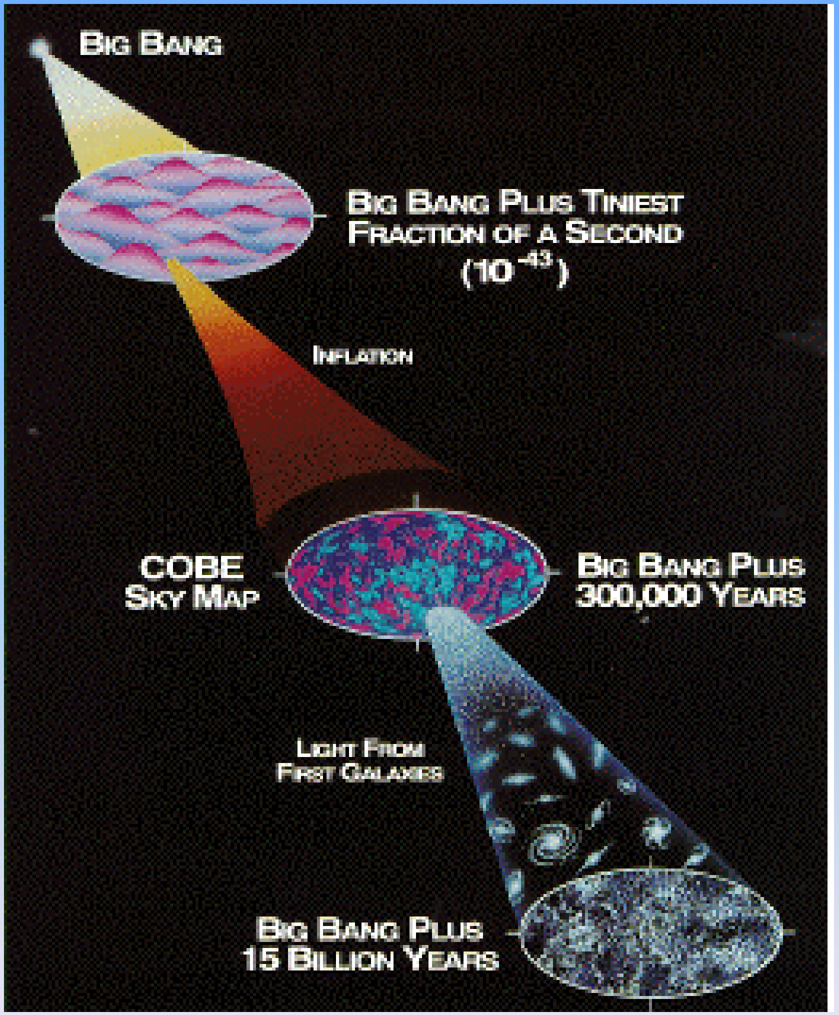
Current theories of gravity can't describe space and time.

Rapid expansion by a factor of 10^{30}

Origin of helium

The Big Bang

- Cooling eventually resulted in the formation of hydrogen, helium, deuterium and lithium atoms
- Stars were born at +200 million years
- Peak of galaxy formation at + 3 billion years



Simplified Timeline of Events after the Big Bang

Time After the Big Bang	Events
The first 1.0×10^{-43} second	Huge random changes in energy occurred everywhere in space. These were so huge that current theories on gravity can't describe space and time. The temperature was an incredible 1.0×10^{32} Kelvin.
By 1.0×10^{-33} second	Everything now seen in the universe was in a volume less than one meter across. It was expanding at enormous speeds
Between 1.0×10^{-33} and 1.0×10^{-35} second	The early universe rapidly expanded. This could have been by a factor of 1.0×10^{30} of its previous size. (This is bigger by a factor of a thousand x a billion x a billion x a billion!)
By 1.0×10^{-6} second (one millionth of a second)	Protons and neutrons began to form.
At one second	The temperature of the universe had cooled to 10 billion Kelvin. It was still very dense. With further expansion the universe steadily cooled. Protons were able to combine and form deuterium. This is an isotope of hydrogen that is needed for the first step of star formation.
Ten seconds	Deuterium was combining to form helium.
Up to 50,000 years	Radiation instead of matter made up most of the universe.
400,000 years	Stable atoms began to form
100 million years	The first stars and galaxies formed 100 million years after the Big Bang. The temperature was 100 Kelvin.
4.6 billion years	The Solar System formed in a universe that had cooled to 3 Kelvin.

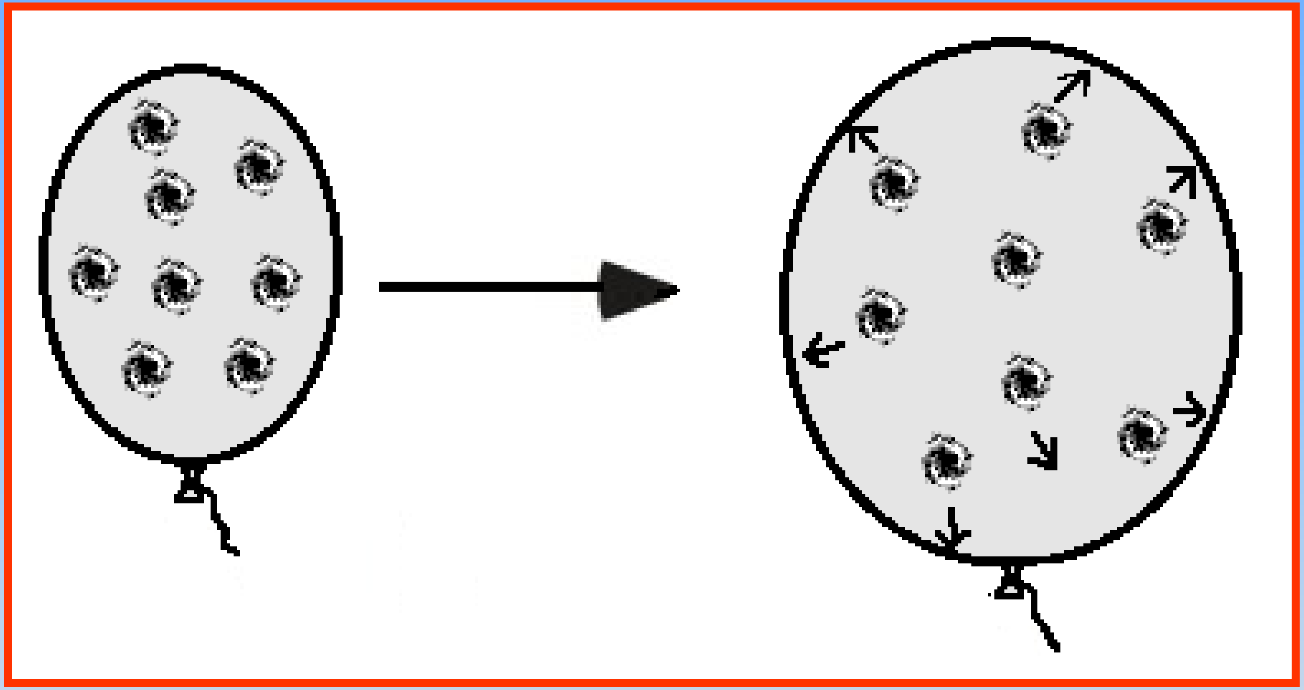
This is 4.6 billion years ago which is 9.1 billion years after the Big Bang

B. Evidence for the Expanding Universe

What is meant by an expanding universe?

- According to the Big Bang model, the point of energy exploded in an incredibly giant and violent event.
- It wasn't like a bomb exploding.
  - When a bomb explodes fragments are sent outward in all directions.
- The Big Bang caused space itself to expand.
  - As space expanded, particles formed and were carried away from each other.

Model of an Expanding Universe

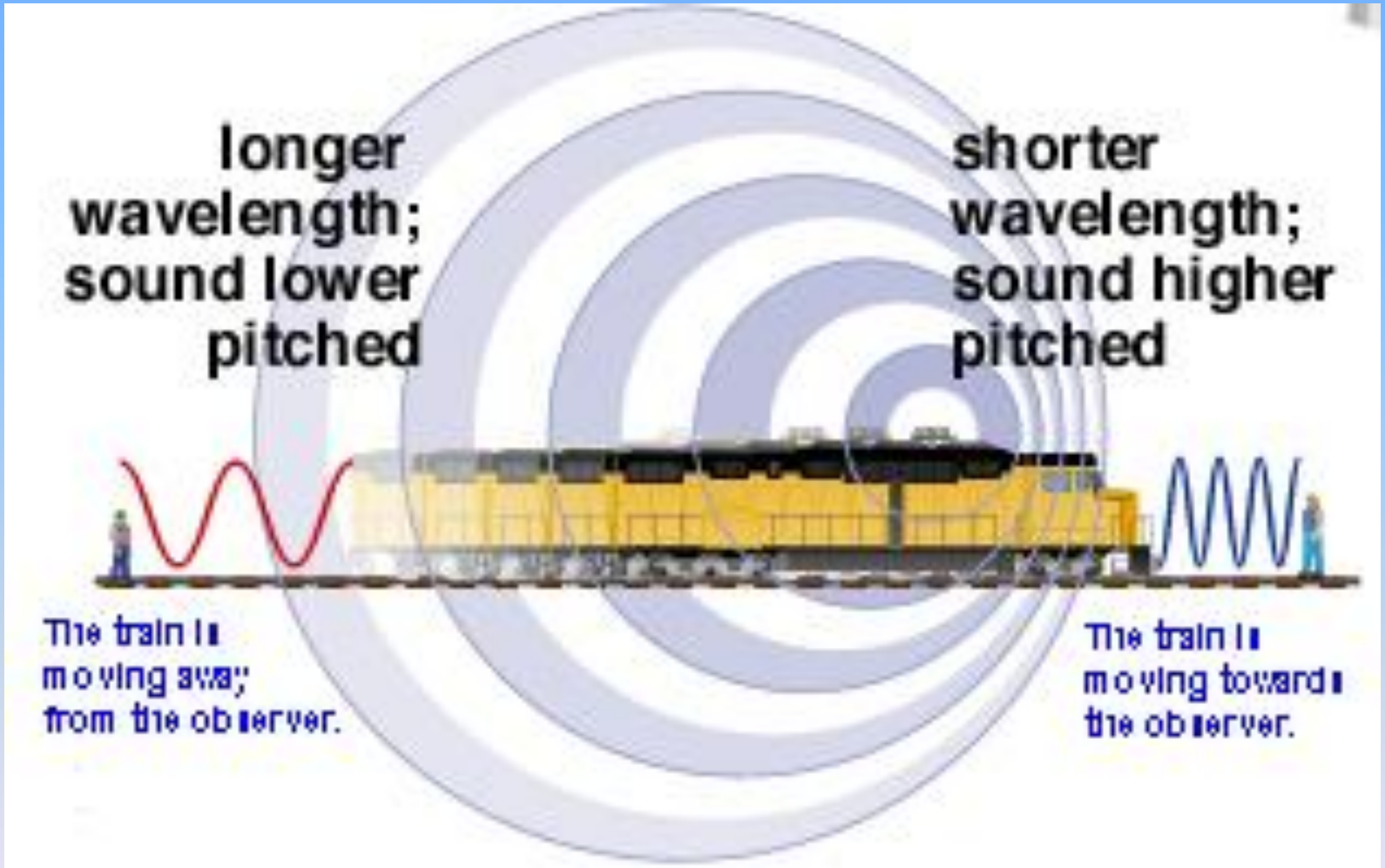


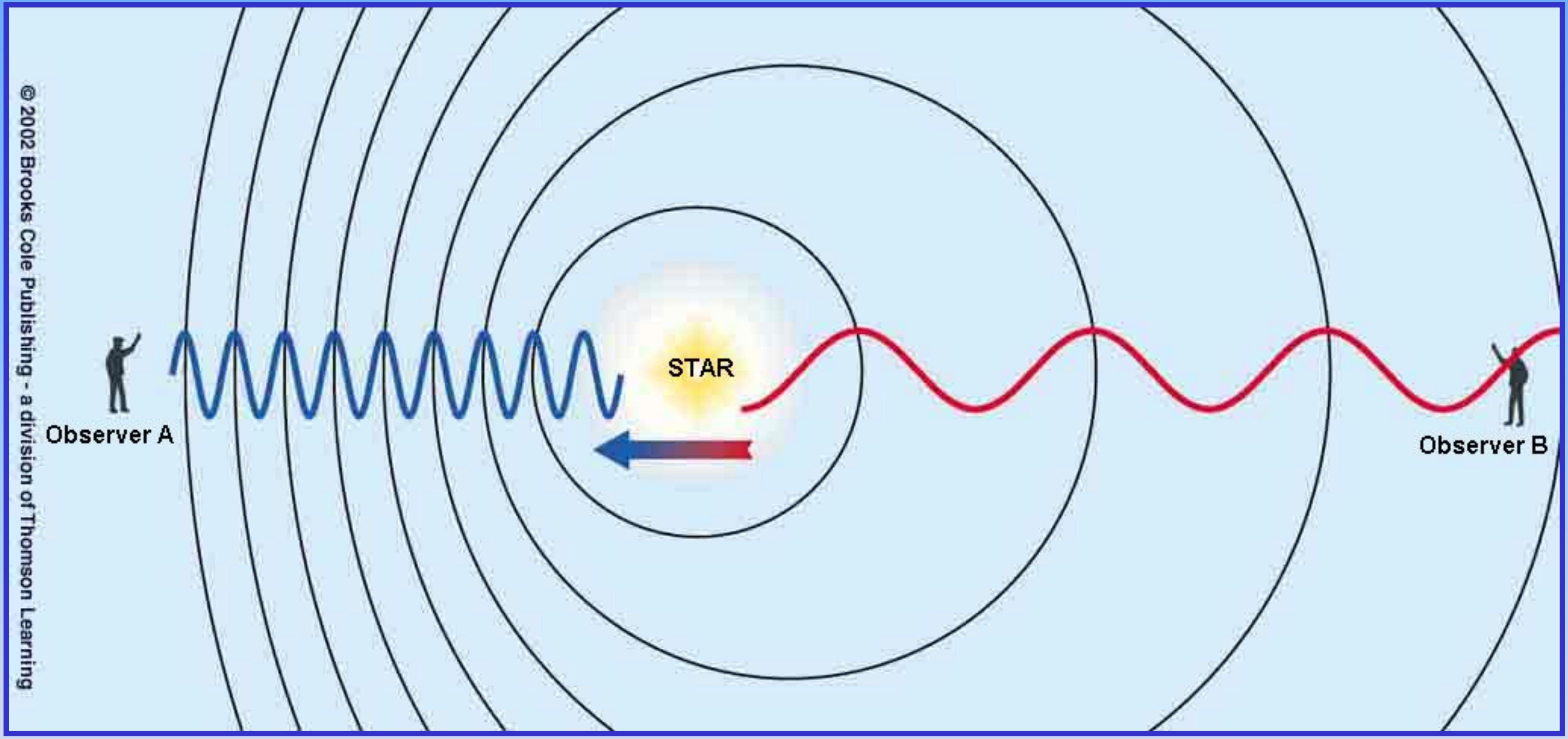
- Imagine the universe as being curved like a balloon.
  - Galaxies are drawn on the balloon. These represent galaxies.
- As the balloon is inflated space between the dots increases.
- When seen from any galaxy, the other galaxies are moving away

1. The __Doppler__ Effect

a. There is a __change__ in __wavelength__ of light or sound as a source moves towards or away from the observer

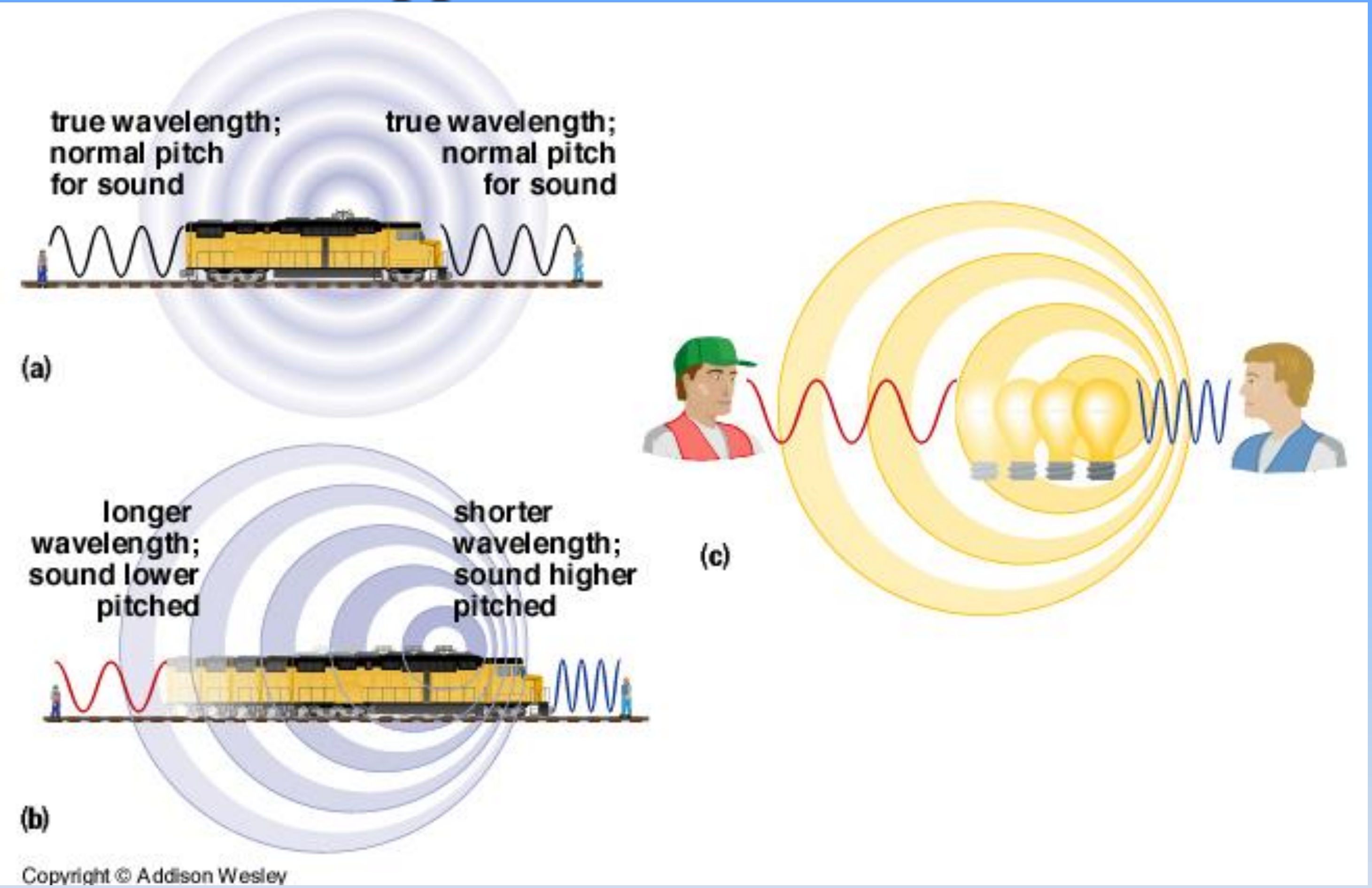
The Doppler Effect for Sound





The Doppler Effect for Light

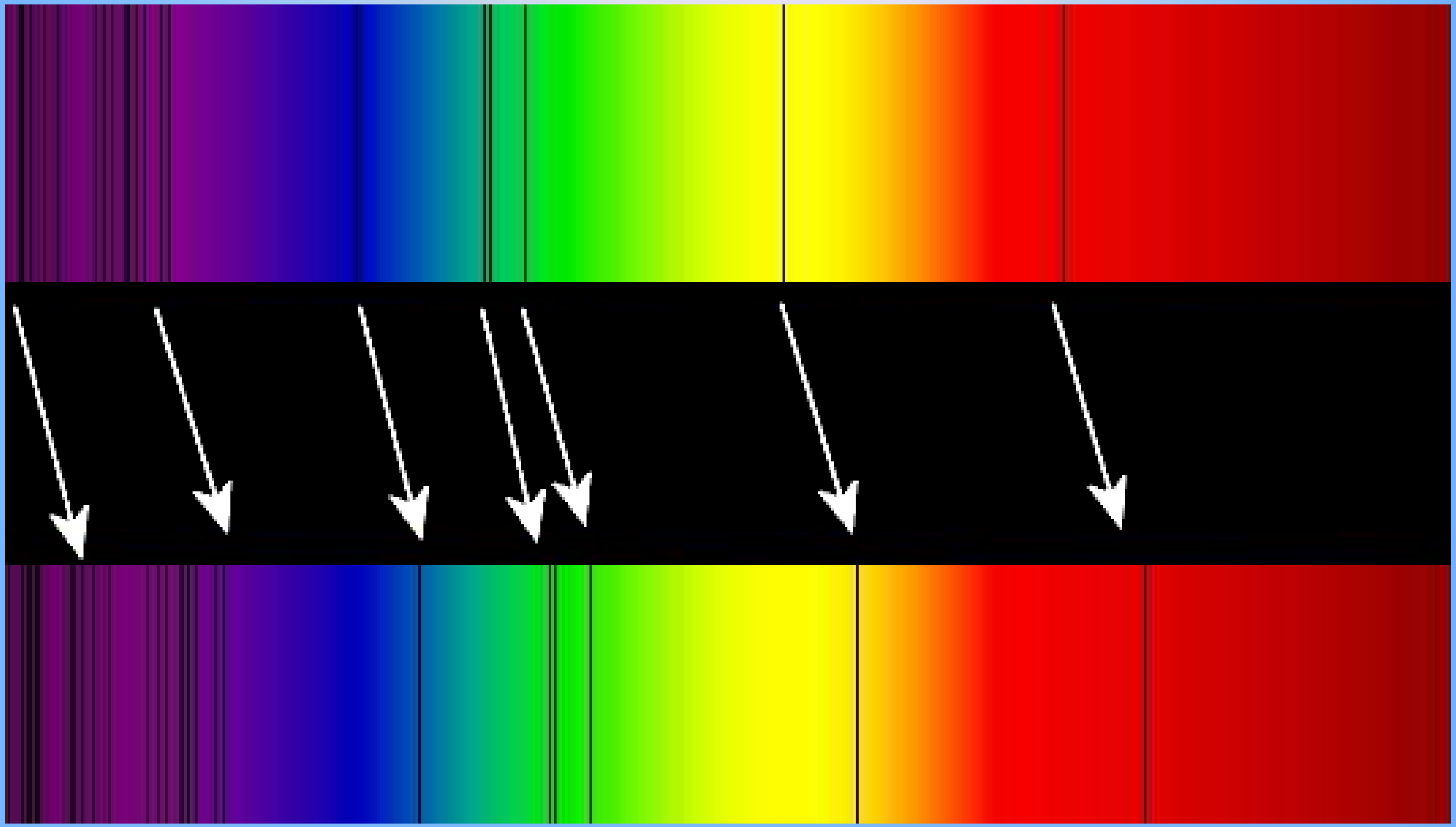
The Doppler Effect Continued . . .



(1) **Approaching**: Frequency increases __**and wavelength decreases**__

(2) **Receding**: Frequency decreases __**and wavelength increases**__

b. The Red Shift of Stellar Light



(1) Black lines are shifted to the **red end** of the spectrum

(2) Indicates that distance between the star and Earth is **increasing**.

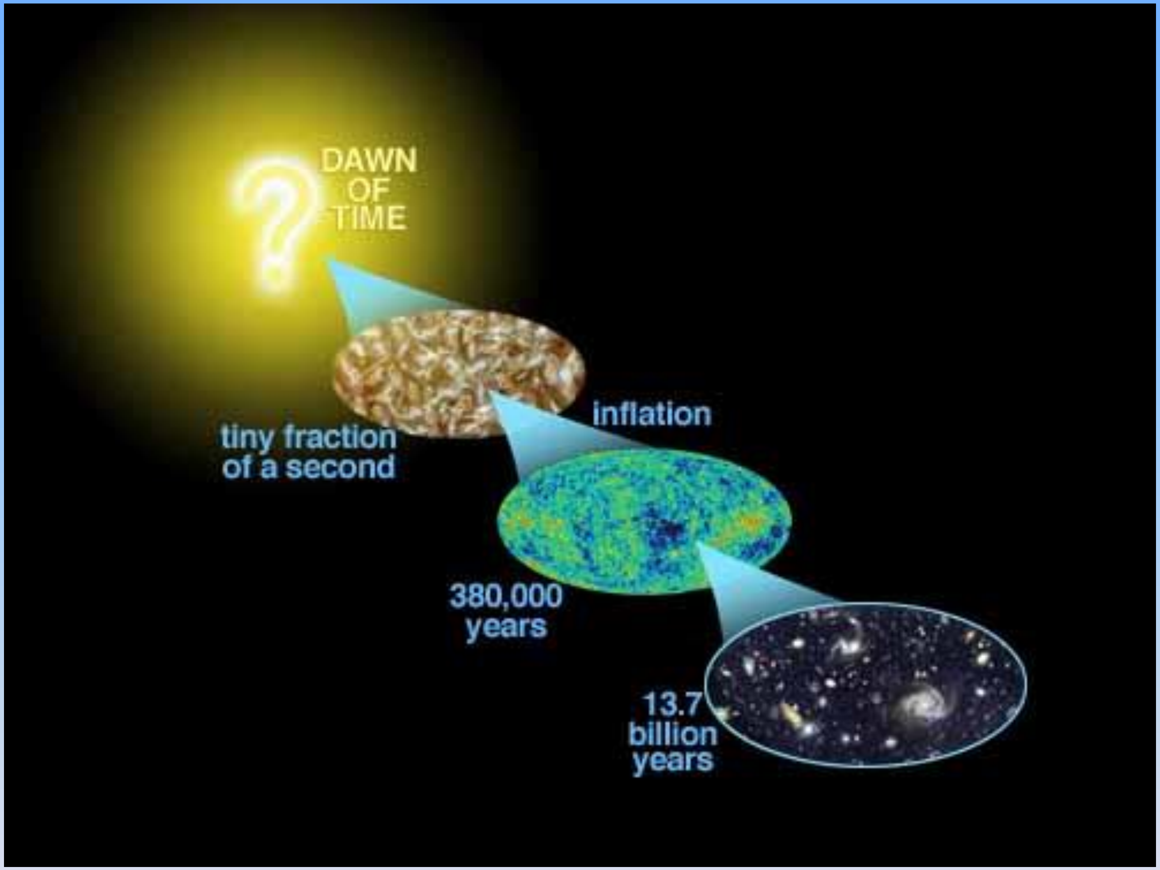
(3) The greater the shift, the greater the velocity of the source.

Summary of Red Shift Evidence

- The spectral lines from almost all galaxies show a **redshift**.
- Edwin Hubble observed that the most distant galaxies had the greatest redshift.
  - Recall that the greater the redshift the faster the light source is moving.
  - Hubble concluded that distant galaxies are moving faster than nearby galaxies.
  - In honor of Hubble, the relationship between distance and speeds of galaxies is called **Hubble's law**.
- The observation that galaxies are moving away from each other supports the concept of an expanding universe caused by the Big Bang.

2. Cosmic Background Radiation

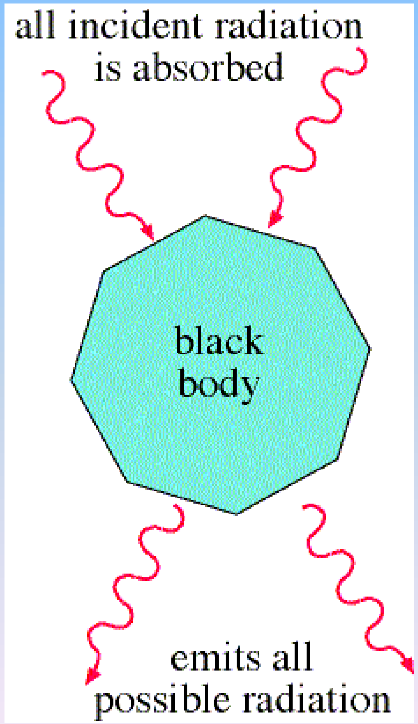
(The "Afterglow" of the Big Bang)

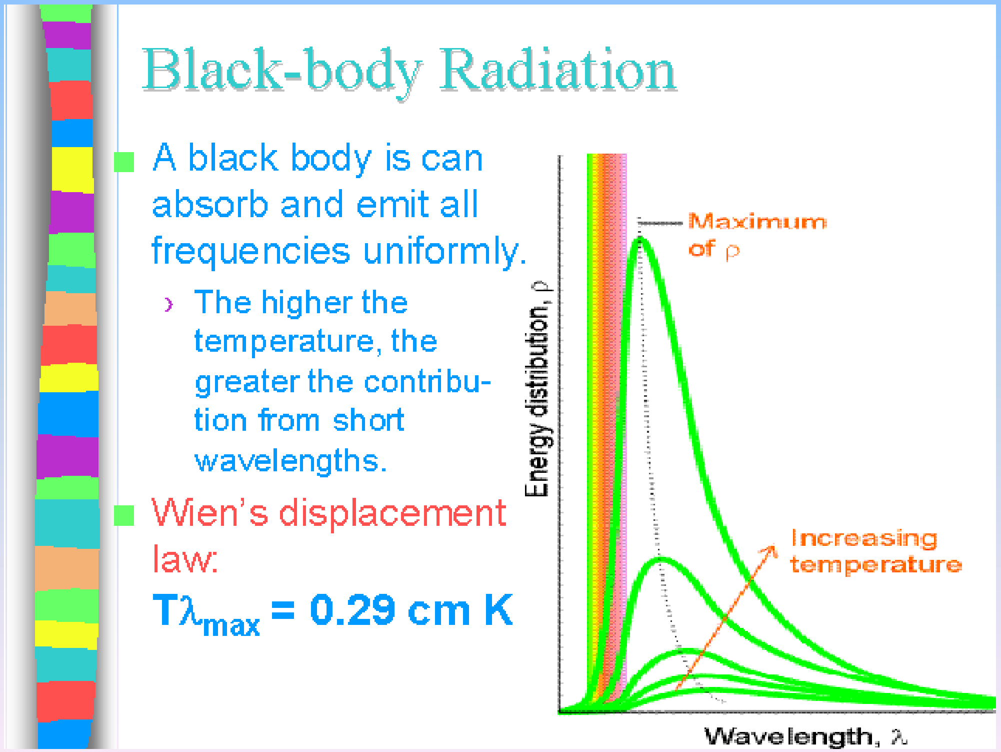


a. Energy output from expansion as a result of the Big Bang should appear cooled and should exhibit itself as background radiation equivalent to a cold blackbody

What is a Blackbody

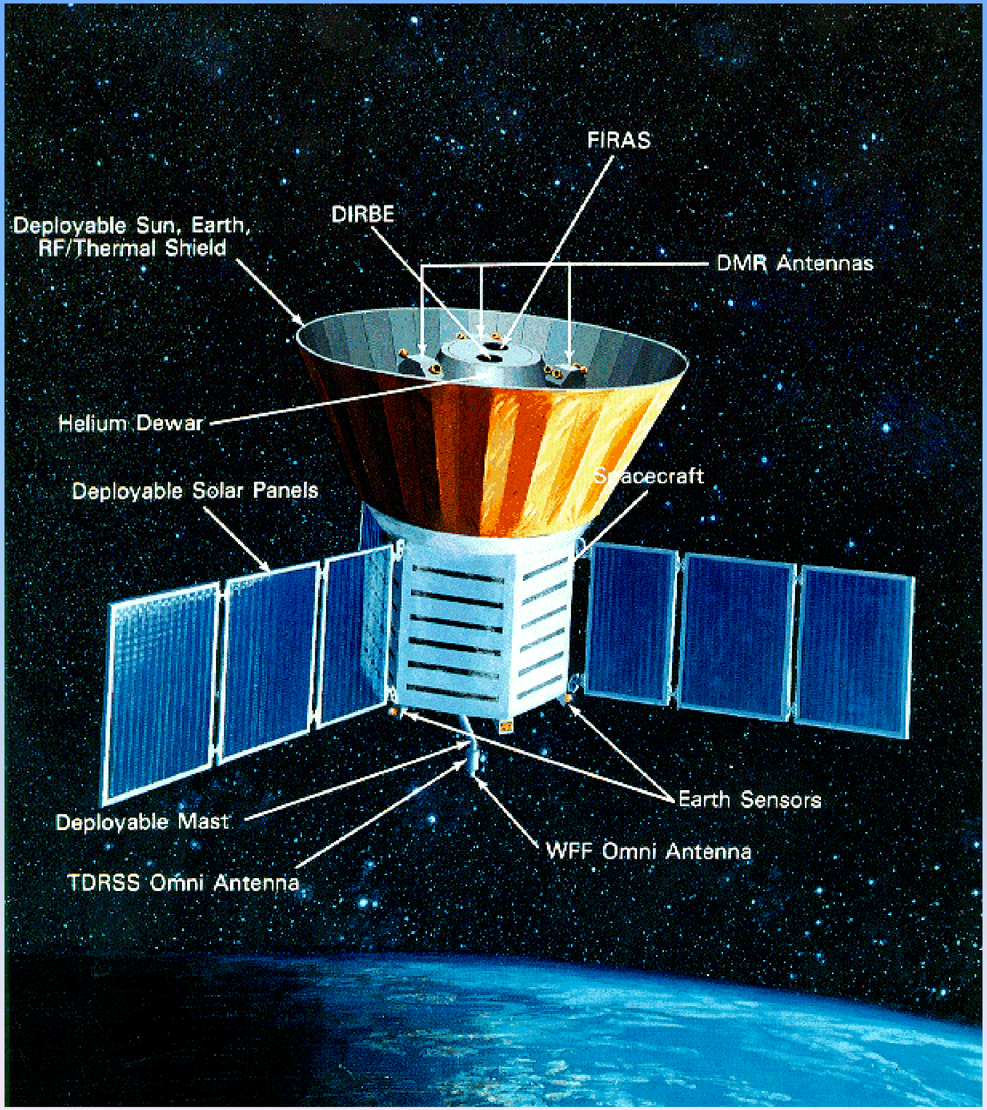
- An object which absorbs equally all the radiation which strikes it.
- Theoretically, a perfect blackbody should emit radiation with an intensity which depends only on the blackbody's temperature, in a very specific fashion:



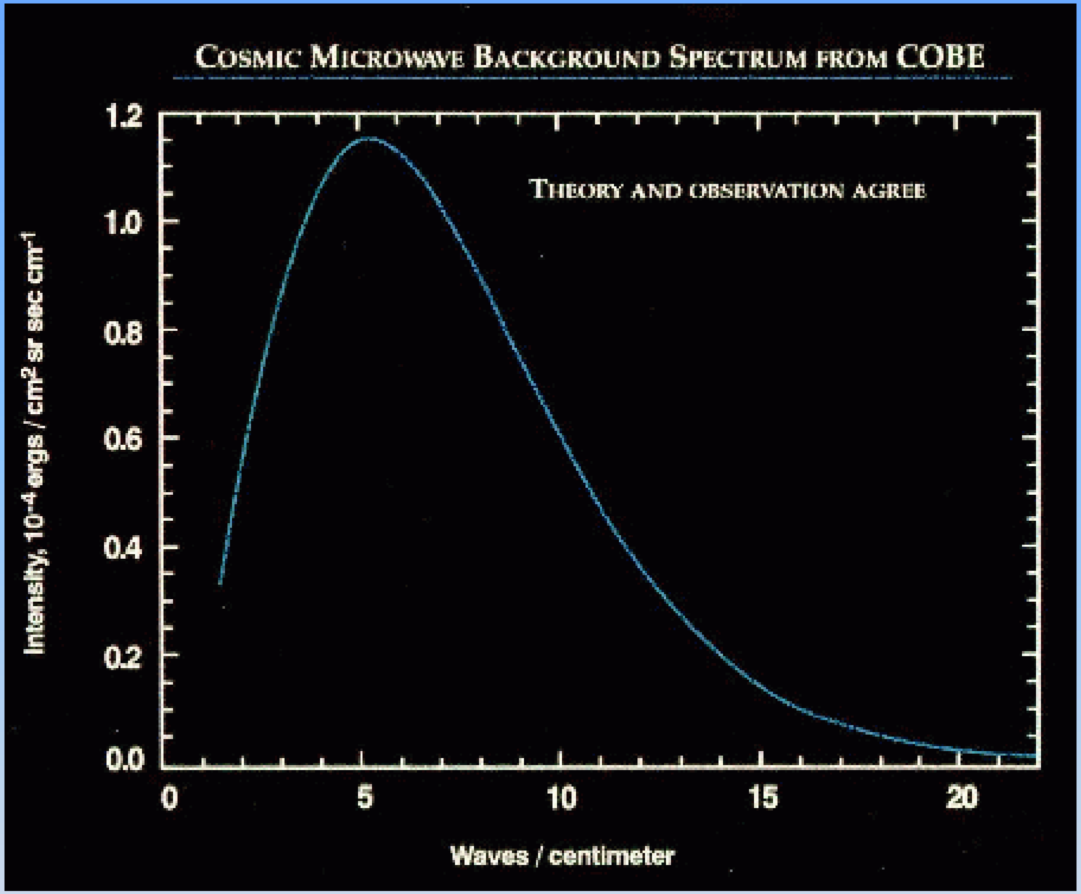


Cosmic Background Explorer (COBE)

- The FIRAS instrument ("Far-Infrared Absolute Spectrometer.“)
  - This device measured the intensity of radiation as a function of wavelength, very precisely.
- Scientists had guessed that the spectrum of the microwave background ought to have a particular shape:
  - that of a **blackbody**



Data from COBE



- The FIRAS instrument measured the spectrum of the CMB precisely, and found
  - exactly a blackbody spectrum, with a peak wavelength of 1.869 mm, corresponding to a temperature of T = 2.726K (+/- 0.010 K).

3. Large amounts of light elements are found in the universe

- Helium is made by fusion in the cores of stars.
  - Most stars are still fusing hydrogen.
  - They have yet not released helium.
- The abundance of helium found in the universe is believed to have been made by the Big Bang prior to the formation of stars.
- Another light element found is deuterium. It is not made by stars.
  - However, it is found in interstellar clouds that have no stars.
  - Its origin is also believed to be from the creation of the universe by the Big Bang.

Why is the discovery of CMB evidence of the Big Bang?

- CMB is coming from everywhere in space, not from a single source
  - Like the universe which is expanding in all directions.
  - This is why it's called background radiation
- It is theorized that the young universe was very hot.
- CMB gives us evidence for these extremely hot temperatures even though it's very cold.
  - The wavelengths emitted were originally very short. As space has expanded, the wavelengths have been redshifted.
  - They appear cooler.

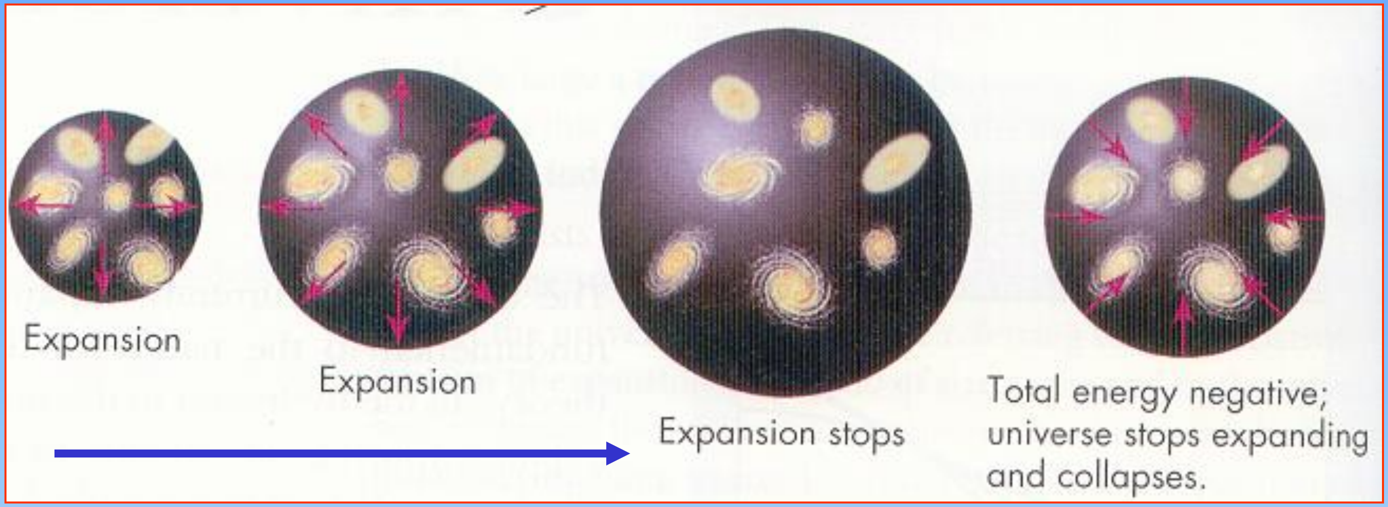
The Universe's Mass – It doesn't add up

- The calculated mass is much greater than the mass of the stars and interstellar matter that has been observed by all types of telescopes.
  - The calculations indicate that the observed mass is one-tenth of the calculated mass.
  - The missing matter can't be seen.
    - Its presence is deduced because it exerts a gravitational force on the matter that can be seen.
    - Astronomers have labeled this unseen matter as **dark matter**.
      - It gives off no light.
      - Even though it has gravity it can't form into stars. Dark matter is likely made of particles that are all around us but can't be seen.
      - Much research is being conducted by scientists to discover exactly what dark matter is and how much is actually present.

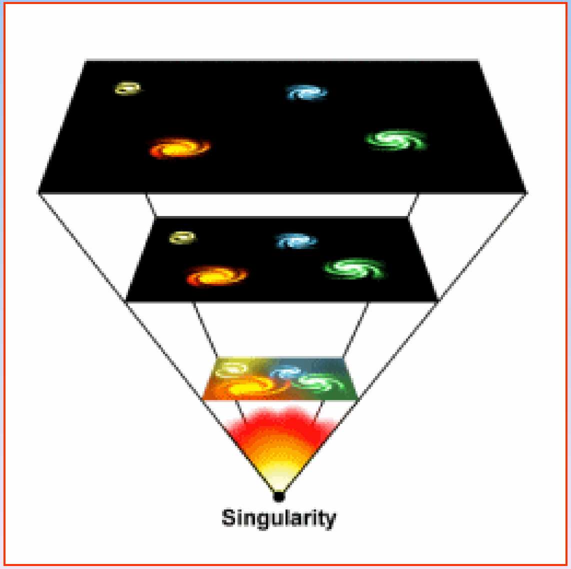
What is the fate of the universe?

There are three theories.

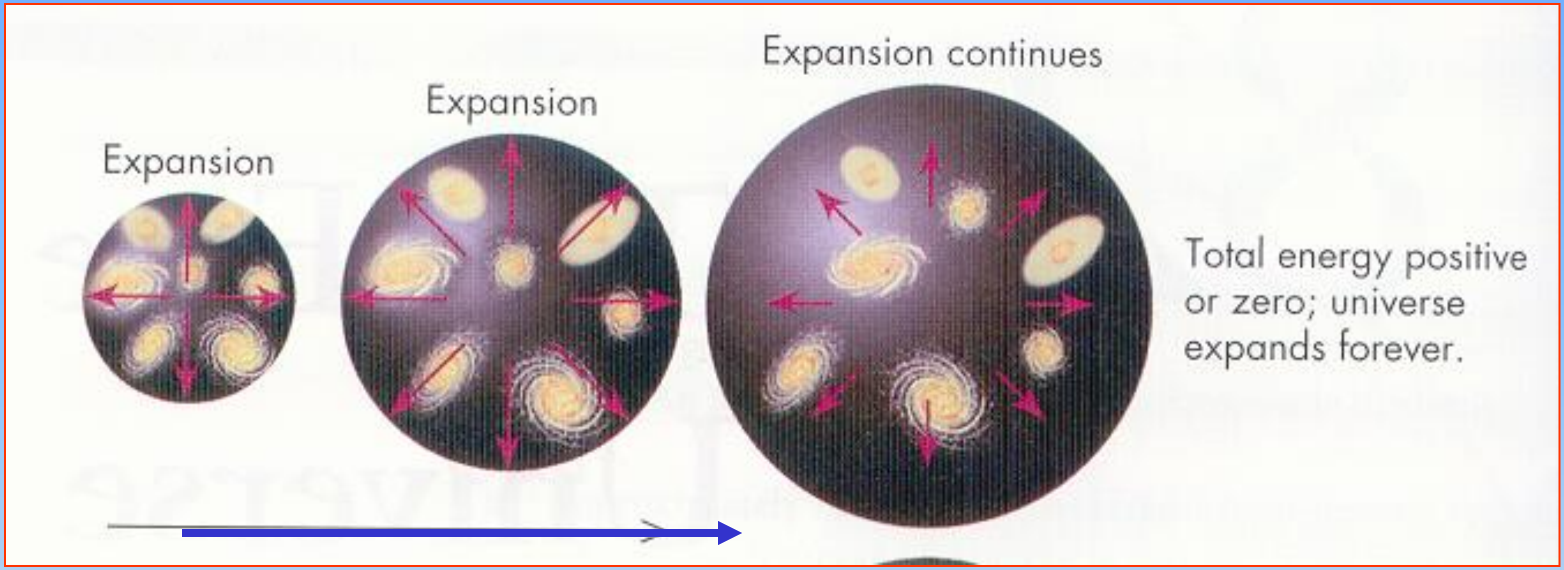
The Big Crunch



- Predicts expansion will be slowed by gravity.
  - It will eventually stop.
- This will cause all objects to be compressed to higher densities.
- The result will be that the universe will collapse back on itself.
- Recent data seems to discount this theory.



The Big Chill



- Predicts that the universe will expand forever.
- Stars will use up their hydrogen and die. In billions and billions of years a cold, black, and empty space will be all that remains.
- Data collected at the end of the 20th Century led to this prediction being most likely.
- However, recent measurements using data from supernovas lead to a third possibility.

The Big Rip

- **Predicts that the universe will end in a huge explosion.**
- **Recent measurements show that the universe is expanding at a faster speed.**

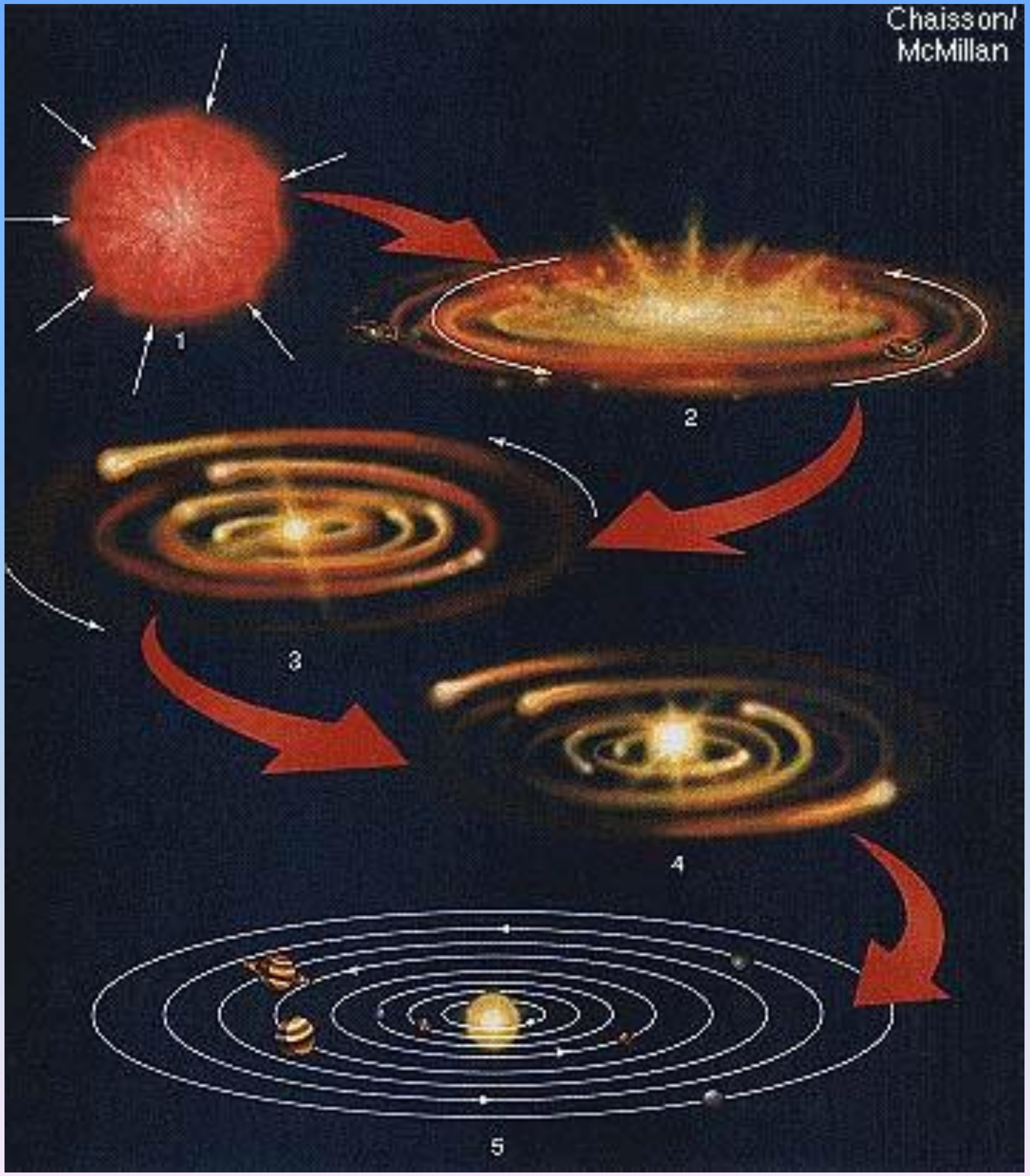
- Astronomers now think that there's a constant level of energy everywhere.
- It's causing all objects in the universe to be repulsed from each other. This unseen energy is working against gravity to speed up expansion.
  - This unseen energy is called **dark energy.**
- If the universe expands faster and faster it will overcome gravity.
  - Galaxies will be torn apart.
  - Even atoms could be ripped apart.
  - All parts of the universe would be pulled away from all other parts.

Which theory is correct?

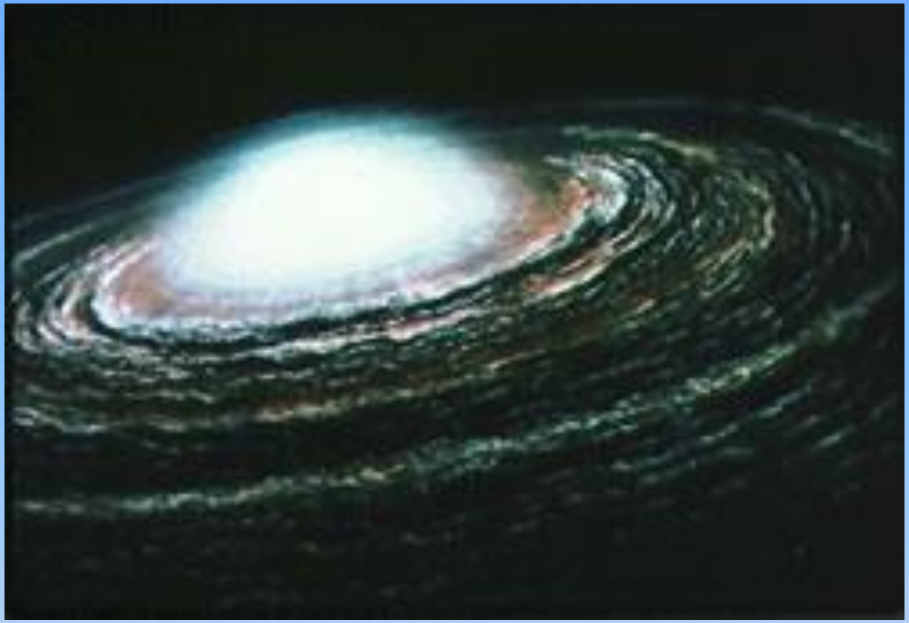
- Nobody really knows.
- Most scientists have ruled out the Big Crunch.
- There is no consensus among scientists about the other two theories.
- Scientists are just beginning to study and understand dark energy.
  - As they continue to analyze data they will refine and debate their theories.
  - Undiscovered phenomenon could even result in the development of new theories.
- The science of cosmology is just beginning to understand the nature of the universe.

C. Origin of the Solar System (__Solar Nebula__ Theory)

1. Planets formed at the __same time__ as the Sun and from the same nebular material.
2. The Solar System is believed to be __4.6 billion__ years old.



The Solar Nebula



- Solar system born 4.6 billion years ago
- A few light-years in diameter
- Composed mostly of gaseous
  - Hydrogen (71%)
  - Helium (27%)
  - Traces of other gases
- Microscopic dust
  - Mixture of silicates, iron compounds, carbon compounds and water ice
- Collapse may have been triggered by a nearby exploding star or a collision with another cloud

Materials in the Solar Nebula

	Metals	Rock	Hydrogen Compounds	Hydrogen and Helium Gas
				
Examples	iron, nickel, aluminum	various minerals	water (H_2O) methane (CH_4) ammonia (NH_3)	hydrogen, helium
Typical Condensation Temperature	1,000–1,600 K	500–1,300 K	<150 K	do not condense in nebula
Relative Abundance (by mass)	0.2%	0.4%	1.4%	98%

- The four types of materials present in the solar nebula are shown.
- Squares represent the relative proportions of each type by mass.

- Good Morning! ☺

- **Lab 8-5 any Questions? Due next Wed.**

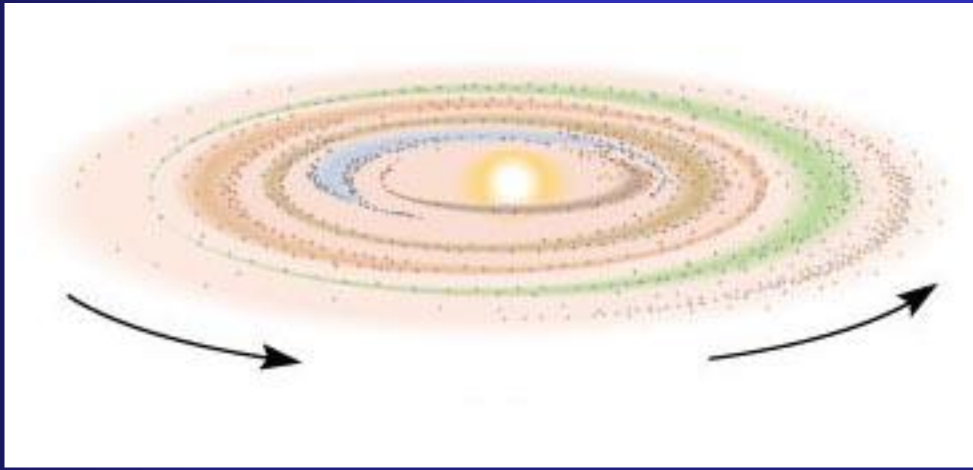
(note change in date)

- **Finish Notes today**
- **Review Class today 10th bring review ditto**

Origin of Our Solar System

Solar nebula theory

- cloud of gases and dust

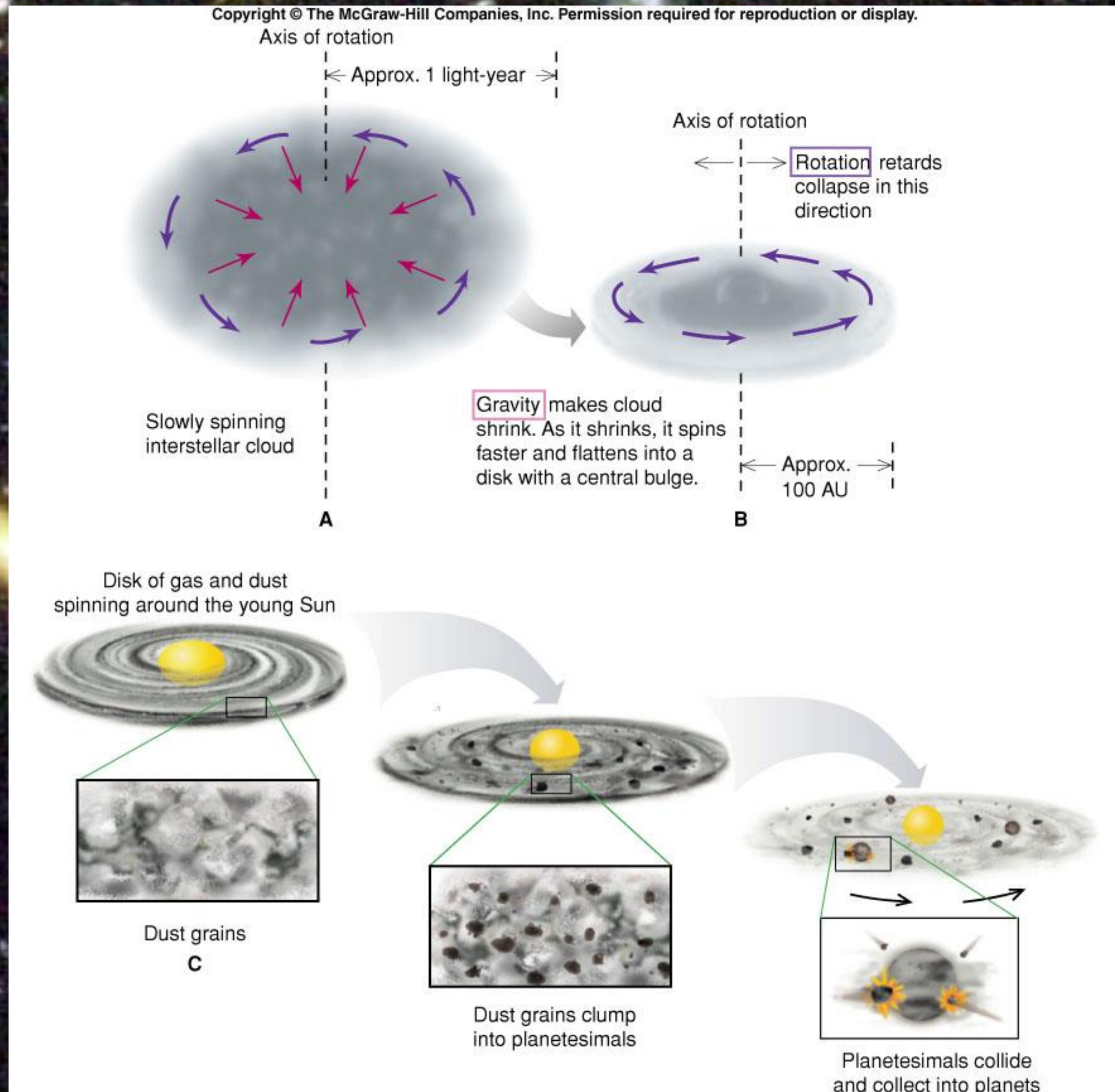


- formed a rotating disk
- condensed and collapsed due to gravity
- forming solar nebula
  - with an embryonic Sun
  - surrounded by a rotating cloud

(A) Collapse of an interstellar cloud

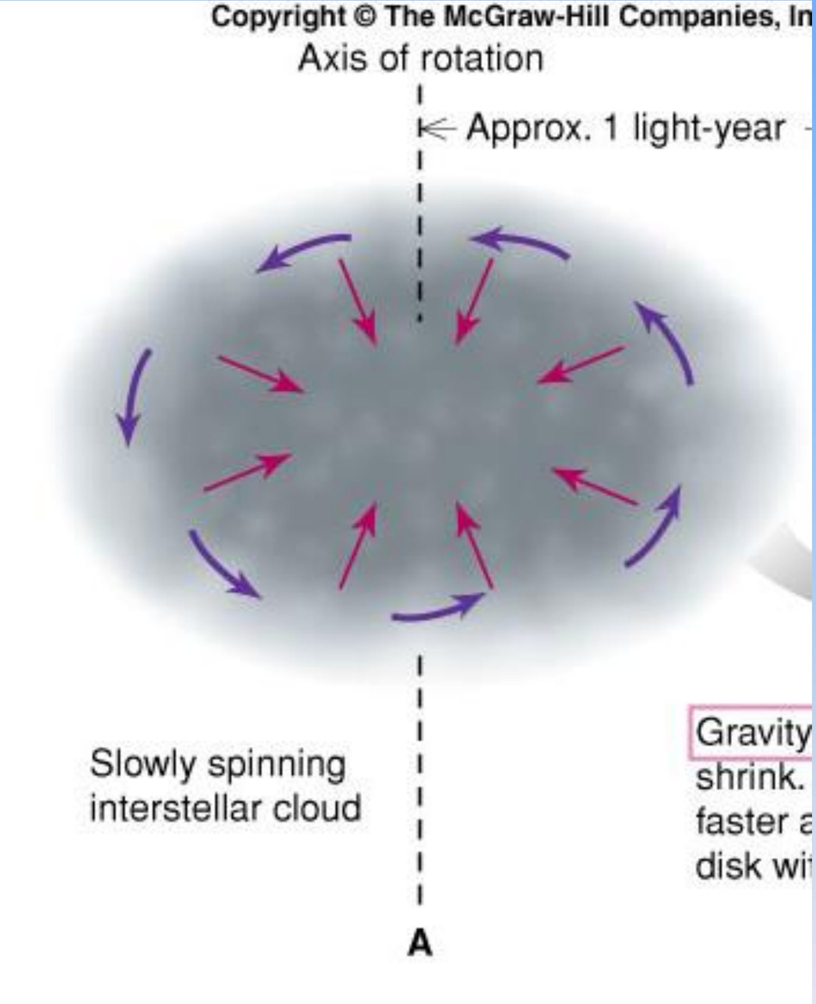
(B) The cloud flattens into a disk

(C) Condensation of dust grains in the solar nebula and formation of planetesimals



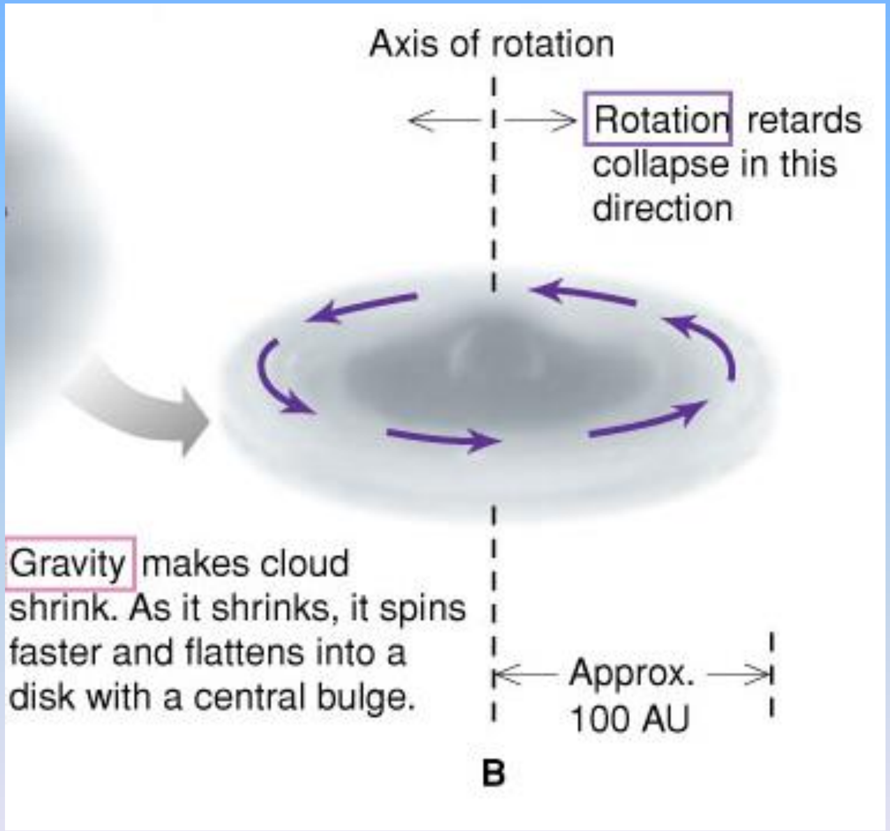
Solar Nebula Theory

- Gravitational attraction between the particles in the interstellar gas cloud (nebula) cause it to collapse inward.
- Could have been caused by:
  - Nearby exploding star
  - Collision with another cloud.

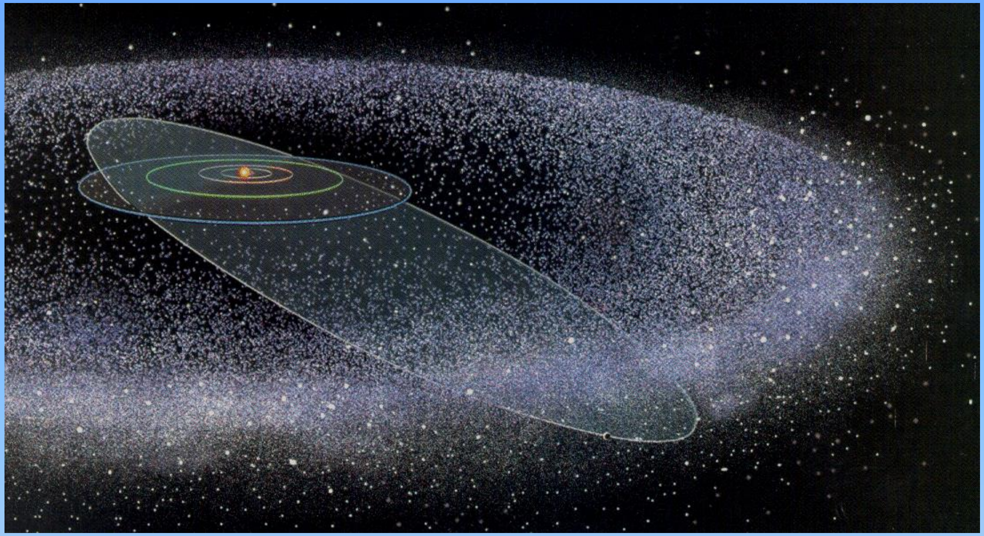


Solar Nebula Theory

- The rotation of the cloud caused it to flatten.
  - Formed a rotating disk.
  - The bulge in the center became the Sun.

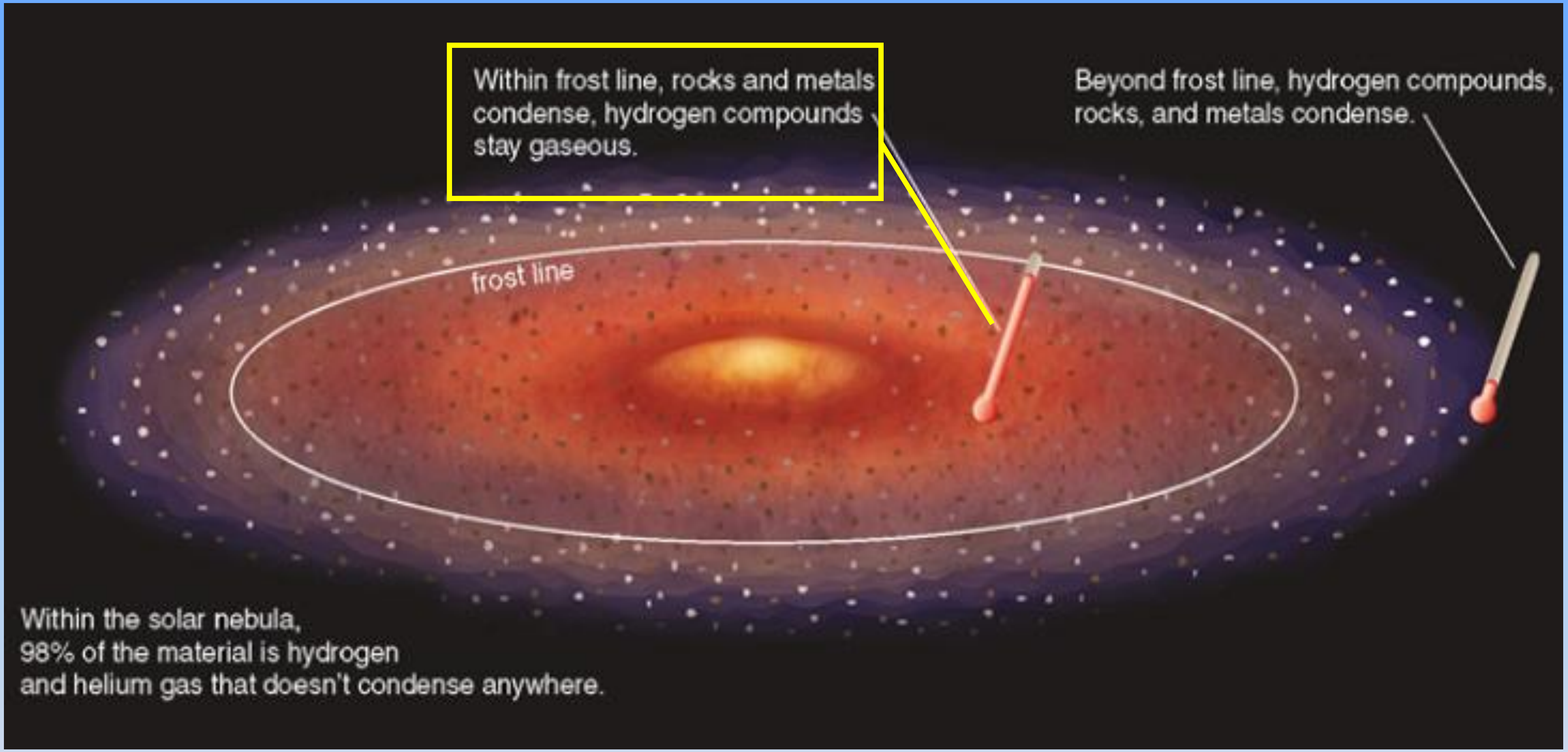


Accretion



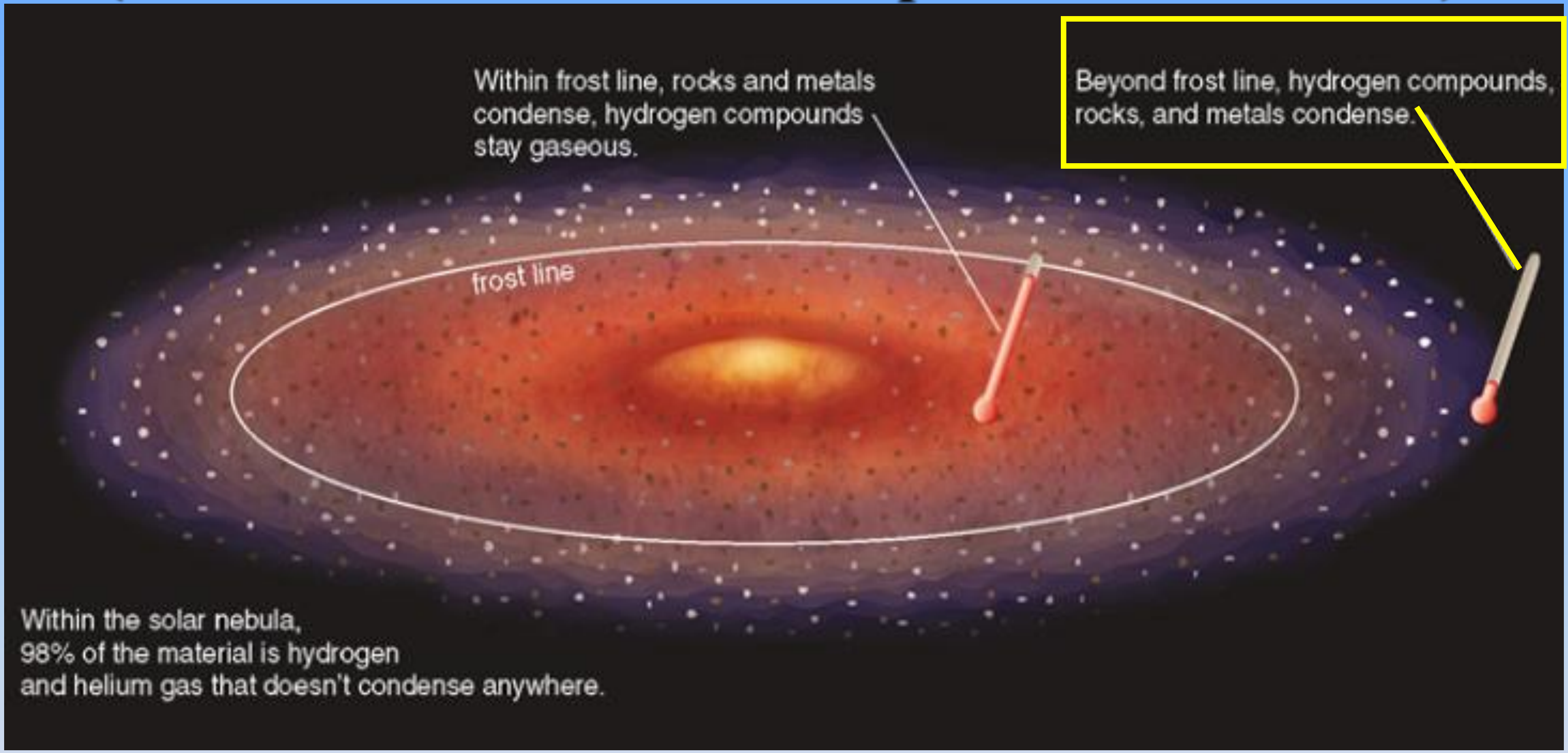
- Particles in the disk began to stick together, possible assisted by static electric forces.
  - The particles grew in size as the combined (a process called "**accretion**.")
  - Composition of particles depended on where they were in the disk.

Inner Part Near the Sun



- Too warm for water-ice to condense
- Solid particles were silicate and iron-rich matter.

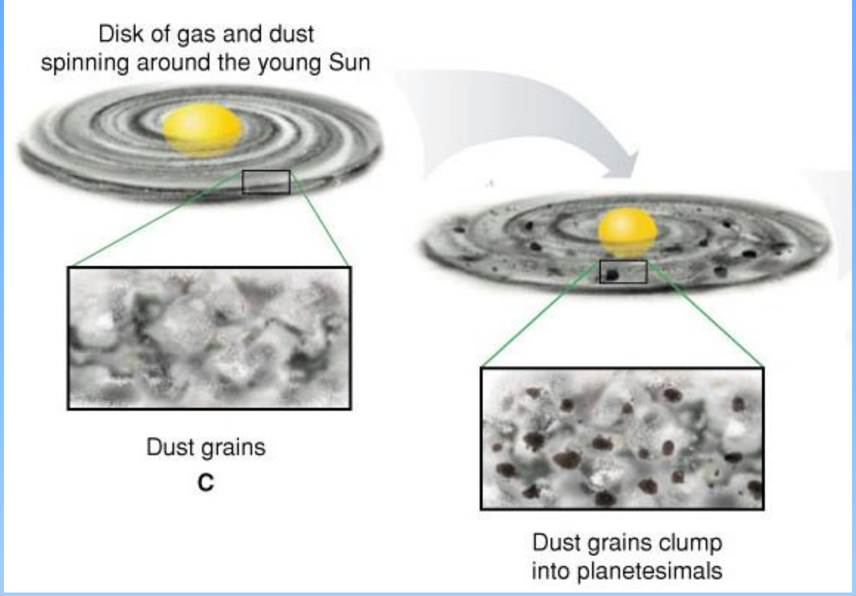
Outer Part of Disk
(at about the distance of Jupiter from the Sun)

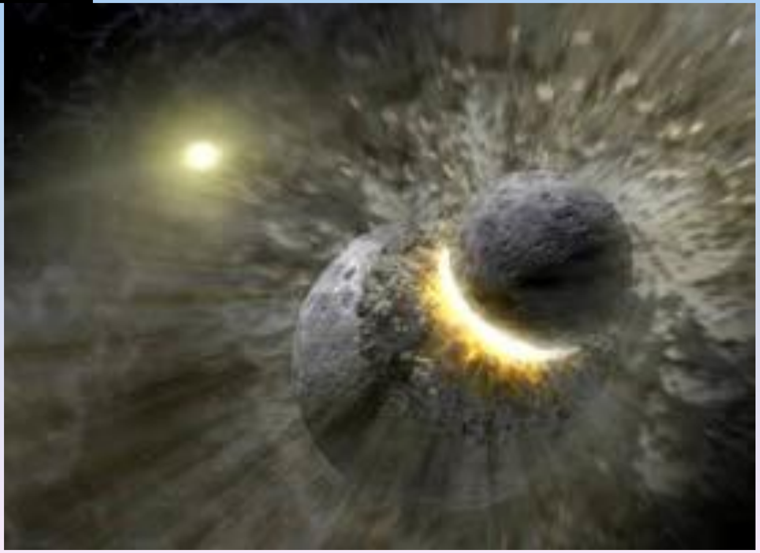


- Cold enough for water-ice to form
- Particles silicate and iron-rich material and frozen water.
- These particles grew much larger than the particles in the inner part of the cloud.

Planetismals Formed

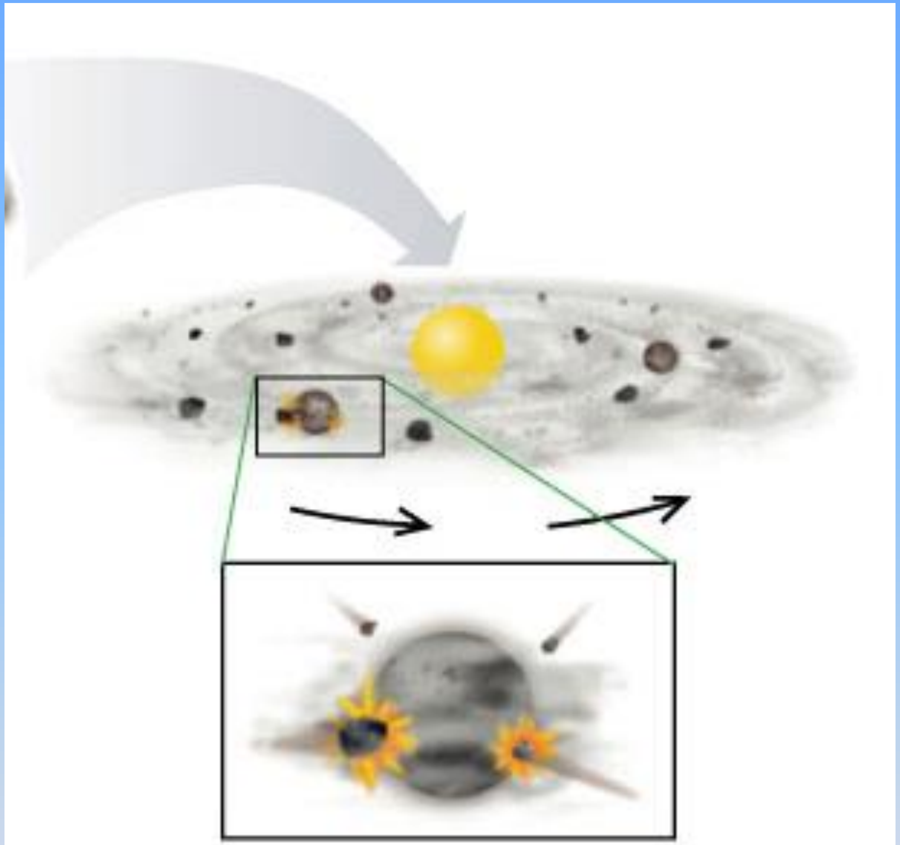
- If collisions between particles were not too violent they stuck together.
- Smaller particles gradually grew until they were several kilometers wide.
- These small, planet-like bodies are called ***planetesimals*.**





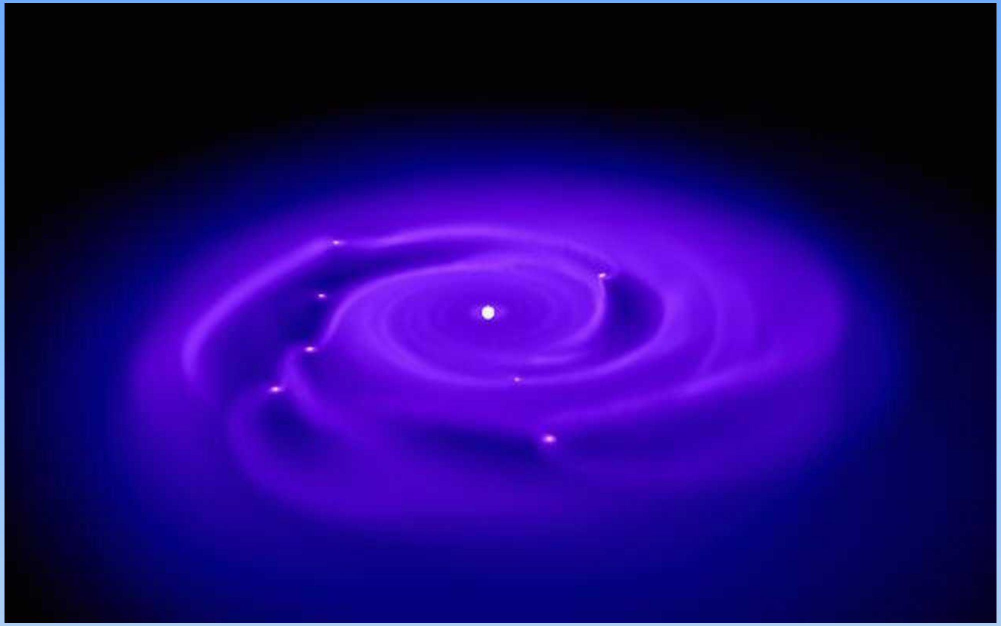
Formation of Planets

- Planetesimals began to collide and grow (accretion)
  - If they were not completed destroyed, they merged.
  - Their orbits became nearly circular.
- Mass increased due to accretion.



Planetesimals collide and collect into planets

Outer (Jovian) Planets



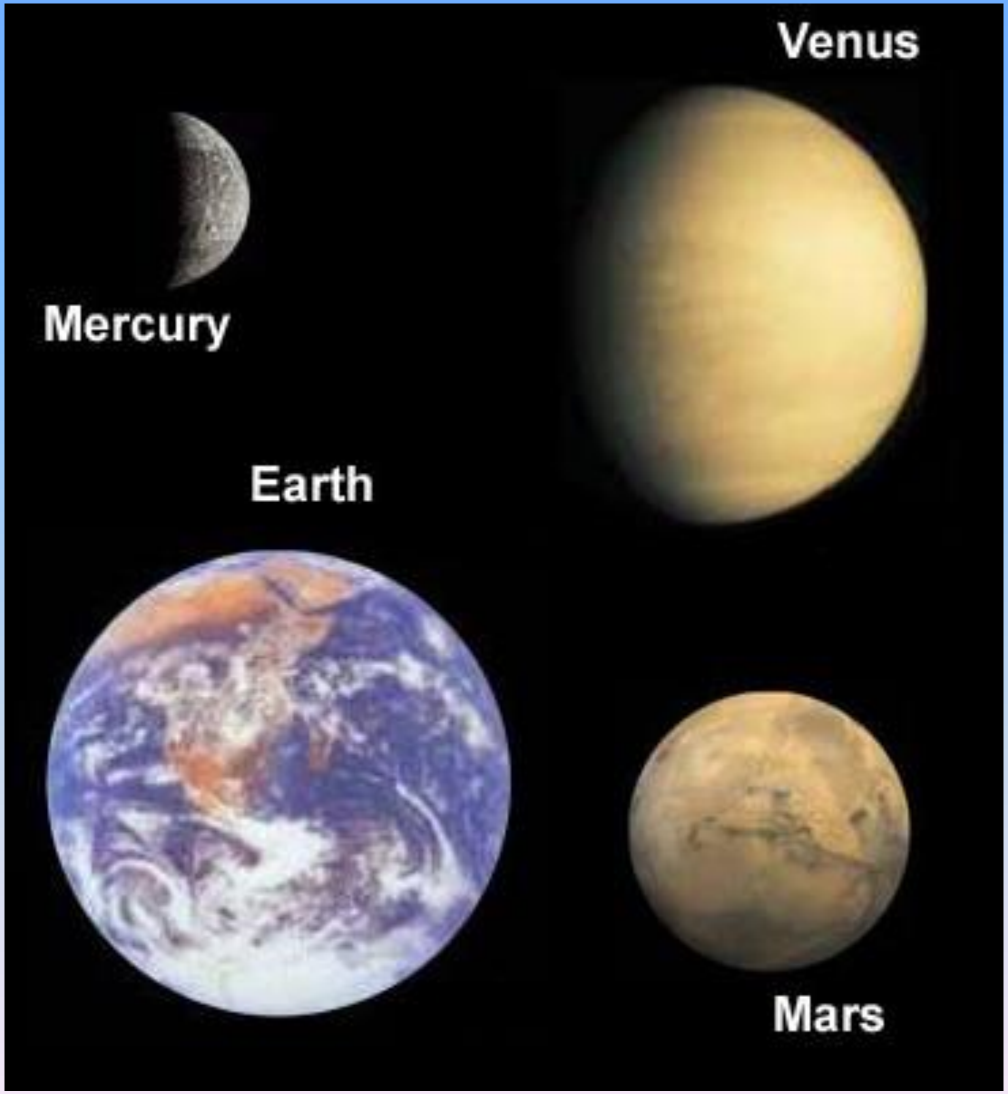
- Grew larger
  - Water-ice could form
  - Water-ice was about 10 times more abundant than silicon and iron-rich compounds.
  - With larger mass, these planets could attract more material.
- Gas could be attracted and retained due to the large gravity.
  - Extremely large hydrogen-rich atmospheres surround Earth-sized rocky bodies (original materials of the planets)
  - Called *gas giants* because of huge gaseous atmospheres.

Summary

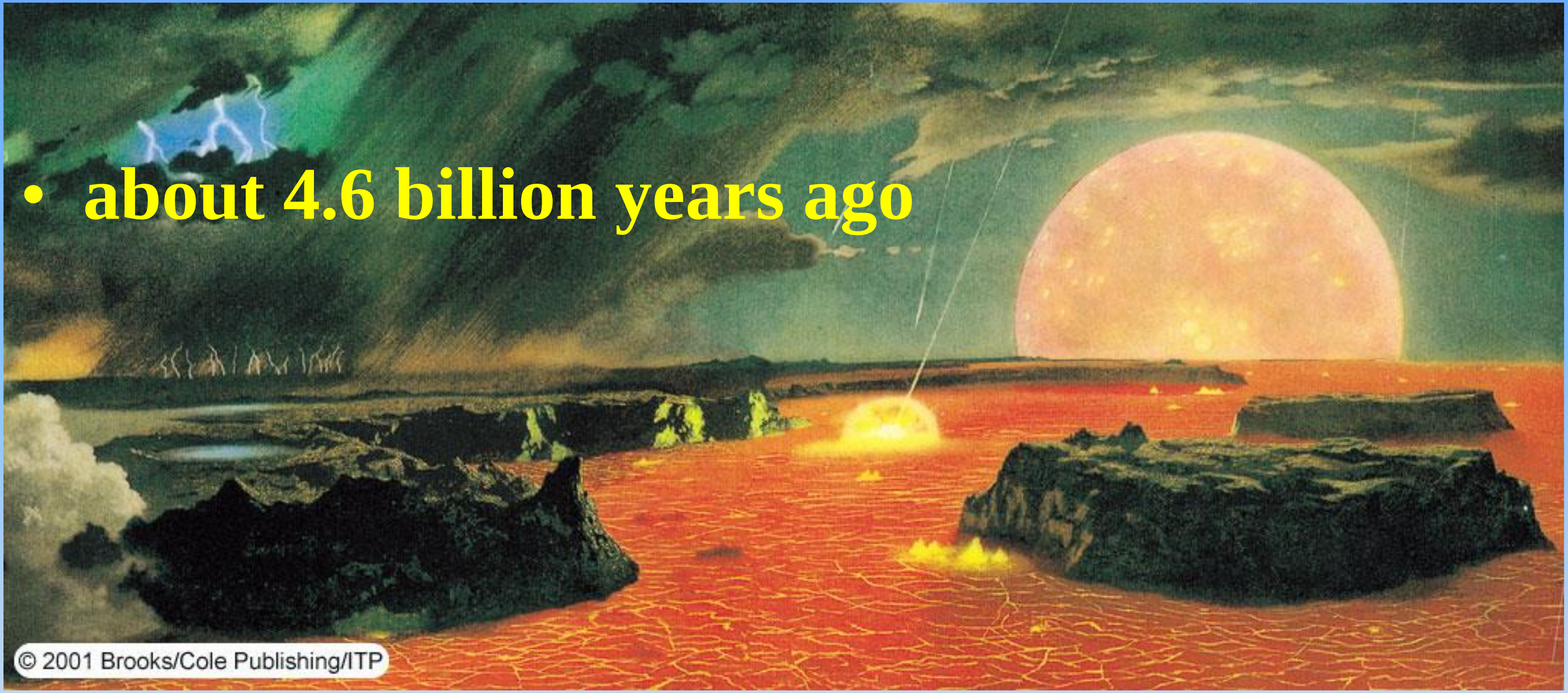
3. **Huge gas and dust cloud became unstable.**
   a. Due to gravitational attraction a condensation formed at one point becoming the ___**sun**_____.
   b. The cloud rotated faster as it contracted.
   c. Some gas and dust was left in a flattened disk surrounding the protosun.
   d. Condensation occurred within the disk forming _**protoplanets**____which continued to move in the same direction as the disk.
4. **As material in the disk became more concentrated in the protoplanets:**
   a. Space between the new Sun and the protoplanets cleared;
   b. Light and heat was able to reach them driving off lighter elements and even most of its atmosphere leaving a more dense core of heavier elements.

5. Terrestrial Planets

a. Closer to the Sun and most lighter elements driven off.
b. Small, rocky, and dense
c. Mercury, Venus, Earth, Mars
d. No atmosphere. (Originally)



Hot, Barren, Waterless Early Earth



- about 4.6 billion years ago

- Shortly after accretion, Earth was
  - a rapidly rotating, hot, barren, waterless planet
  - bombarded by comets and meteorites
  - with no continents, intense cosmic radiation
  - and widespread volcanism

Origin of the Atmosphere & Oceans

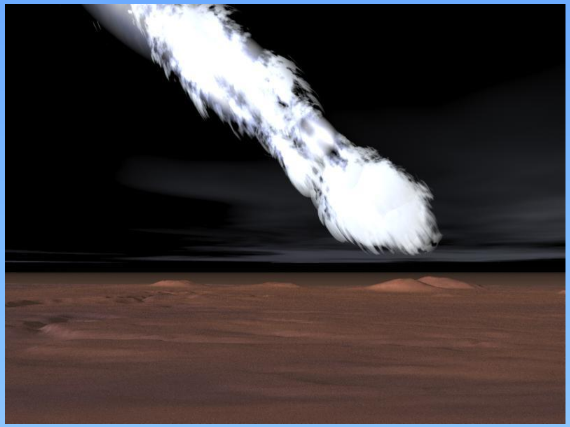
e. Numerous impacts from objects from space (meteors, comets)

f. __Volcanic Outgasging__: Atmosphere evolved from the release of water from volcanoes.

g. Meteorites

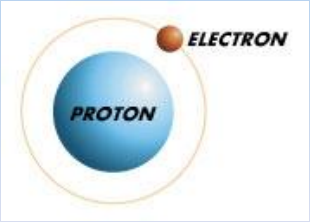
- Some meteorites contain water which likely was released into the impact when the vaporized upon impact with Earth’s surface.

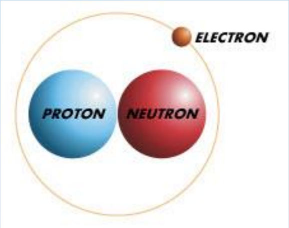
Comets



- A new class of comets, “main belt comets” may have formed within the orbit of Jupiter
  - Contain “Heavy” water (HDO) which has equal parts Hydrogen, Oxygen, and Deuterium (an isotope of H with extra neutron)

Hydrogen



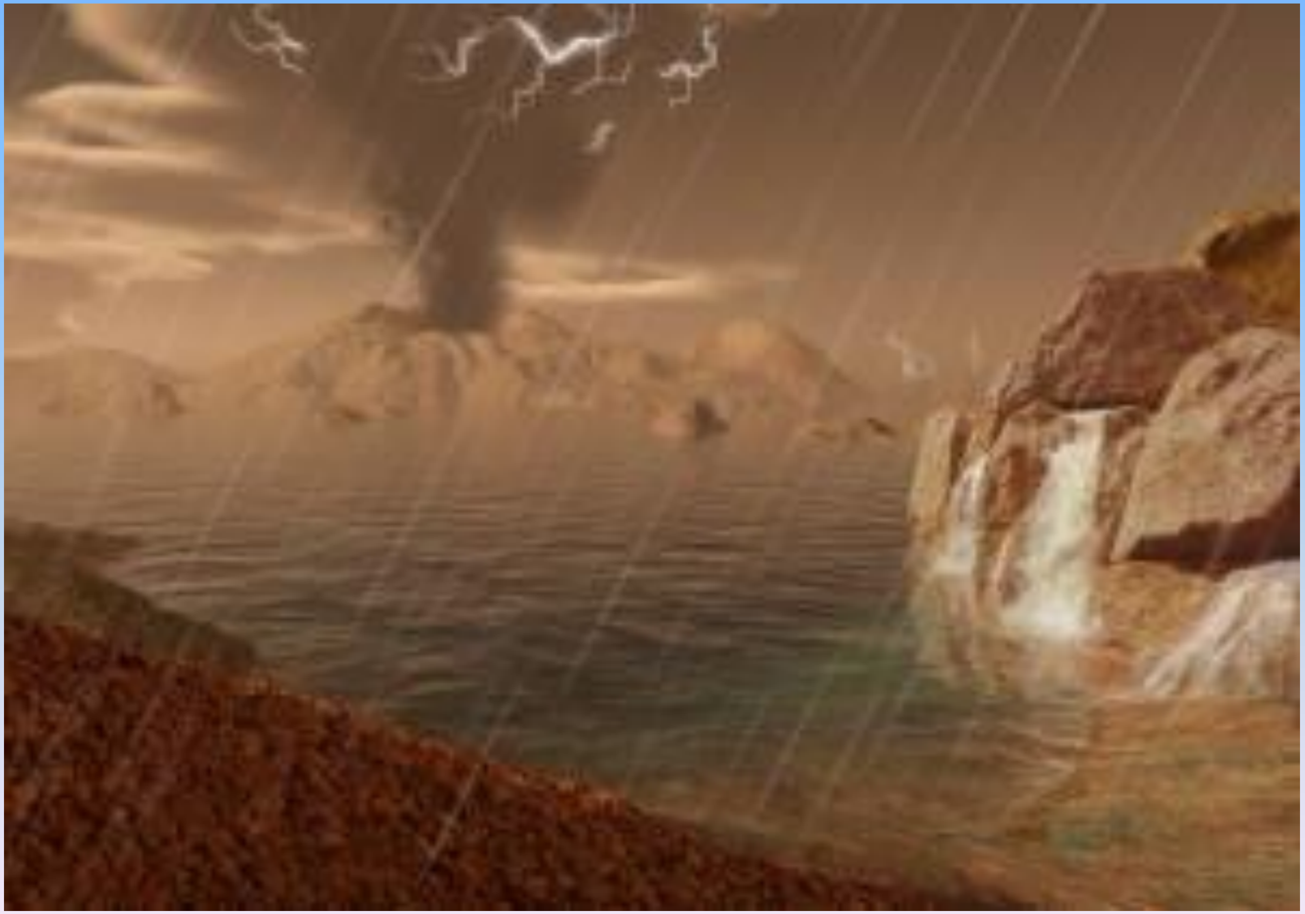


Deuterium

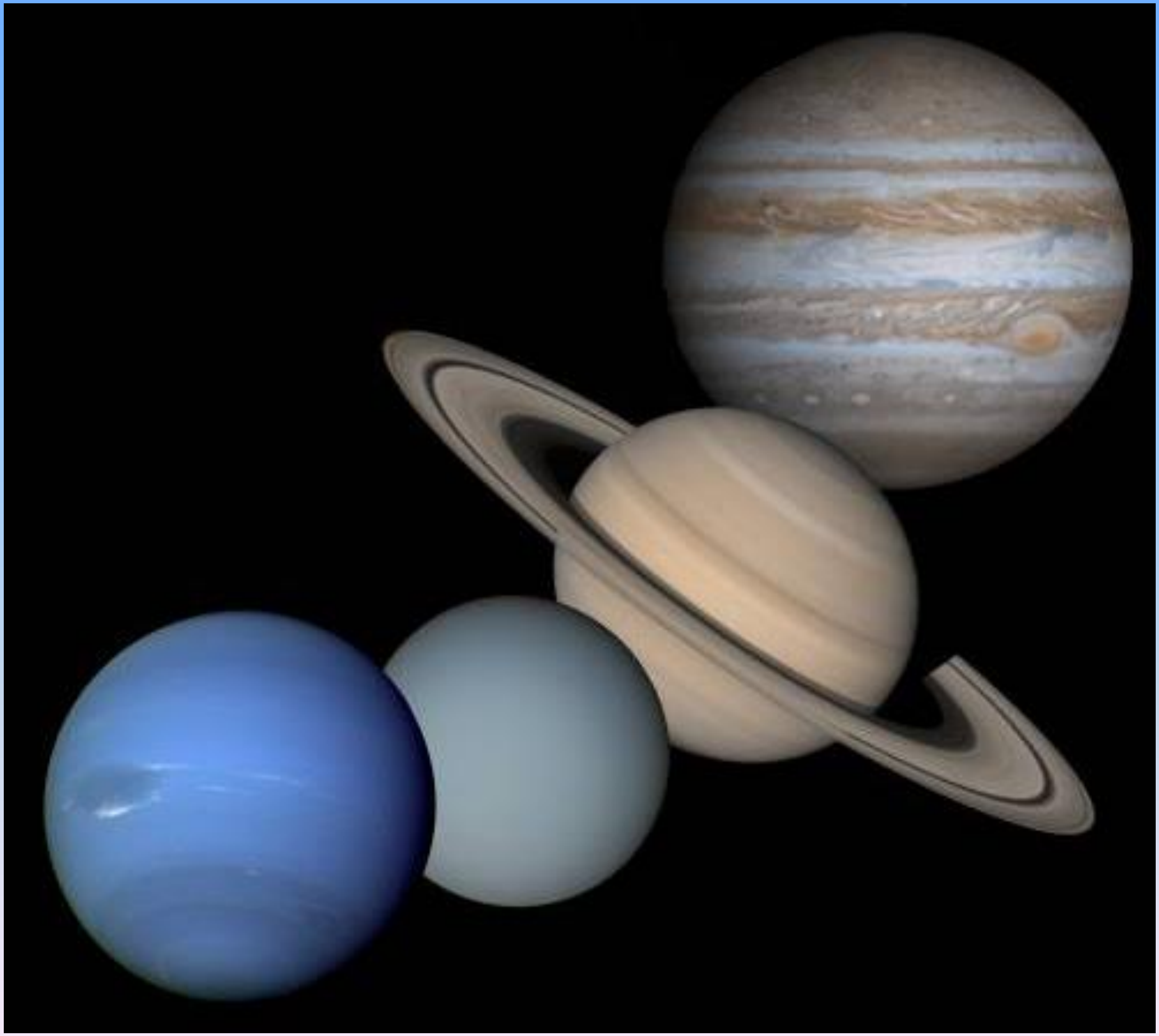
- Earth’s oceans contain HDO
- Comet impacts might have contributed significant water to the formation of Earth’s atmosphere and the oceans.

h. Origin of Earth's Oceans:

Release of water from precipitation over millions of years early in Earth history.

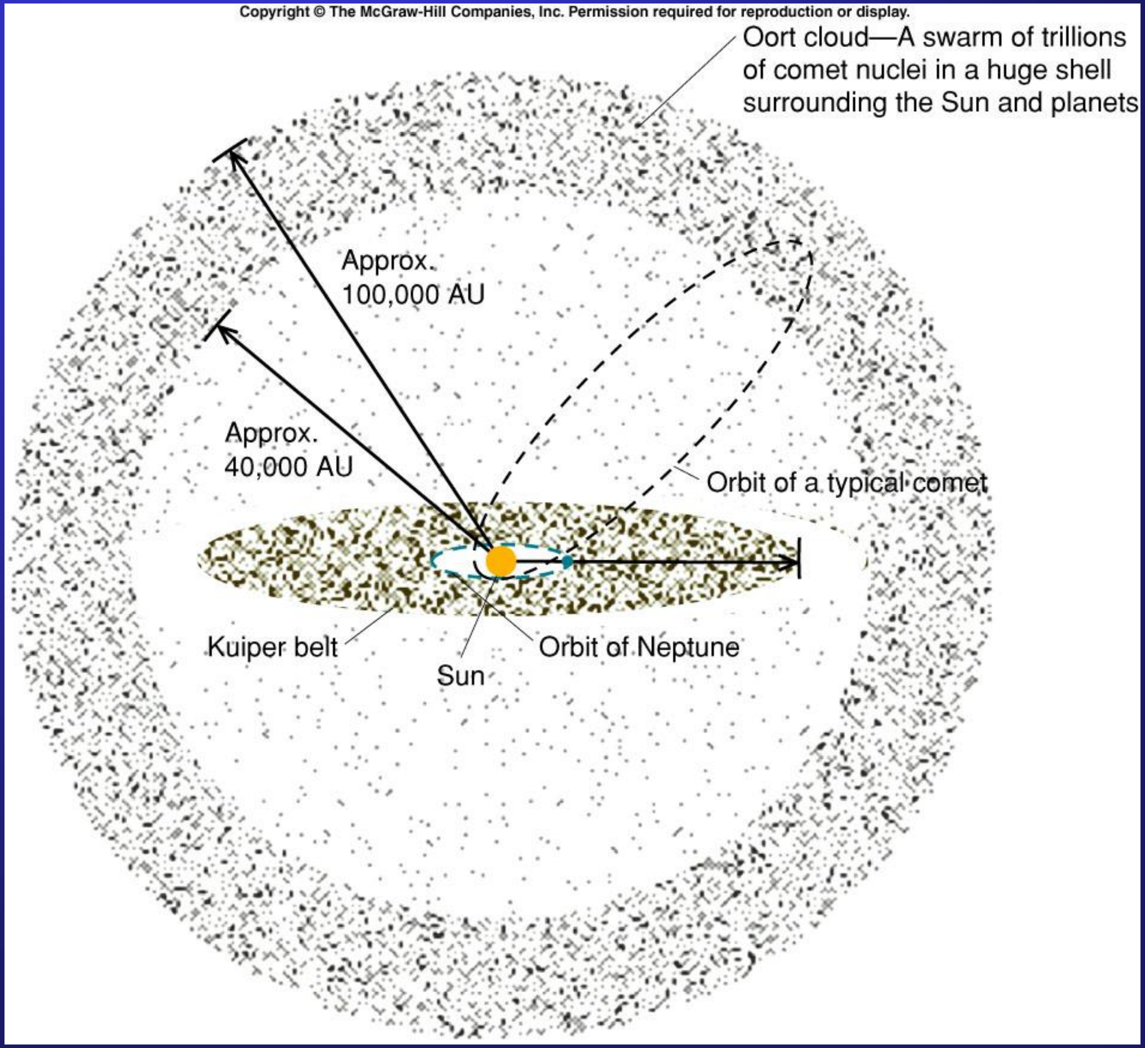


i. Planets beyond Mars are made of lighter elements and are the __Gas Giants__________.

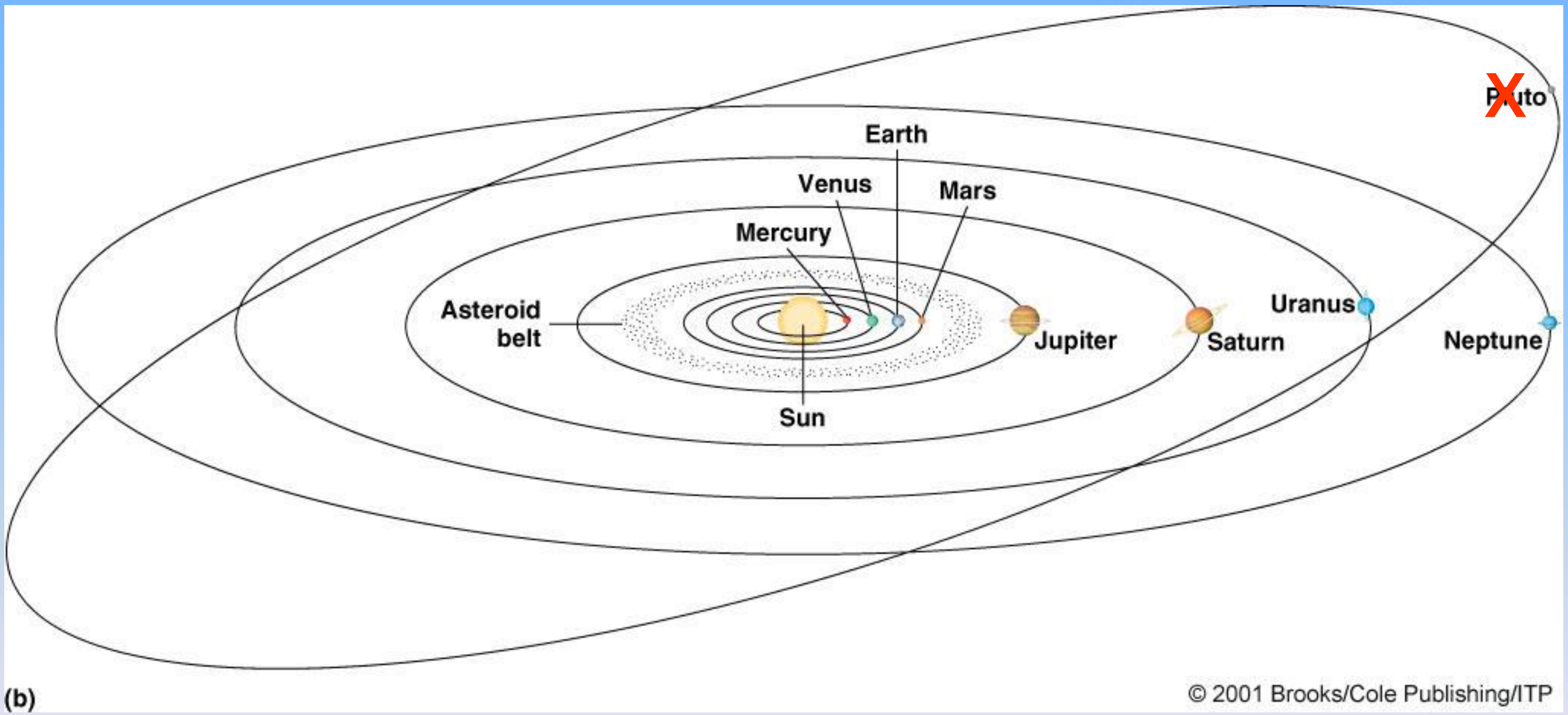


Oort Cloud and Kuiper Belt
Source of Comets

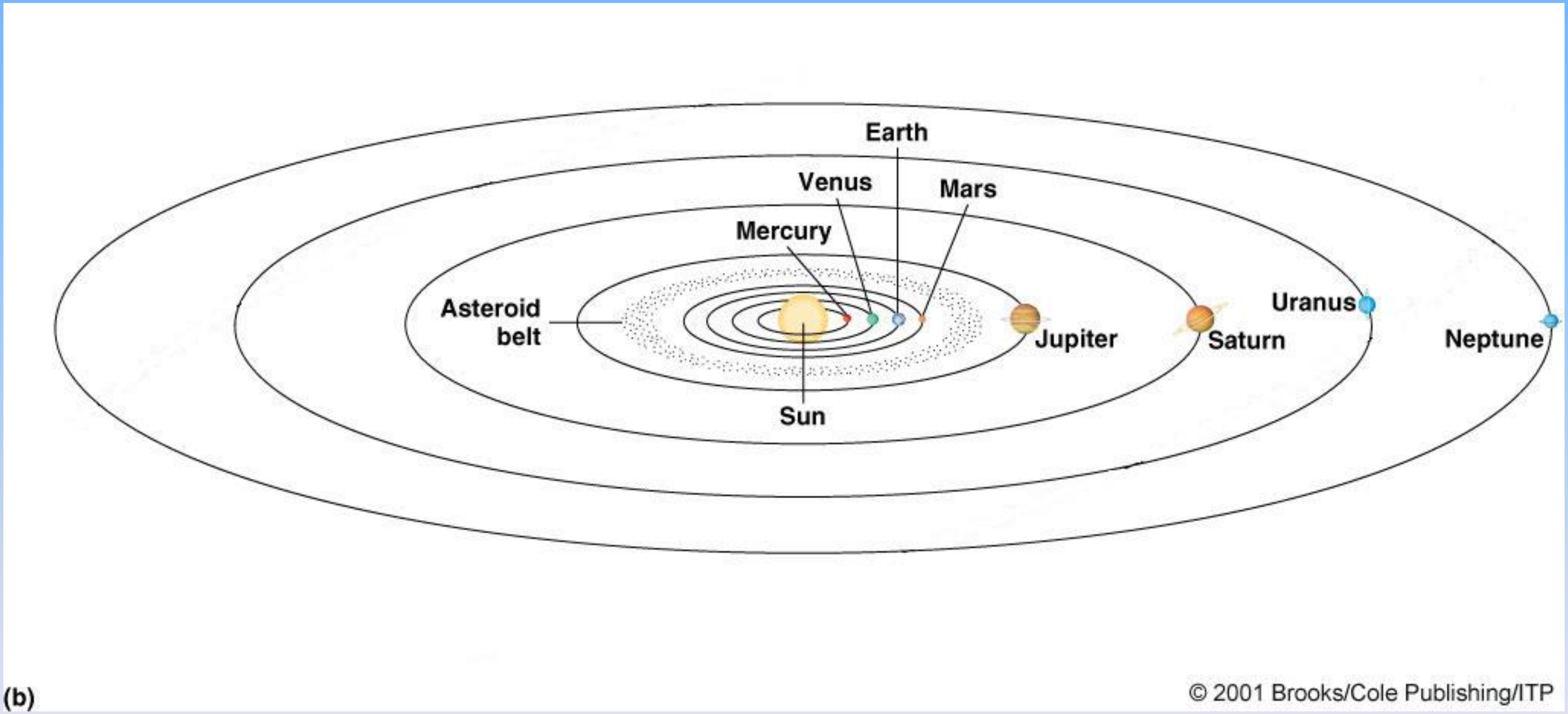
- Kuiper belt –
  - a region extending from just past Neptune to a little past Pluto
- Oort cloud
  - Huge spherical region thousands of times farther from the Sun than Pluto



Solar System Configuration



Solar System Configuration



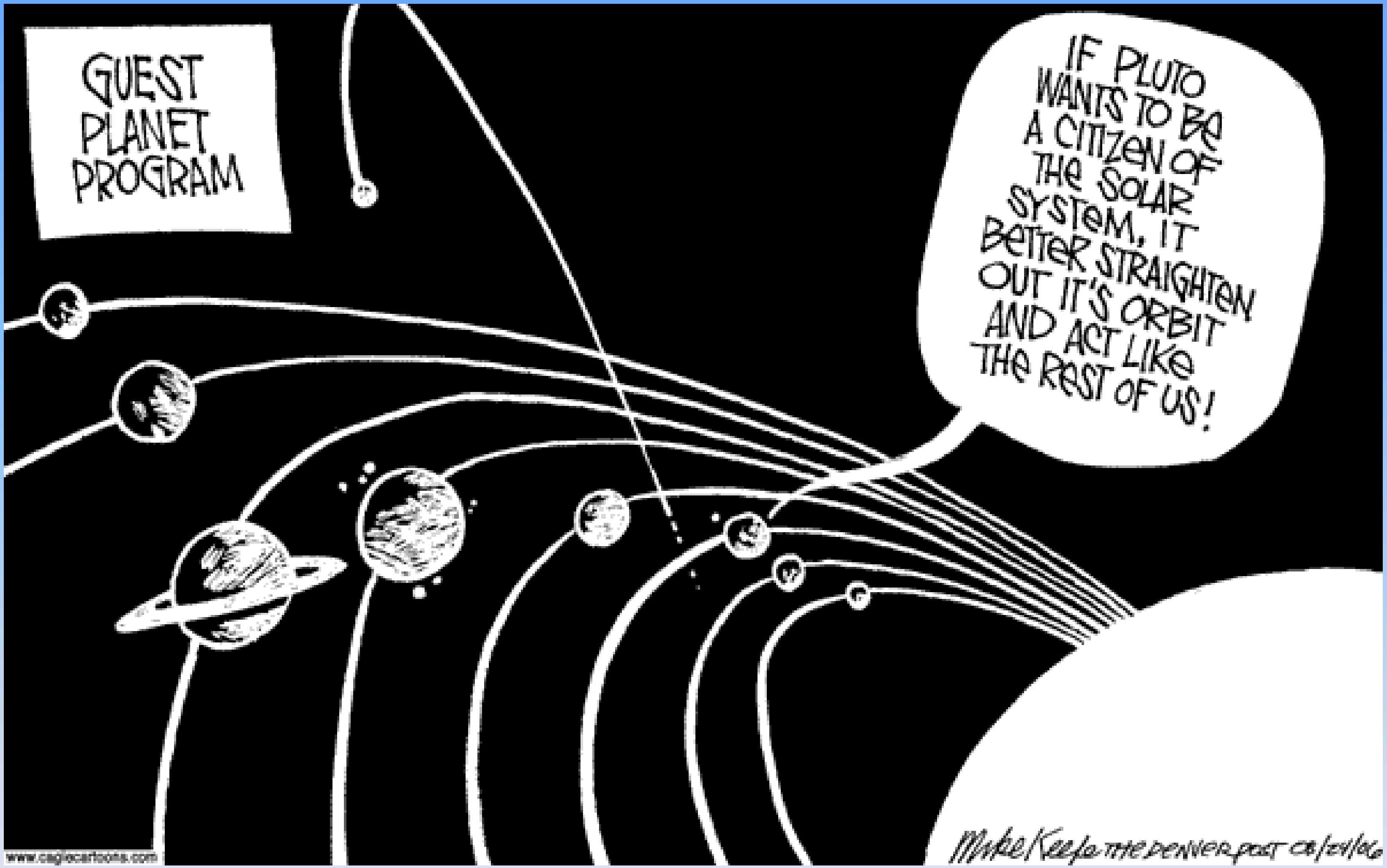
Pluto is no longer considered a planet!

Pluto's Been Demoted!

- On August 24, 2006 the International Astronomical Union redefined the definition of a planet as:
  - "a celestial body that is in orbit around the sun
  - has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a nearly round shape,
  - and has cleared the neighborhood around its orbit."

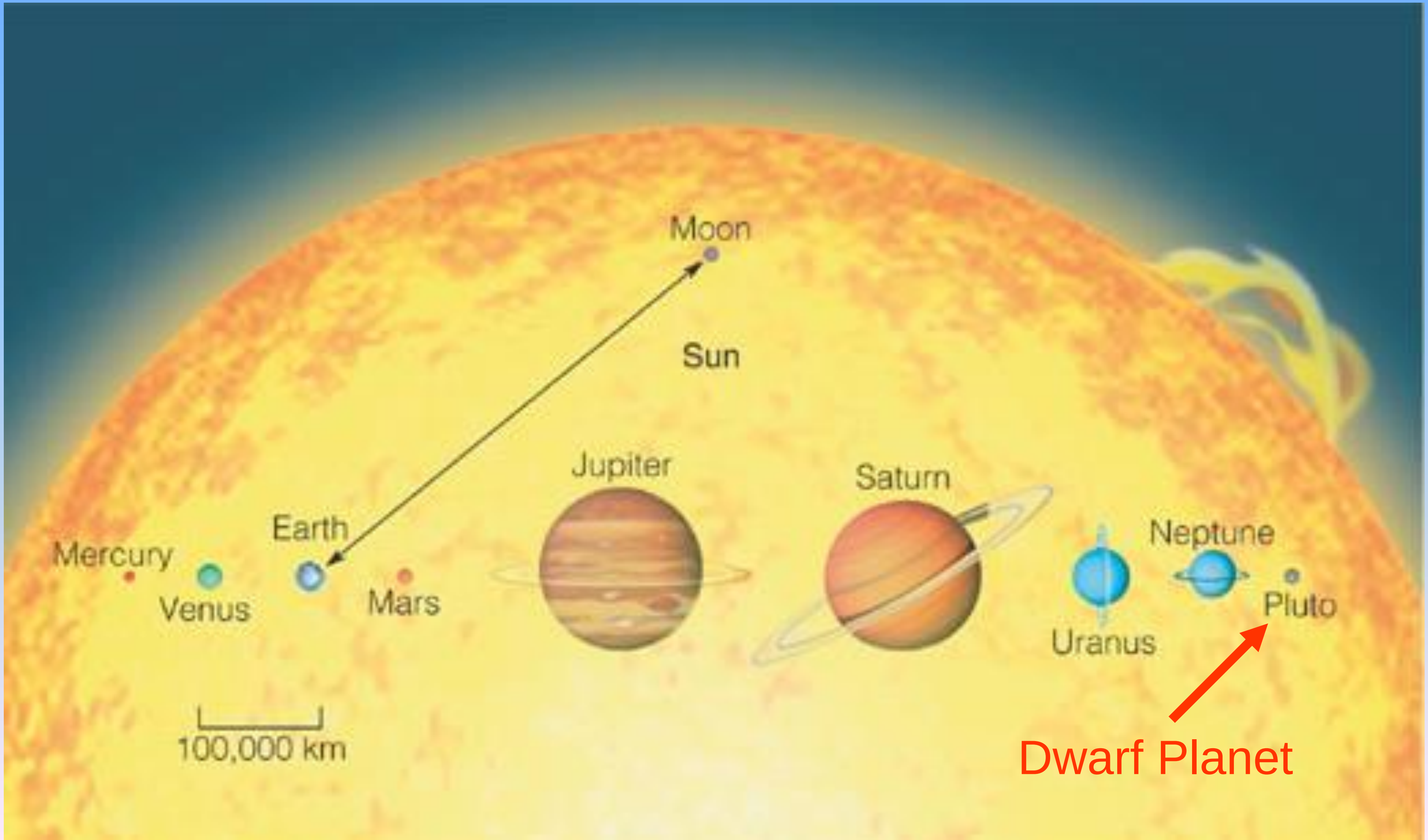
Pluto is now considered a “Dwarf Planet”

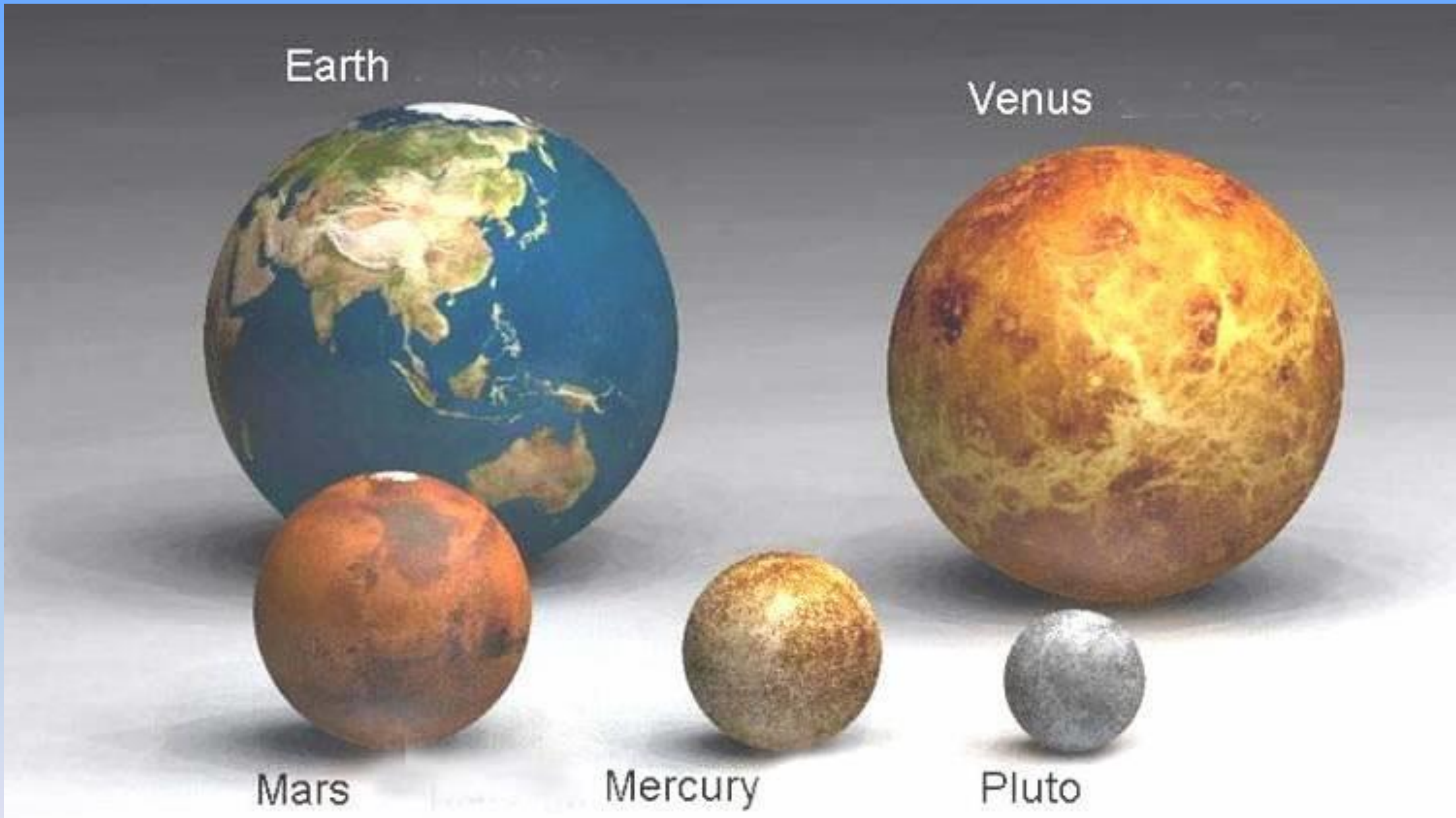
- Pluto lost its status as a planet because it’s highly eccentric orbit crosses over the orbit of Neptune.
  - **As such it hasn’t “cleared the neighborhood around its orbit.**
- A dwarf planet like Pluto is
  - Any other round object that
    - Has not “cleared the neighborhood around its orbit
    - Is not a satellite

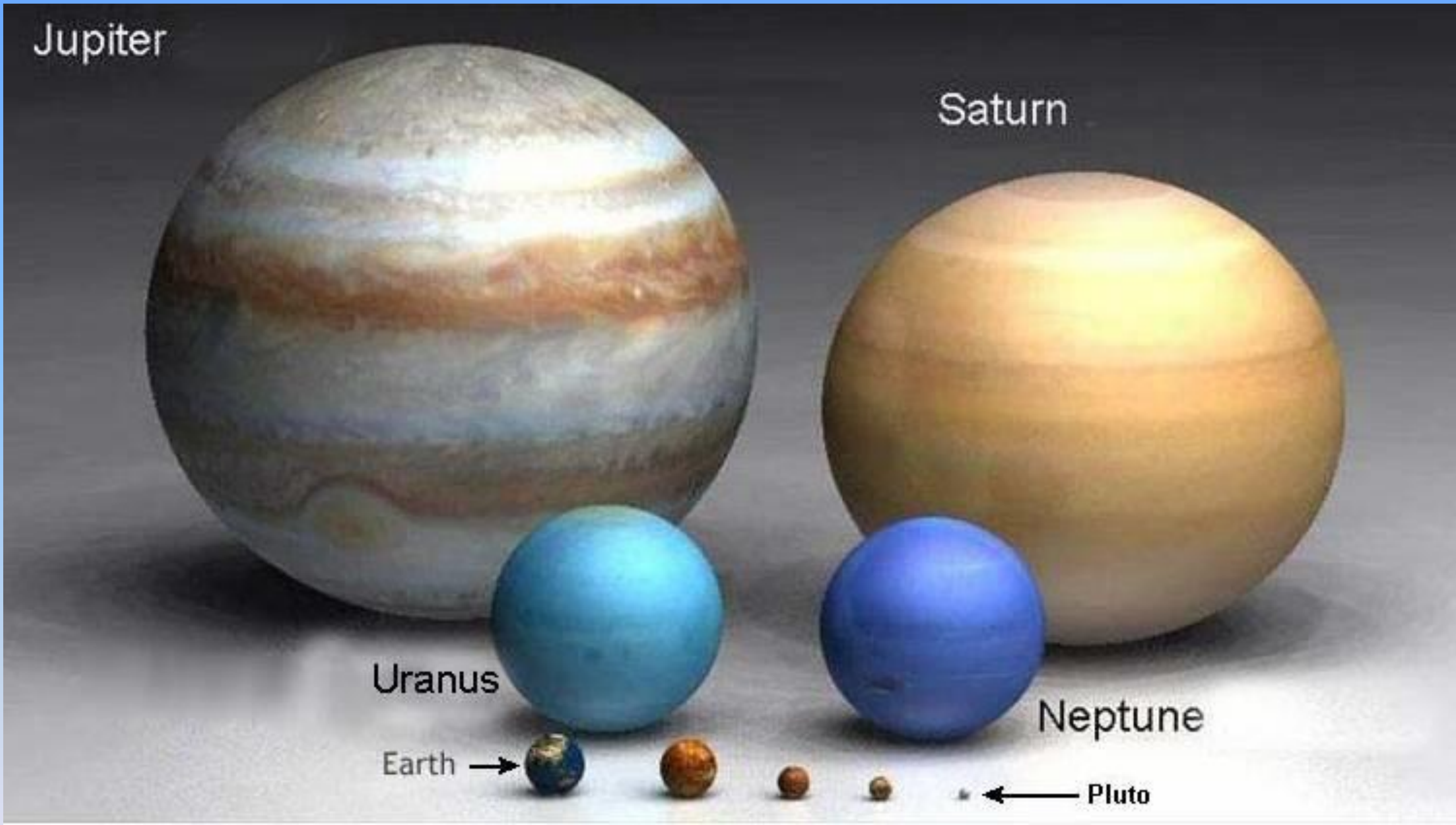

GUEST PLANET PROGRAM
IF PLUTO WANTS TO BE A CITIZEN OF THE SOLAR SYSTEM, IT BETTER STRAIGHTEN OUT IT'S ORBIT AND ACT LIKE THE REST OF US!
www.caglecartoons.com
Mike Keefe THE DENVER POST 08/24/06

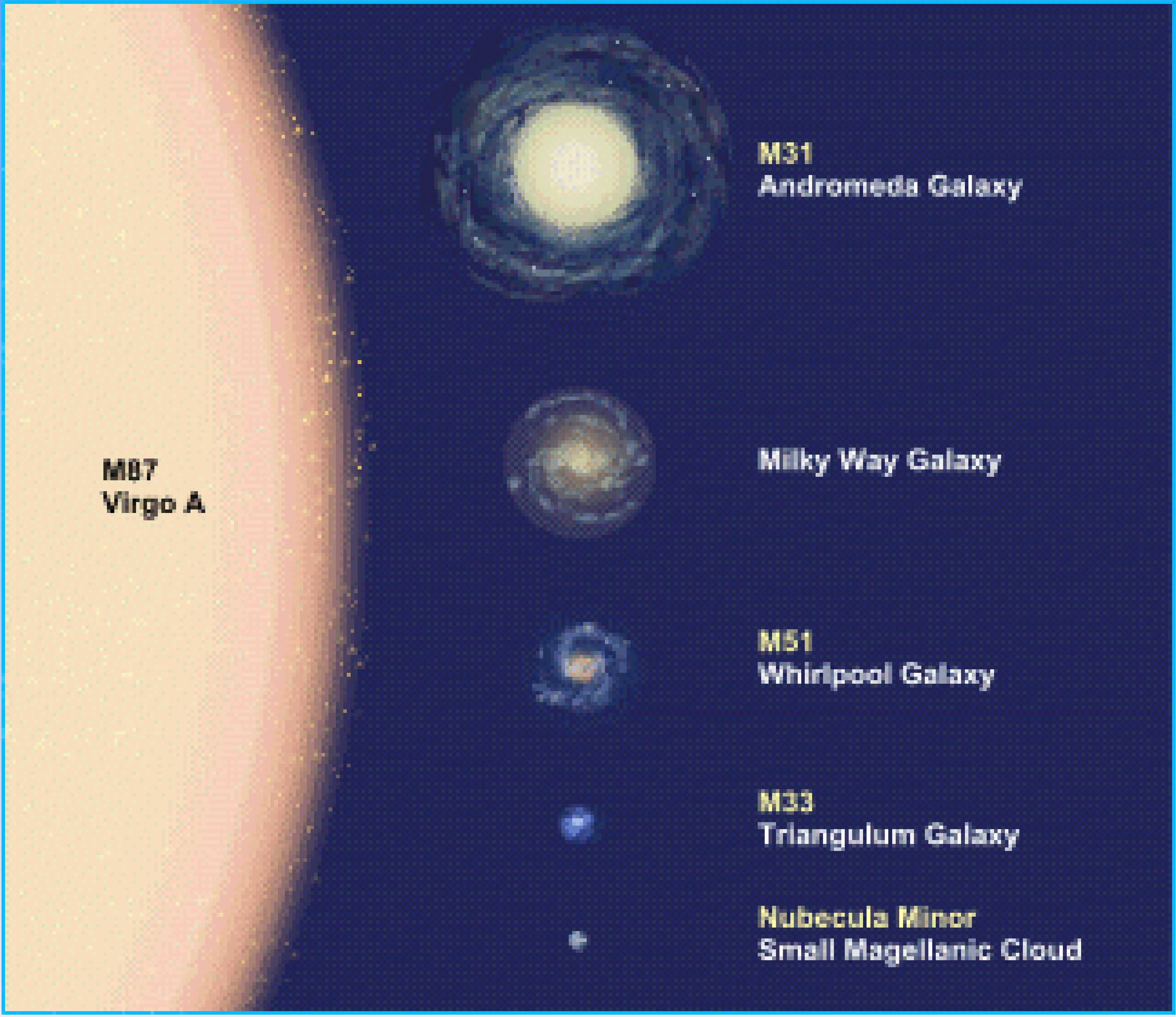

I CAN'T BELIEVE I HAVE TO SIT AT THE "LITTLE PLANETS" TABLE...
PLUTO

Relative Sizes of the Sun and Planets




Earth
Venus
Mars
Mercury
Pluto


Jupiter
Saturn
Uranus
Neptune
Earth
Pluto


M31
Andromeda Galaxy
M87
Virgo A
Milky Way Galaxy
M51
Whirlpool Galaxy
M33
Triangulum Galaxy
Nubecula Minor
Small Magellanic Cloud