

Space and all the matter and energy in it.

The Universe



The Night Sky

- Observing the sky dates to ancient times.
- **Stars:**
 - Appear as point sources of light.
 - Able to generate their own light.
 - Stars twinkle because of differences in the atmosphere
- **The Sun:**
 - An average sized star.
 - About 5 billion years old!



Light Year

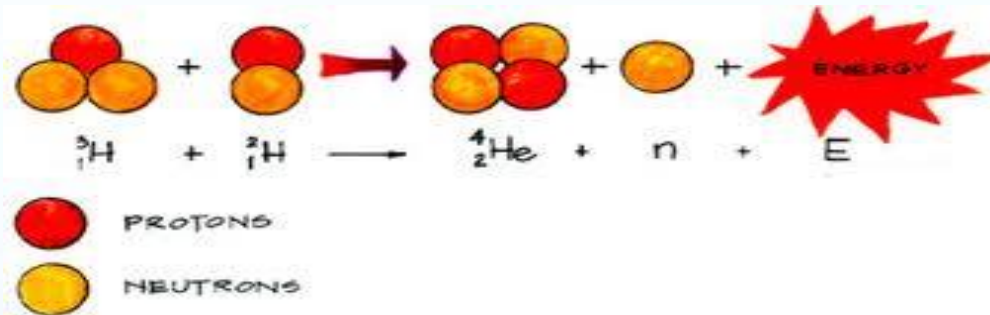
- **Unit** used to measure **distances in the universe**.
- Equal to the **DISTANCE** that **light travels in 1 year**.
 - 1light year = 6 trillion miles!
- Light travels at 300,000 km/sec (186,000 mi/sec)
 - Our Galaxy, **the Milky Way** is about **100,000** light years in diameter!
 - The second closest star to us is **over 4** light years away!



Our own galaxy,
the Milky Way!

Stars

- Massive, dense balls of gas (mostly hydrogen).
- They give off tremendous amounts of **ENERGY**.
- Powered by **fusion reactions**:
Hydrogen atoms fuse to form Helium atoms.



- This is a **THERMO-nuclear** reaction:
 - Thermo = heat (released)
 - Nuclear = involves the **NUCLEUS** of the atom

Star Anatomy

1. Core:

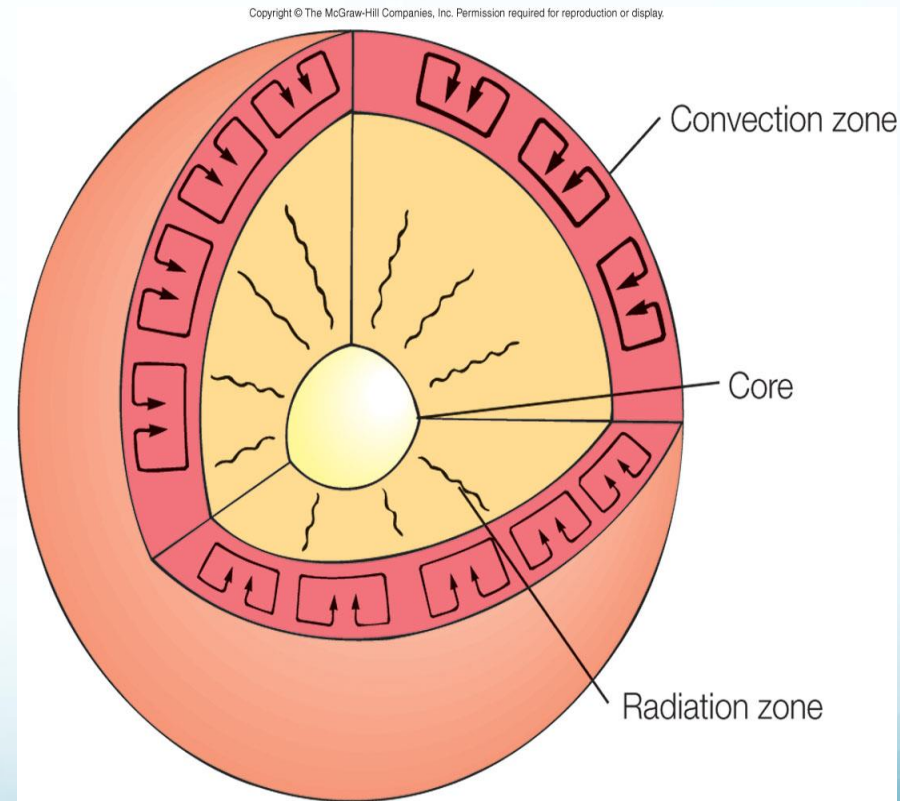
- Very **hot, dense, central** region.
- **Nuclear fusion** occurs here.
- Releases **electromagnetic radiation**

2. Radiation zone:

- Region of **compressed gas**.
- Takes radiations **thousands of years** to pass through it!
- Less dense than core.

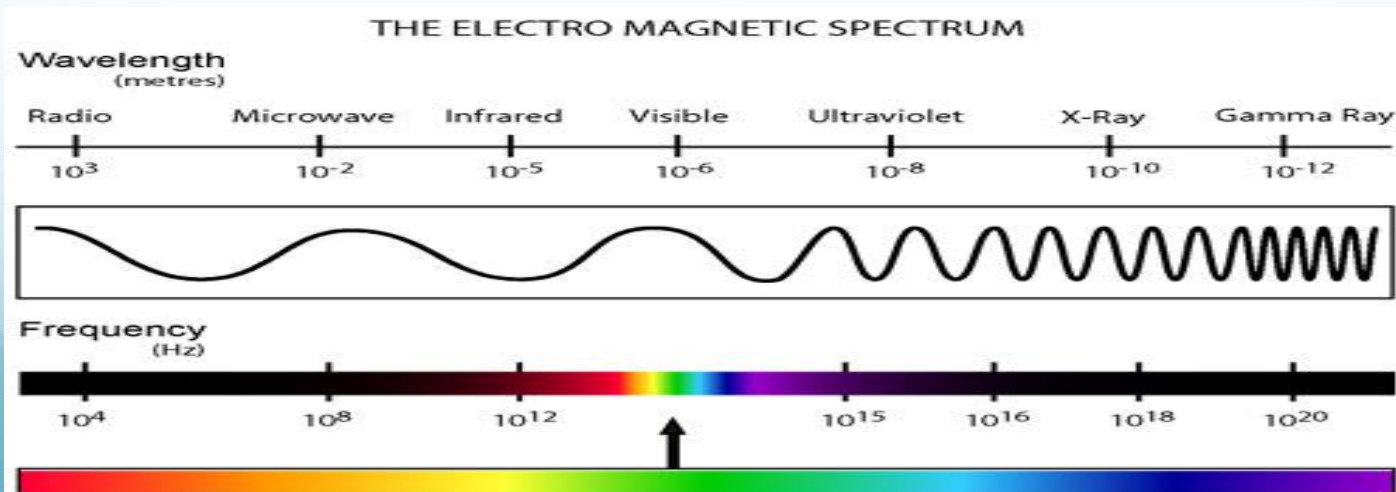
3. Convection zone:

- Here **hot gases rise, cool and sink** again.
- This **process emits light, heat and other electromagnetic radiation** into space



Electromagnetic Radiation

- A term used to describe all the **different kinds of energies** released into space by stars such as the Sun.
- They all **travel in waves** and are made of tiny **particles called photons**.
- They differ in their wavelengths.



Star Atmosphere

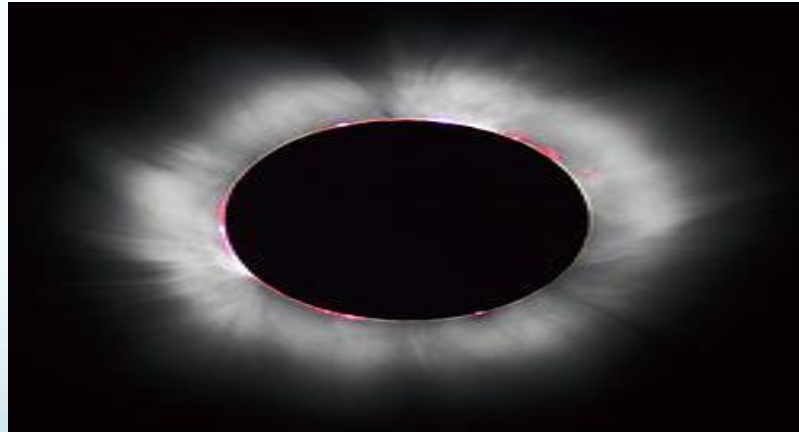
- The **atmosphere** of a star has **3 layers**:

1. Photosphere –

- Innermost layer
- Actual surface of the star
- Bubble-like granules are tops of the convection currents.

2. Chromosphere –

- Middle layer
- Higher temperature
- Reddish light



3. Corona –

- Outermost layer
- Extends millions of miles into space.

Star Color & Temperature

Class	Temperature (kelvins)	Conventional color
O	$\geq 33,000$ K	blue
B	10,000–30,000 K	blue to blue white
A	7,500–10,000 K	white
F	6,000–7,500 K	yellowish white
G	5,200–6,000 K	yellow
K	3,700–5,200 K	orange
M	$\leq 3,700$ K	red

- Stars have **different colors**.
- Their **color** is mostly related to their **surface temperature**:
 - Blue: hottest
 - Red: coolest
- **Classification scheme**:
 - Based on temperature **hottest to coolest** or **OBAFGKM**
 - **Only Bored Astronomers Find Gratification Knowing Mnemonics!!**

<http://www.youtube.com/watch?v=lurFmd8xDe0>

Brightness of Stars

- Measuring Brightness:

1. **Apparent Magnitude:**

Brightness as it appears from Earth.
(depends on distance)

2. **Absolute Magnitude:**

How bright a star **ACTUALLY** is.
This is an intrinsic quality of the star
and known as **LUMINOSITY**.

Luminosity:

Amount of light the star emits.

APPARENT MAGNITUDE



ABSOLUTE MAGNITUDE

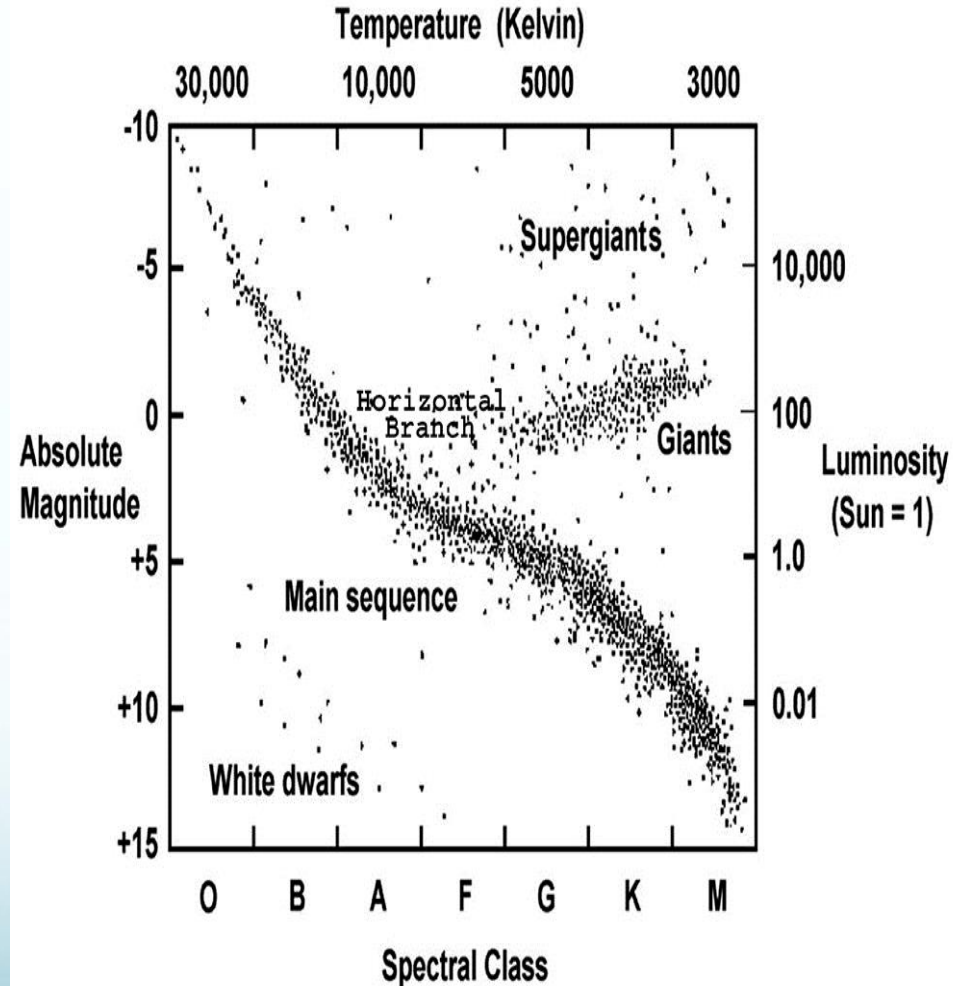


H – R Diagram

Hertzsprung-Russell Diagram

- Relationship between **luminosity** (or absolute magnitude) and **temperature** (or spectral class) of stars.
- Shows how stars change over time.
- Some star stages:
 - Main sequence stars
 - Red giants
 - White dwarfs

<http://www.youtube.com/watch?v=Kqe6F-Qf9Tk>



Star Evolution

- How stars change throughout their life.
- Stars are born, live, grow old, die.
- The lifetime of a star depends on its **mass**:
 - ***Less massive*** stars have ***longer lives...***
Fuse hydrogen SLOWER
 - ***More massive*** stars have ***shorter lives...***
Fuse hydrogen FASTER
- <http://www.youtube.com/watch?v=4s7vyDLgk3M>

Nebula

- The **birthplace** of stars.
- A massive cloud of gas and dust, **mostly hydrogen**.
- This cloud collapses into clusters...due to **gravity**.
- Eventually a **PROTOSTAR** forms.
- **Protostar** = a newborn star.



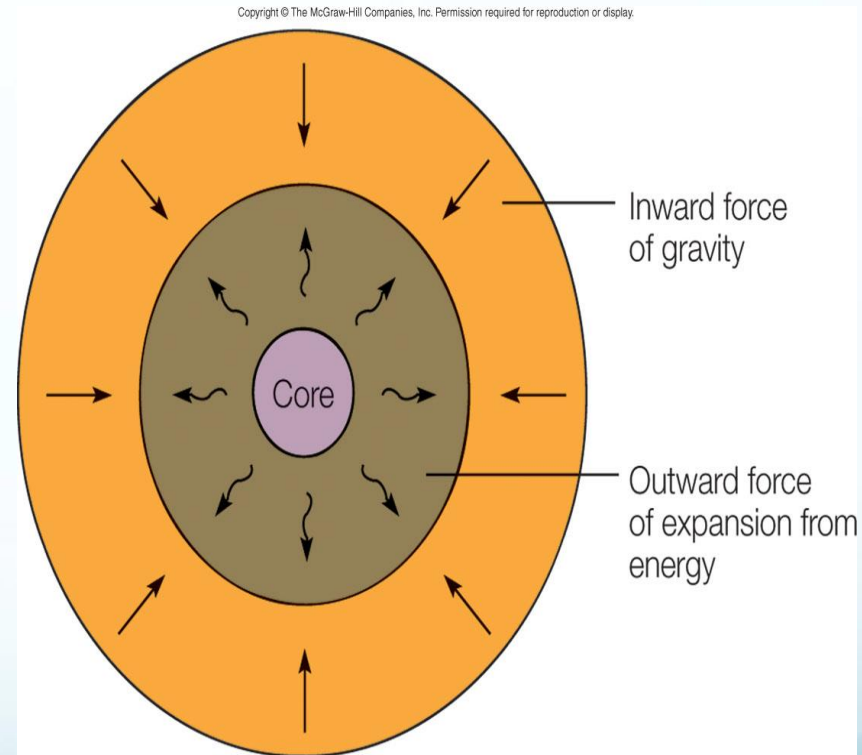
Main Sequence

This **Protostar** eventually settles into a **balance** of the **2 forces** acting on it:

- 1) **Inward** force of **gravity**
- 2) **Outward** force of **pressure**
(from nuclear fusion)

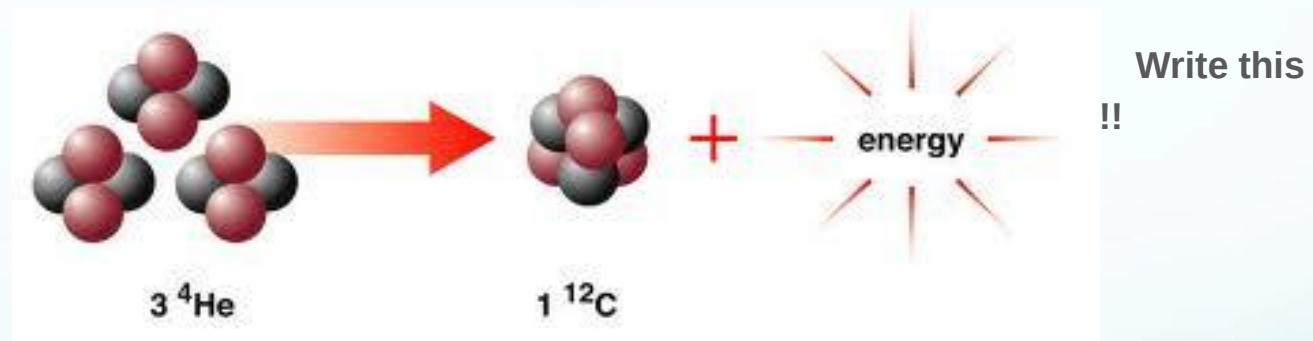
It is now called a **Main Sequence Star.**

Stars spend most of their life in this stage!!!



Red Giant

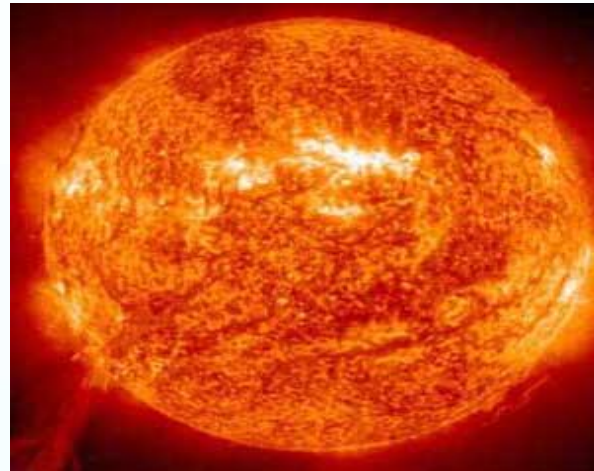
- **Main Sequence** stars will eventually run out of hydrogen fuel...
- When this happens, the star will start fusing **helium** to form **carbon**. $3\text{He} \rightarrow \text{C} + \text{energy}$



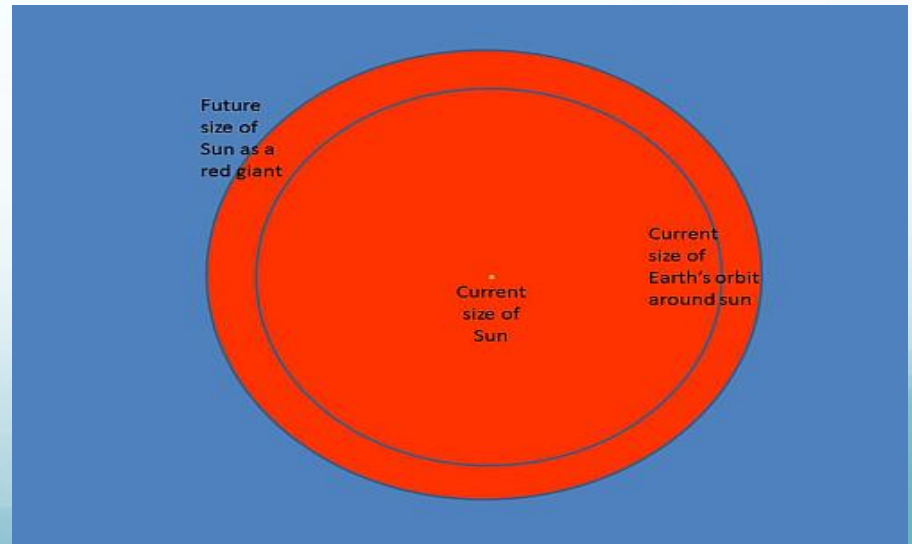
- This reaction gives off more energy and the star will **expand** into a **Red Giant**.

More about Red Giants

- A Red Giant is a star in **old age**...
- It **expands** and swallows up any planets in its orbit.



<https://www.youtube.com/watch?v=r35EookK-vFs&spfreload=10>

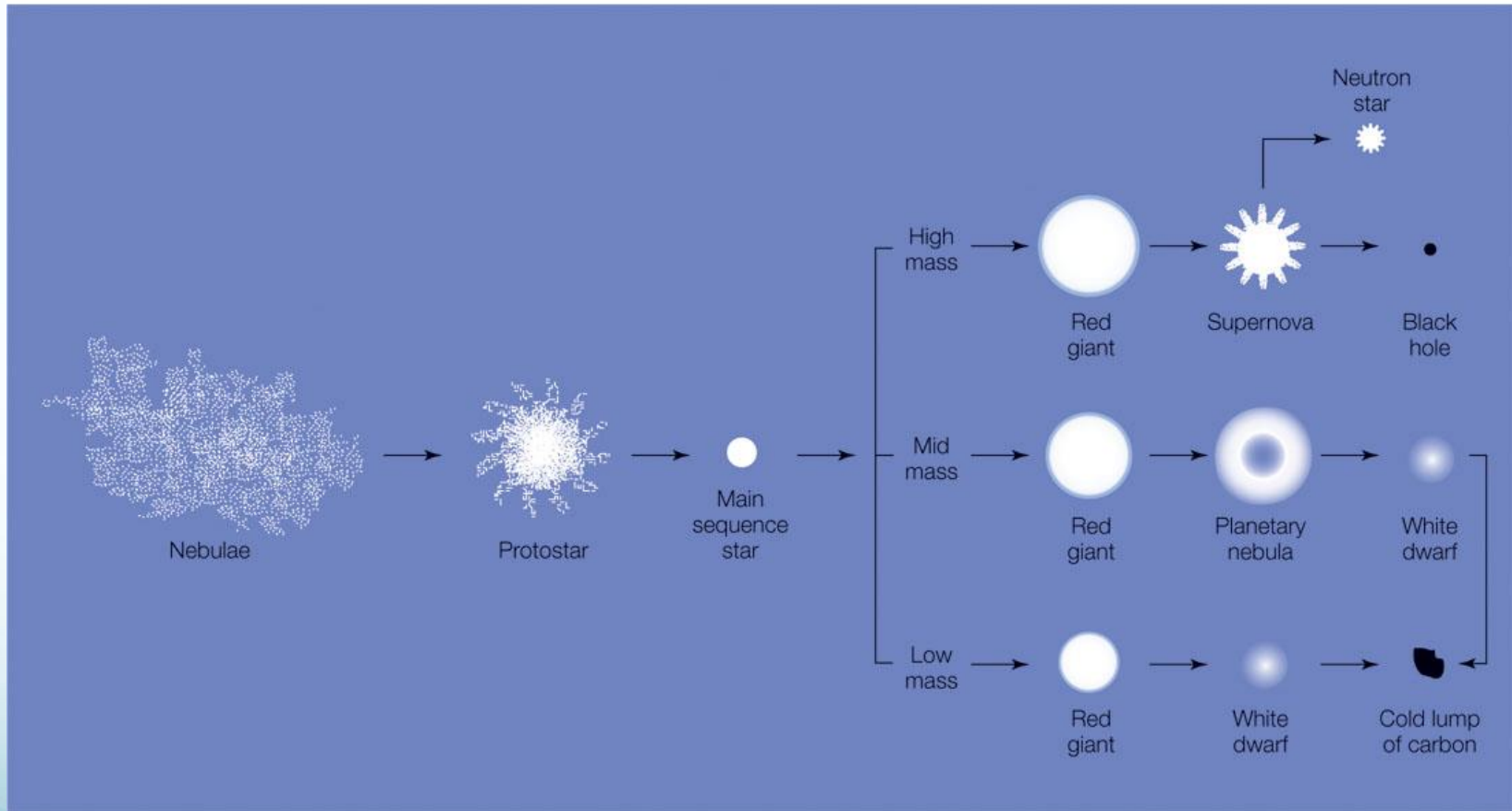


Mass Decides the Rest!

- **Three possible outcomes for a Red Giant:**
 1. Low mass stars –
will collapse into a **White Dwarf**. (our sun)
 2. Mid mass stars –
will form a **planetary nebula** and then a
White Dwarf.
 3. High mass stars –
will explode into a **Supernova** and then form a
neutron star or a **black hole**.

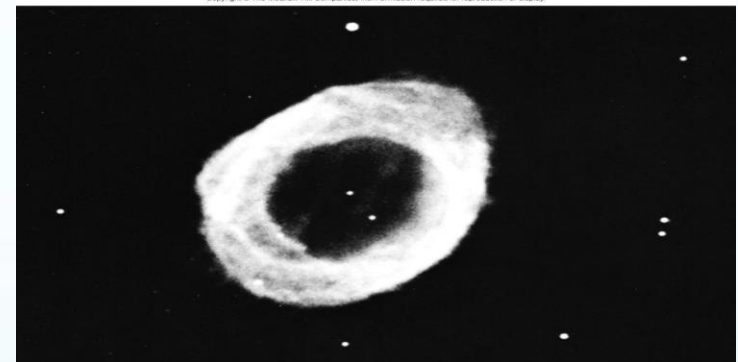
Star Life Cycle Summary

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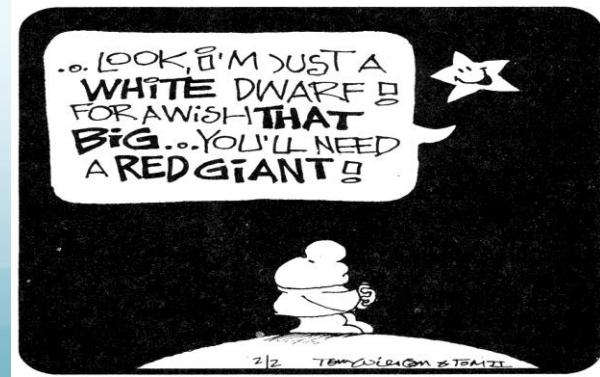


The End → Low & Mid Mass Stars

- Star core is now all **carbon**, surrounded by **Helium** and **Hydrogen**.
- With less fusion pressure gravity wins and the star collapses.
- The outer layers are blown away...this forms a **planetary nebula**.
- The carbon core contracts to form a **white dwarf**.



Ziggy



The End → High Mass Stars

- Carbon starts to fuse!
- This causes...
 1. Many elements to form...all the way up to **IRON**.
 2. Finally, the star collapses and explodes.
 3. This is a **supernova**!



Supernova!

- <http://www.youtube.com/watch?v=tXV9mtY1AoI>
- The **end event** for **high mass** stars.
- **Creates all the elements of the Periodic Chart!**
- What's left???

Neutron star

OR

Black Hole

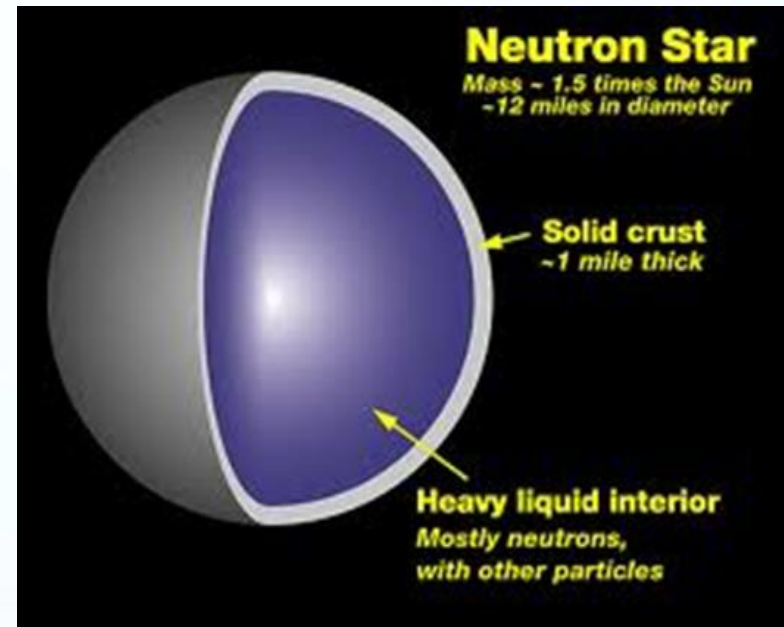
The Periodic Table
of Elements

1 H 1.01																	18 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 15.99	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97	
87 Fr (223)	88 Ra (226)	89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)	

End States for Massive Stars

1. Neutron star:

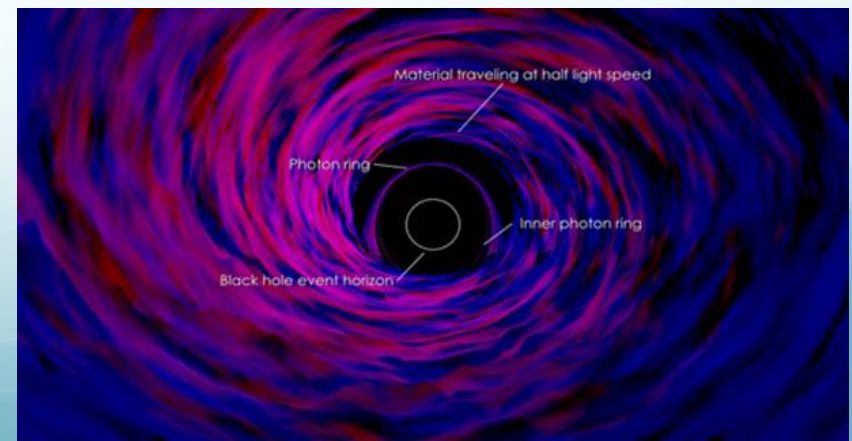
- Remaining **core is smaller**
- **Gravitational pressure** fuses protons and electrons into **neutrons**.
- A **rotating neutron star** emits light and is called a **Pulsar**.



2. Black hole:

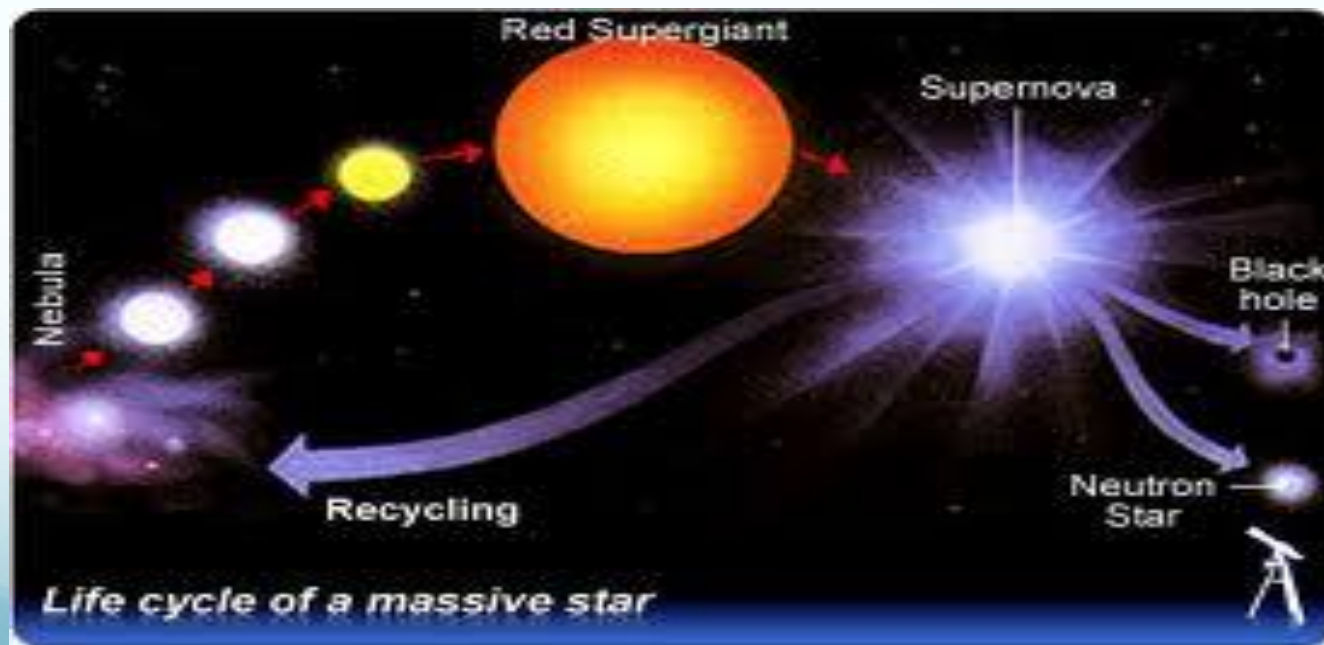
- Remaining **core is bigger**
- Gravitational pressure overwhelms all forces!
- Even light cannot escape the **dense, compact mass** of the Black Hole!

Gravity is the most important force in the universe!!



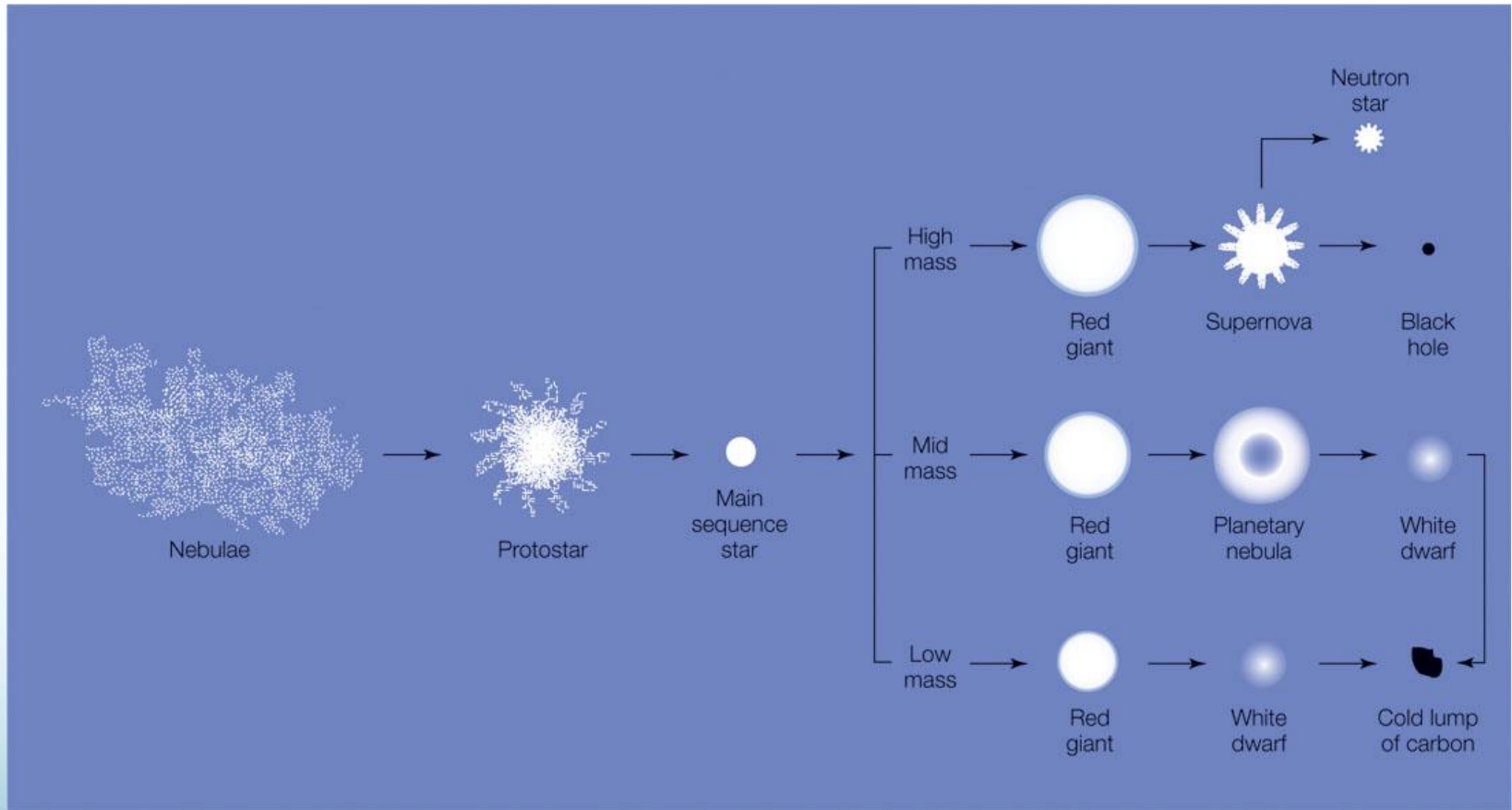
Neutron Stars & Black Holes

- <http://www.youtube.com/watch?v=awzk6YbP7QA&feature>



Star Life Cycle Summary

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<http://www.youtube.com/watch?v=mzE7VZMT1z8>

Galaxy

- A large assembly of **millions to hundreds of billions** of stars. Along with **gas and dust**.
- Held by **gravitational forces** of all its member stars
- A **basic unit** of the universe.
- Classified by their **shapes** into **three main types**.



3 Types of Galaxies



Spiral

have arms of stars, gas, and dust that curve away from the center of the galaxy in a spiral pattern

Ex. – Milky Way



Elliptical

shaped like spheres or eggs;
have almost no dust or gas
between stars;
contain old stars



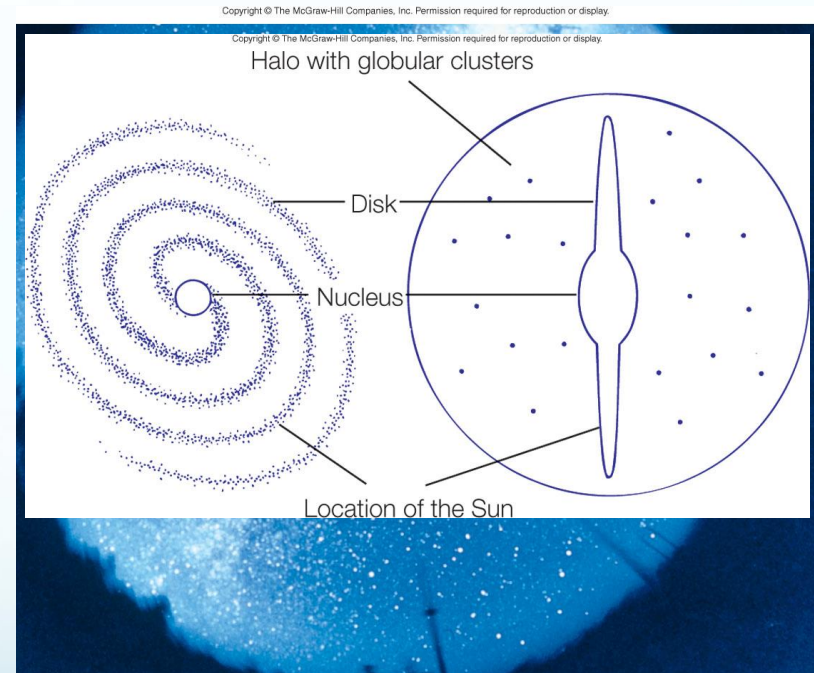
Irregular

faint galaxies
without a definite shape; smaller than the other types of galaxies; contain fewer stars

The process of galaxies colliding to create a larger galaxy is known as “galactic cannibalism.”

The Milky Way

- Our galaxy!!
- Contains about **300 billion stars**
- **Diameter** ~100,000 ly
- **Structure:**
 1. **Nucleus** – concentration of stars
 2. **Rotating flattened disk** of more stars, hydrogen gas and other elements.
 3. **Spherical halo** - Containing star clusters.



Other Galaxies

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- **Our nearest neighbors:**
 1. Dwarf galaxy -
 - ~1,000 light years in diameter
 - Being pulled apart by the gravity of our galaxy.
 2. Andromeda -
 - 2 million light years away
 - Very similar to Milky Way
- **Billions** of other galaxies exist in the universe.

Star Systems

- A smaller number of stars **within a galaxy** that are bound by gravity.
- May consist of two stars (known as a **binary system**), three stars (known as **ternary systems**) or up to hundreds or thousands of stars (a **star cluster**)
 - Example is the Pleiades Star Cluster!



The Big Bang Theory

- Theory that the universe began about **13.7 billion years ago** from an initial **release of energy**.
- The Big Bang theory is a **model** which helps explain **observed facts** about the universe.
- **Supporting evidence:**
 1. Expansion of the Universe.
 2. Cosmic background radiation.

Misconception:
Describing this theory as the “Big Bang” misnomer because there really was not an explosion.

Expansion of the Universe

- In 1929, Edwin Hubble, observed that galaxies were moving away from each other. This idea of an "**expanding**" universe formed the basis of the Big Bang theory.
- This is now known as "**Hubble Law**".
- **Hubble Law** – the farther away a galaxy is, the faster it is moving away from us!

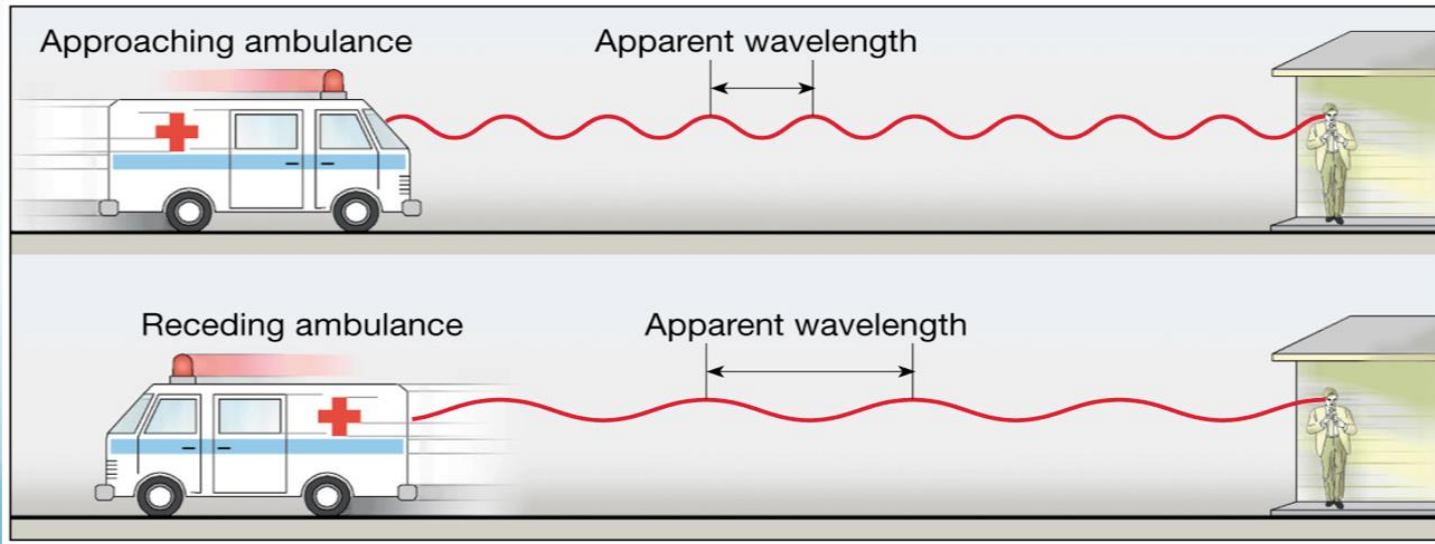


"Equipped with his five senses, man explores the universe around him and calls the adventure Science."

Edwin Powell Hubble

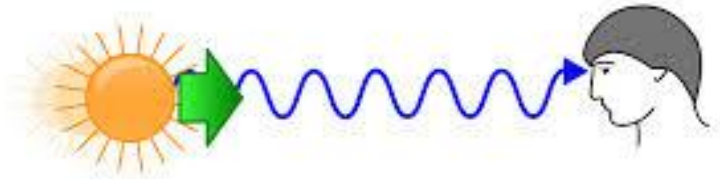
The Doppler Effect

- The apparent change in wavelength of a sound or light source caused by the relative motions of the source and/or the observer.
- <http://www.youtube.com/watch?v=Kg9F5pN5tII>

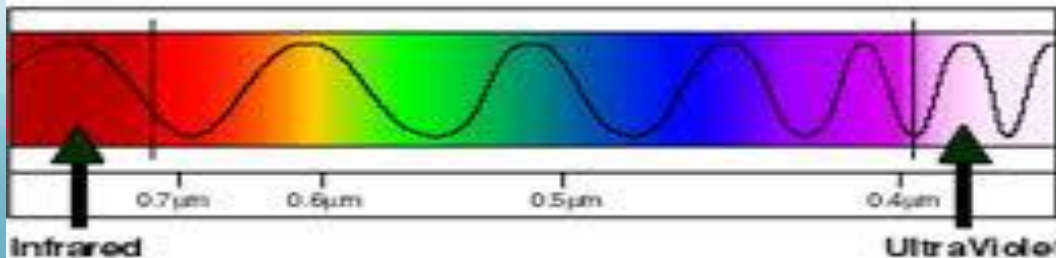


Redshift

- A characteristic of light waves. As the wavelength spreads out it “**shifts**” into the red end of the spectrum:



Red Shift/Blue Shift
The Doppler Effect with Light



Big Bang Theory & Doppler Effect

- <http://www.youtube.com/watch?v=0rJPvGML9A0>



More Evidence: Cosmic Background Radiation

- In 1965, astronomers Arno Penzias and Robert Wilson discovered **Cosmic Background Radiation** and won the 1978 Nobel Prize.

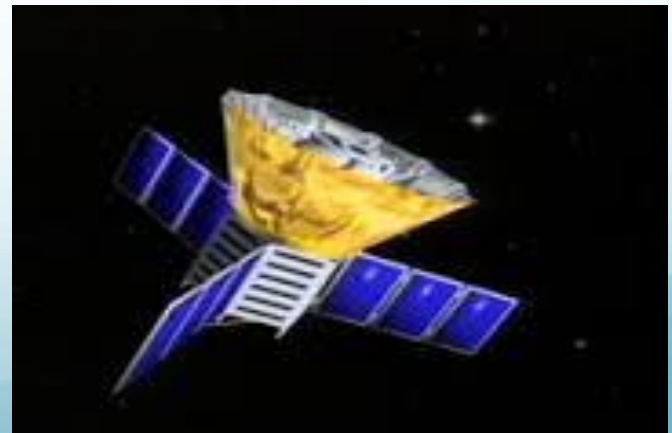


- http://www.youtube.com/watch?v=McvfJ_flYvo

COBE

Cosmic Background Explorer

- Launched in 1989 to **investigate** cosmic (microwave) background radiation and provide measurements that would shape our understanding of the universe.
- http://www.youtube.com/watch?v=_mZQ-5-KYHw



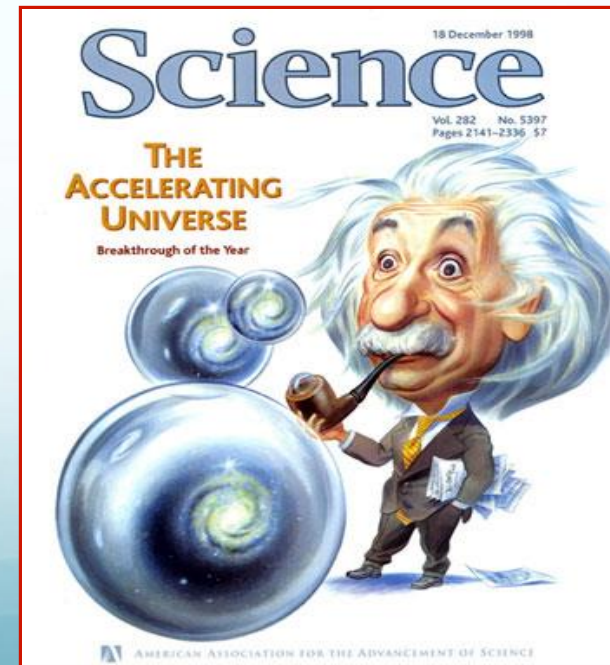
Hubble Space Telescope

- Named in honor of **Edwin Hubble** and launched in 1990.
- Hubble is a telescope that orbits Earth. Its position **above the atmosphere** (~350 miles up) gives it a view of the universe that far surpasses that of ground-based telescopes.
- One of NASA's **most successful and long-lasting missions**. It has beamed hundreds of thousands of images back to Earth.
- http://www.youtube.com/watch?v=oAVjF_7ensg

Big Bang in the Future

- The Big Bang model describes **our current** understanding of the universe.
- New discoveries, like dark matter and dark energy, will lead to **refinement** of today' s theories.
- **Science is a process!!**

The more we
know...the more
we know we don' t
know!!



Universe Topics

- Quasars Theory of Relativity
- Pulsars The Big Bang
- Andromeda Galaxy Hubble telescope
- Birth of a star Extraterrestrial life
- Galaxy clusters Ancient Astronomy
- Neutron stars Constellations
- Classifying stars Solar Eclipse
- Classifying galaxies Supernova
- Black holes Space exploration
- Time travel Travel at the speed of light
- Dark matter The Milky Way
- Cosmic rays Expanding Universe