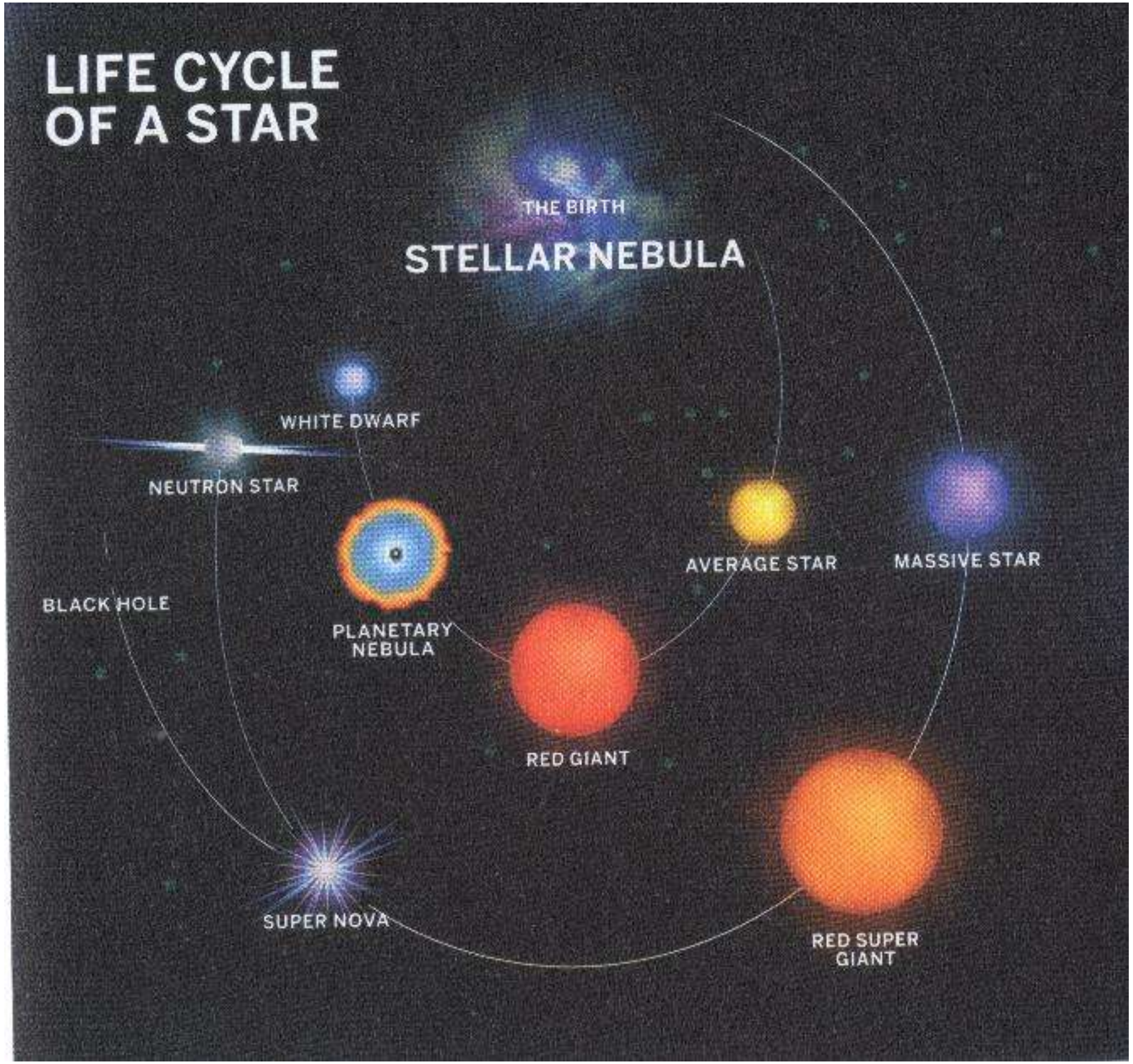
Life Cycle of Stars

Introduction

Jim Rauf


LIFE CYCLE
OF A STAR
THE BIRTH
STELLAR NEBULA
WHITE DWARF
NEUTRON STAR
AVERAGE STAR
MASSIVE STAR
BLACK HOLE
PLANETARY
NEBULA
RED GIANT
SUPER NOVA
RED SUPER
GIANT

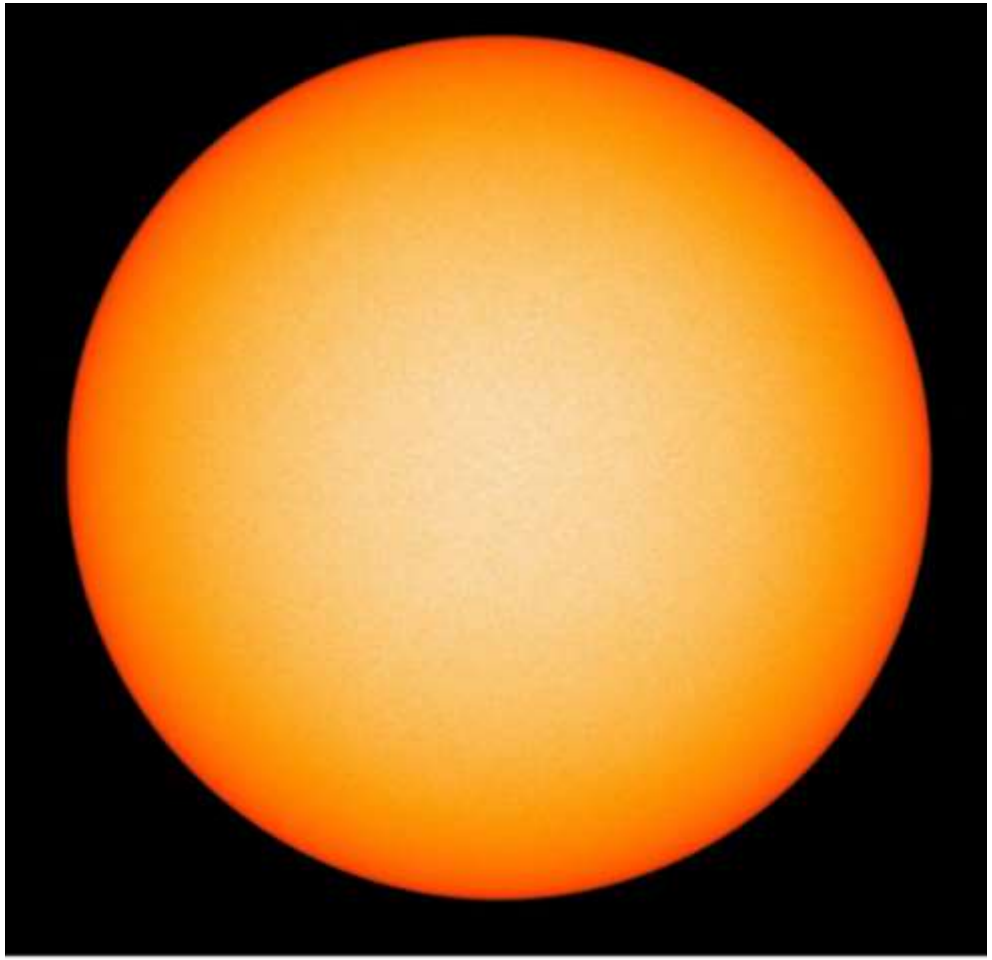
Introduction-Topics

- Definition of Star
- Description of Stars
- Number of Stars in Visible Universe
- Classification of Stars-R-M Chart
- Main Sequence Stars
- How Do We Know About Stars
- Do Stars Have Planetary Systems
- Matter for First Stars-Big Bang Theory
- Hubble and Einstein’s Theory of Relativity-Expanding Universe
- Forces of Nature-Gravity, Electromagnetism, Strong and Weak Nuclear Forces
- Star Formation-Proto Stars
- Nuclear Fusion (Burning)-Source of Stars’ Energy
- Where Does Energy Go
- Radiation Spectrum –Light
- Composition of Stars-Finding Elements from Spectroscopy
- Types of Stars-Their Lives
- How Stars Die
- What Happens to Stars’ Matter
- Super Novae-Sources of Elements
- Our Star –The Sun
- The Sun’s Future

Definition of a Star

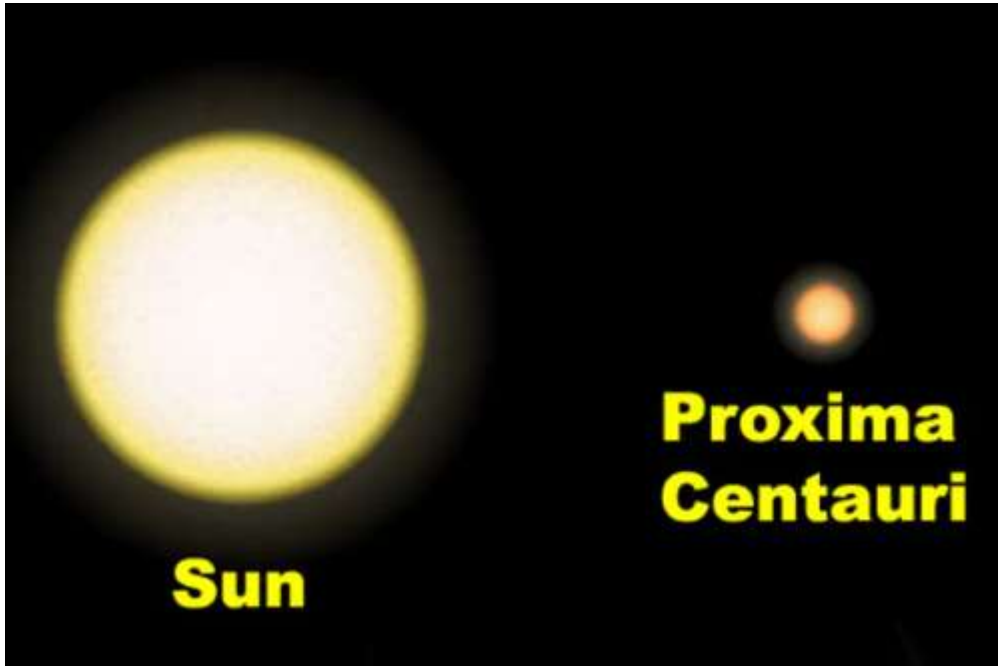
- A star is any **massive self-luminous** celestial body of **gas** that **shines by radiation** derived from its **internal energy sources**
    - Nuclear fusion
- Most stars have masses between 0.3 to 3 the mass of the Sun (**one solar mass**)
- The theoretical lower mass limit for an ordinary star is about 0.075 solar mass

- **The Sun**
- Diameter: 1,390,000 km (862,000 miles)
- Mass: 1.989e30 kg (4.376e30 lbs)
- Surface Temperature 5,800 K (~10,000 F)
- Core Temperature 15,600,000 K (~28,000,000 F)

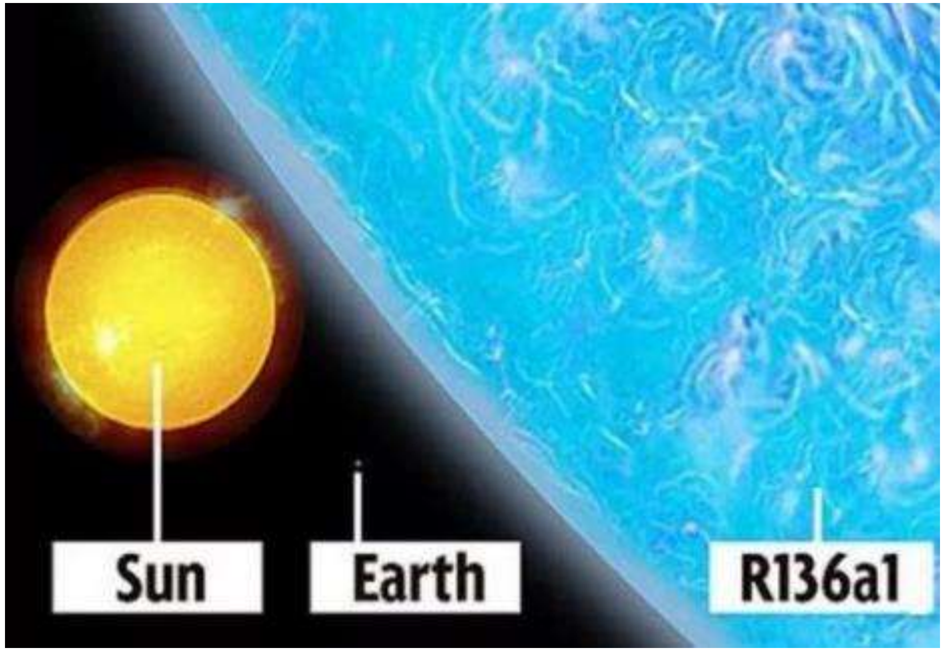


Definition of a Star

- The smallest stars in general are **red dwarfs**
- **Proxima Centauri** the star nearest to the Earth is a red dwarf
- These stars are only about 50% or less the size of the Sun

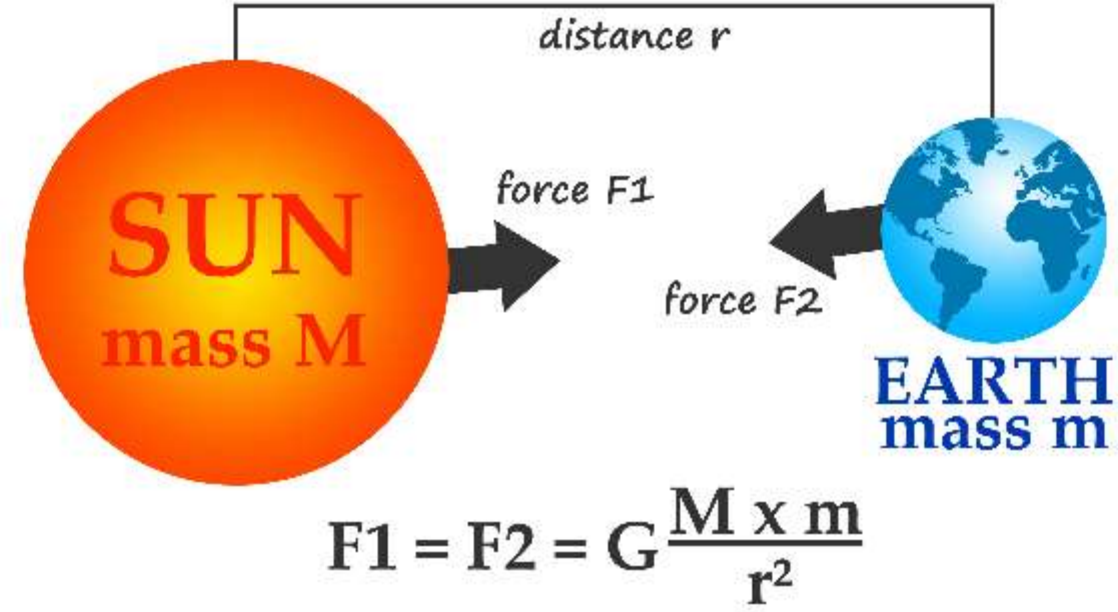


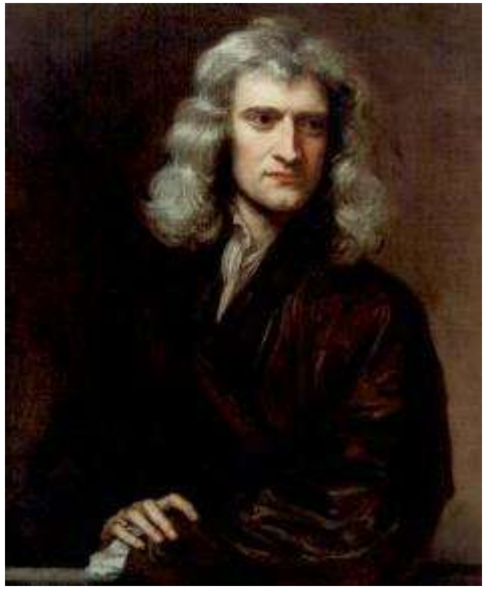
- The star with the mass discovered to date is **R136a1**, with a mass about 265 solar masses
- The theoretical upper limit to the masses of **nuclear-burning stars** (the **Eddington limit**) is several hundred solar masses



A Few Equations

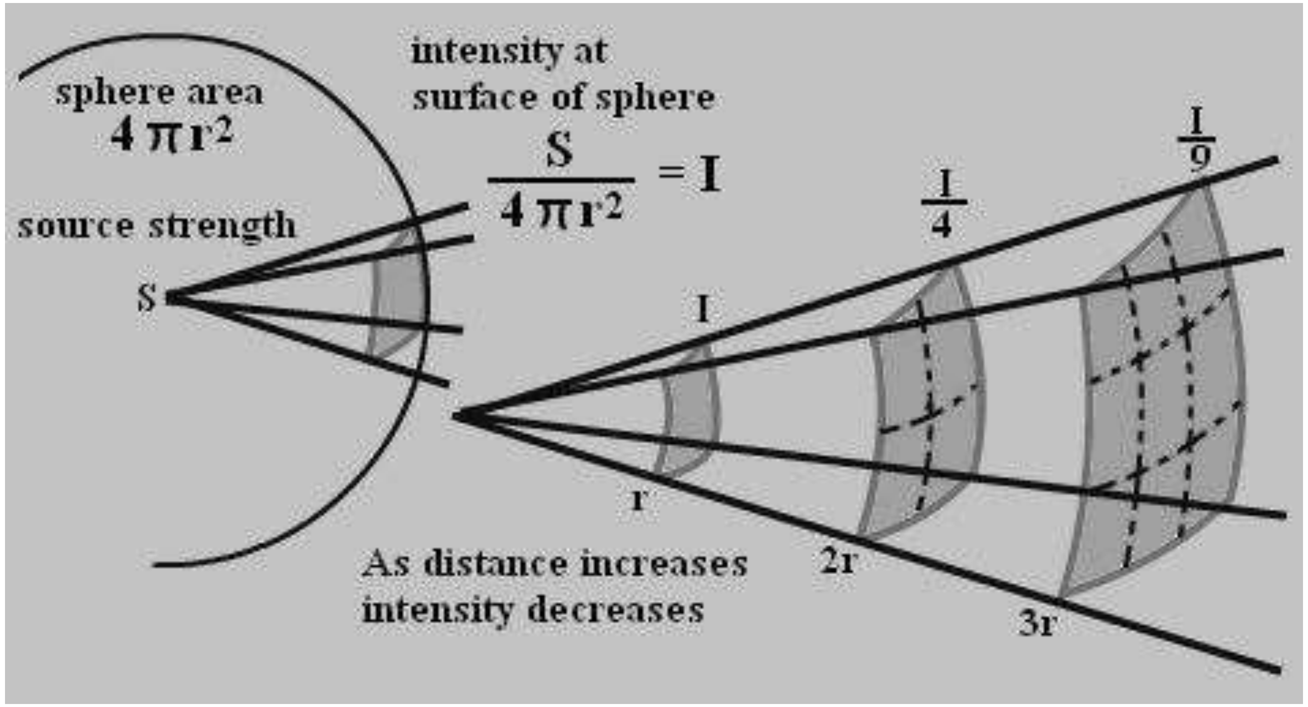
- **Isaac Newton** (1642-1726)
- **Classical Universal Law of Gravity**





The Inverse Square Law

- **Inverse Square Law**

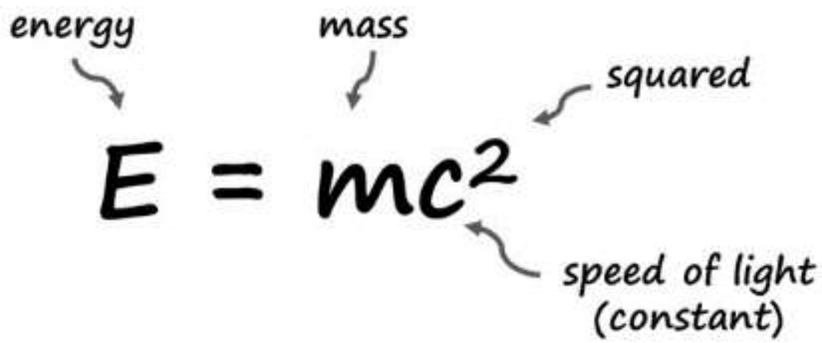


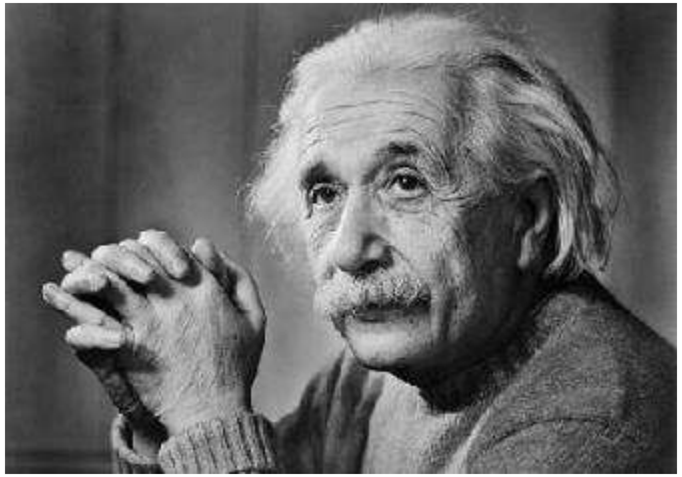
- **Intensity** decreases as distance from its source increases
- At the surface of the Sun the intensity of the **solar radiation** is ~ **6.33×10 7 W/m 2** (watts, per unsquared meter
- At Earth the Sun's intensity is ~**1,367 W/m 2**

- **Inverse Square Law** applies to:
  - Electromagnetic radiation
  - Sound
  - Illumination
  - Electrostatic forces
  - Gravitational force

A Few Equations

- **Albert Einstein** (1879-1955)
- **Energy-Mass Equivalence**





- Source of stellar energy

Powers of Ten-Big Numbers and Small Numbers-Scientific Notation

$10^0 = 1$
$10^1 = 10$
$10^2 = 100$
$10^3 = 1000$
$10^4 = 10{,}000$
and so on.

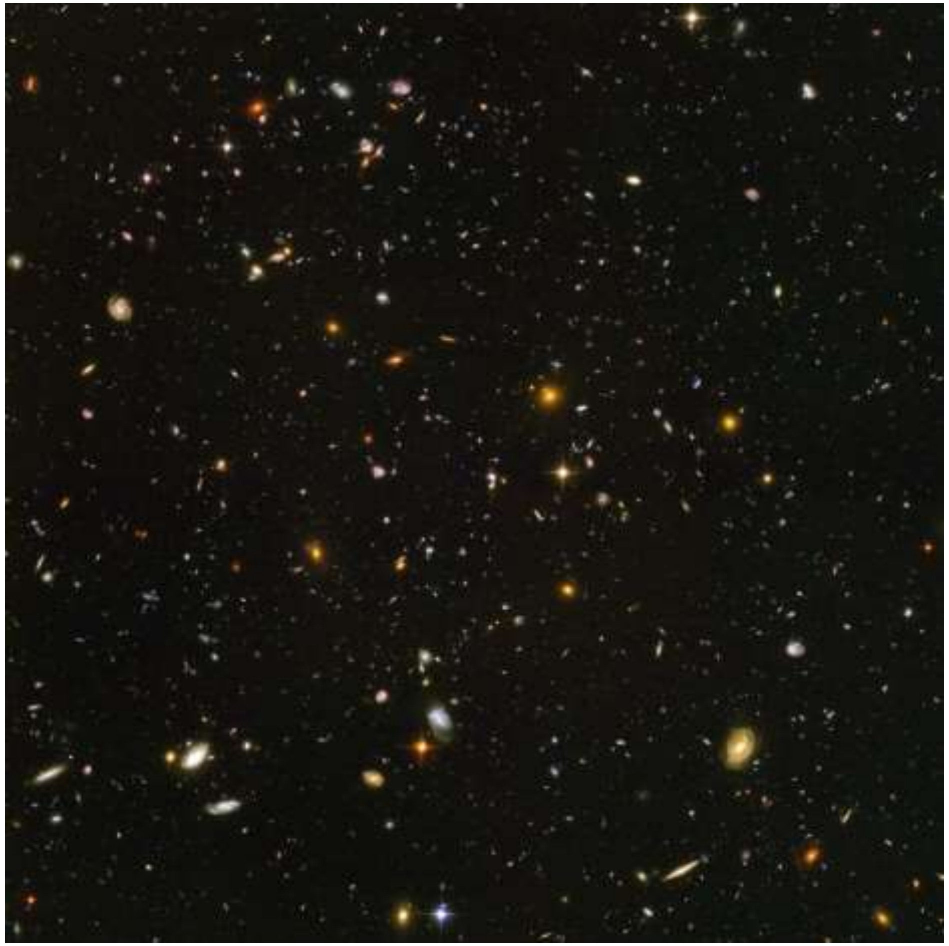
$10^0 = 1$
$10^{-1} = {}^1/_{10} = 0.1$
$10^{-2} = {}^1/_{10} \times {}^1/_{10} = 0.01$
$10^{-3} = {}^1/_{10} \times {}^1/_{10} \times {}^1/_{10} = 0.001$
$10^{-4} = {}^1/_{10} \times {}^1/_{10} \times {}^1/_{10} \times {}^1/_{10} =$
0.0001
and so on

Some numbers written as powers-of-ten:

One hundred (100)	10^2
One thousand (1000)	10^3
One million (1,000,000)	10^6
One billion (1,000,000,000)	10^9
One trillion (1,000,000,000,000)	10^{12}
One one-hundredth (0.01)	10^{-2}
One one-thousandth (0.001)	10^{-3}
One one-millionth (0.000001)	10^{-6}
One one-billionth (0.000000001)	10^{-9}
One one-trillionth (0.000000000001)	10^{-12}

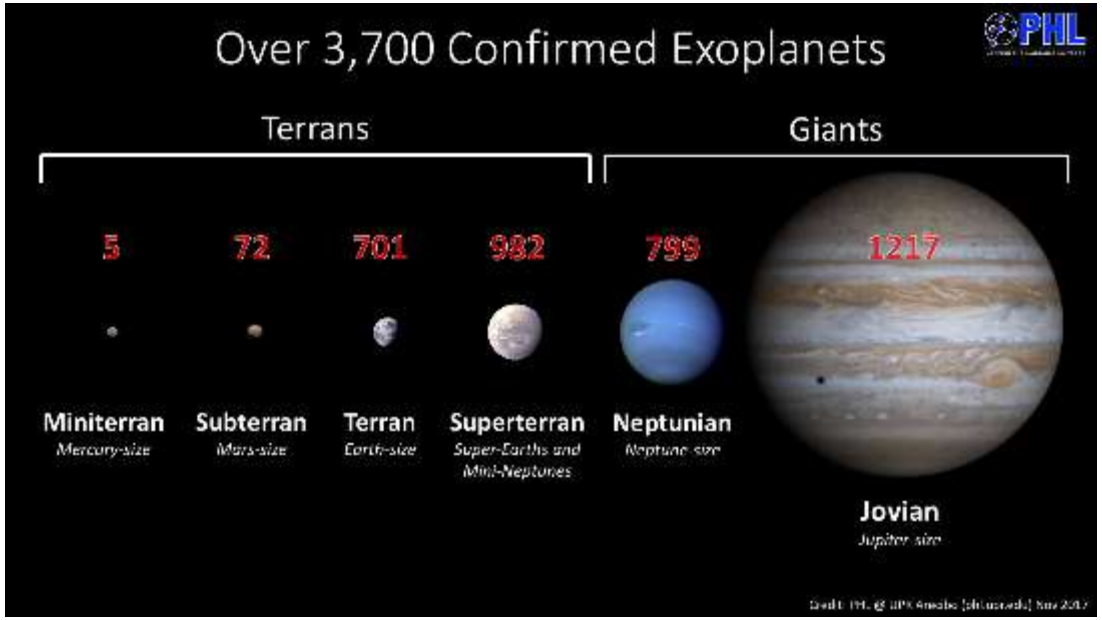
How Many Stars Are There?

- About 3,000 stars are visible to the unaided eye on a clear moonless night
- About 100,000 stars can be seen using a small telescope
- There are an estimated one hundred billion (100,000,000,000) stars in our own Milky Way galaxy, although some estimates range up to four times that many, much depending on the number of brown dwarfs and other very dim stars
- A typical galaxy may contain anywhere between about ten million and one trillion stars
- There may be around **ten billion trillion** (10,000,000,000,000,000,000,000 or 10^22) stars in the observable universe
- Or possibly anywhere up to 10^24



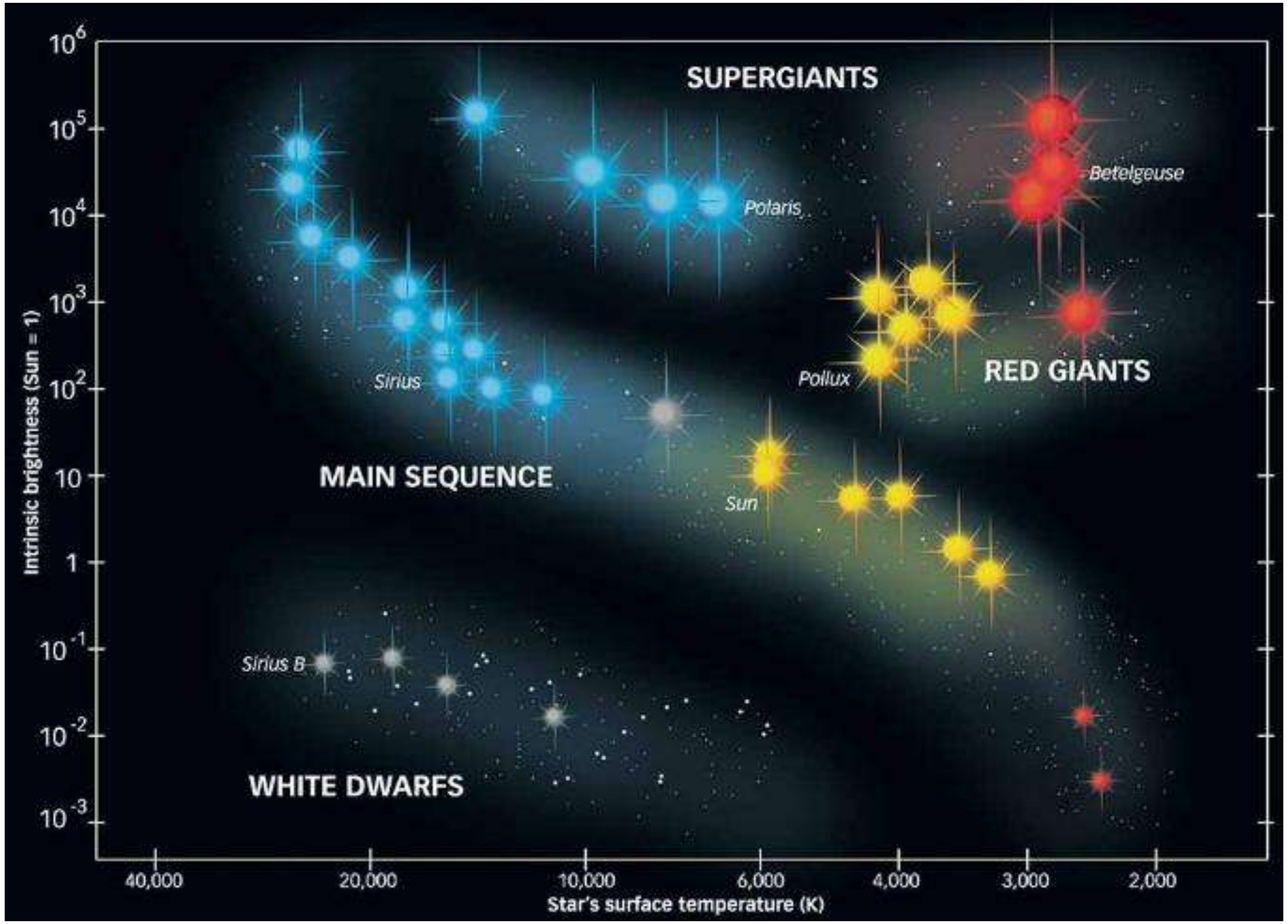
How Many Stars Are There? - Exoplanets

- Worlds orbiting other stars are called “exoplanets,”
- More than 4,000 exoplanets have been discovered and are considered "confirmed"
  - Most are **Jupiter** –size
  - Some are **Earth** size
  - Fewer are **Mars** or **Mercury**- size
- There are thousands of "candidate" exoplanet detections that require further observations in order to say for sure whether or not the exoplanet is real
- The first exoplanets were just discovered about two decades ago
- Since the early 1990s, the number of known exoplanets has doubled approximately every 27 months



- Recent findings suggest that the planets of stars with multiple planets orbit in near circular orbits (like those of the Sun)
- Planets of stars with one or two planet systems orbit in more elliptical orbits

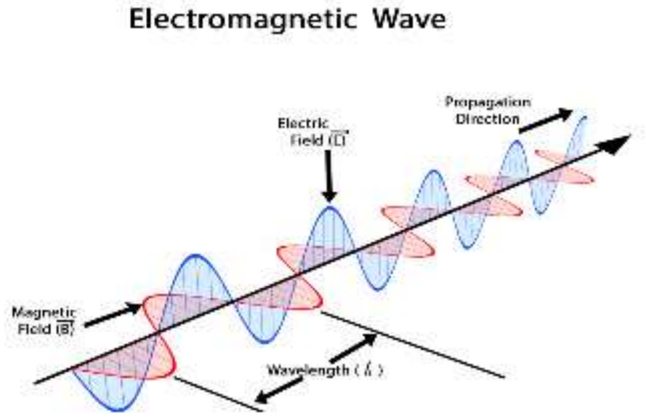
Hertzsprung-Russell Diagram



H-R plot shows that the relationship between temperature and luminosity of a star was not random but instead appeared to fall into distinct groups

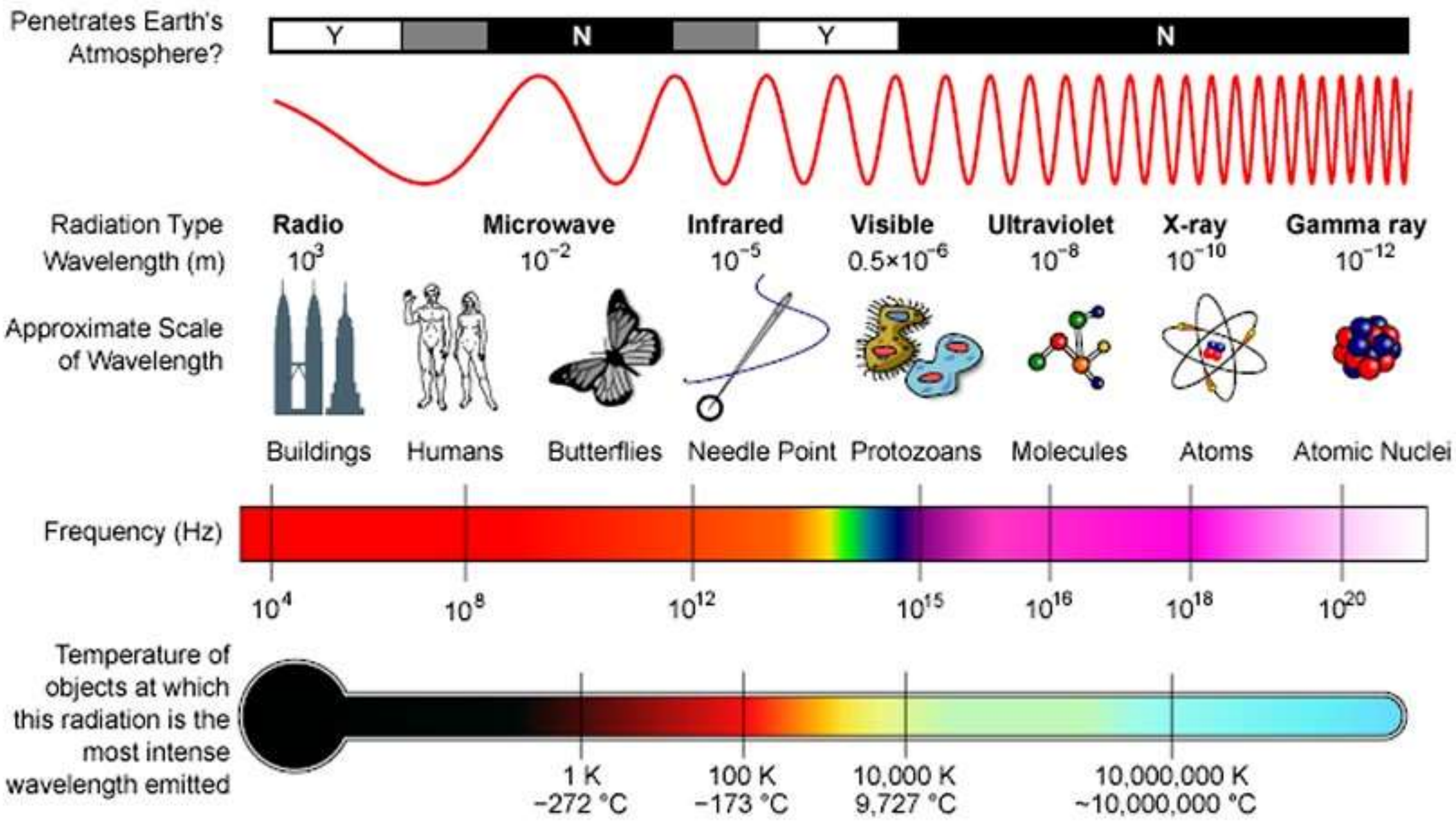
Electromagnetic Radiation-Basis of Knowledge of Stars

- **EM radiation (EMR)**is created when an atomic particle, such as an electron, is accelerated by an electric field, causing it to move
- The movement produces oscillating **electric and magnetic fields**, which travel at right angles to each other in a bundle of light energy called a **photon**
- Photons travel in harmonic waves at the fastest speed possible in the universe: 186,282 miles per second (299,792,458 meters per second) in a vacuum, also known as the **speed of light**
- The waves have certain characteristics: **frequency, wavelength** or **energy**
- The higher the frequency the greater their energy



- Everything from high energy gamma rays, X-rays, ultra-violet, visible, infra-red light, microwaves to radio waves are **EMR**

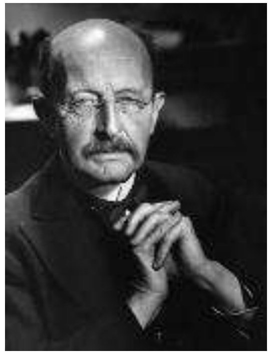
The Electromagnetic Radiation -Spectrum

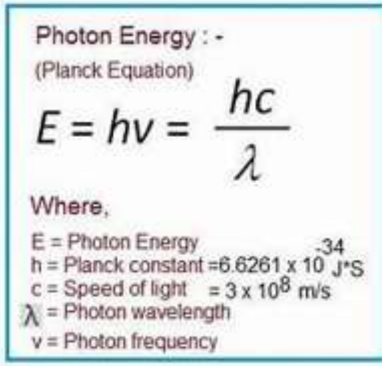


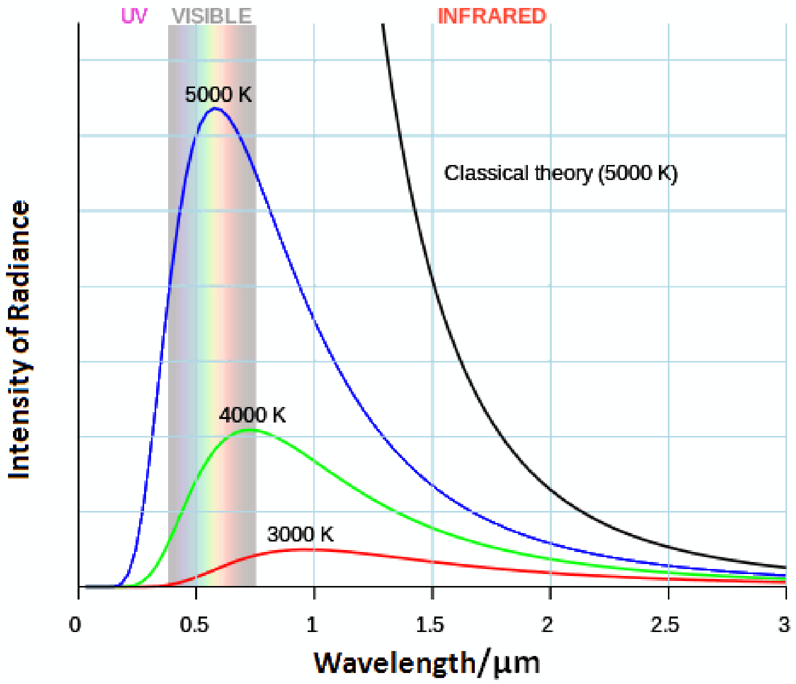
Electromagnetic Radiation

- **Black body** –absorbs all electromagnetic radiation that falls on it
- When heated it radiates energy in the form of **electromagnetic waves**
- They have a broad range of wavelengths such as visible, ultraviolet, and infrared light
- Higher temperatures have higher intensity
- **Max Planck** (1858 –1947) in 1900 made a revolutionary proposal in order to explain the observations
- He proposed that only certain amounts of energy could be emitted – i.e. **quanta**
- Planck found the energy carried by electromagnetic radiation must be divisible by a number now called **Planck's constant**, h
- Energy could then be calculated from the equation

E = hv

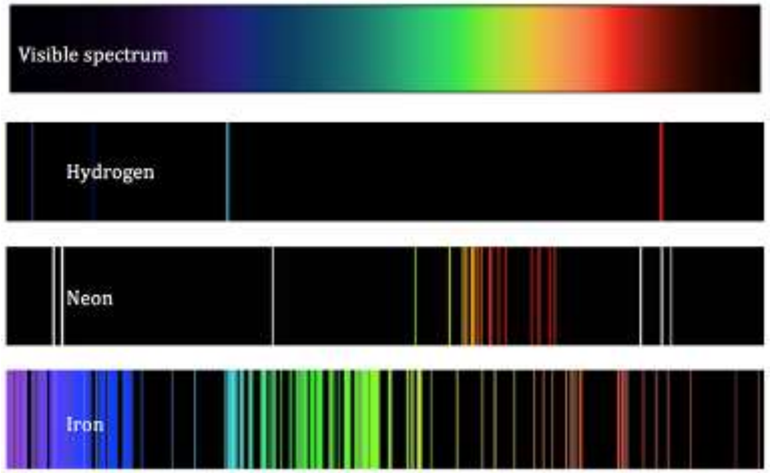






Spectroscopy

- **Spectroscopy** is the study of the interaction between matter and electromagnetic radiation as a function of the wavelength or frequency of the radiation
- The **emission spectrum** of an element is the spectrum of frequencies of electromagnetic radiation emitted due to an atom making a transition from a high energy state to a lower energy state
- The photon energy of the emitted photon is equal to the energy difference between the two states
- Each element's emission spectrum is unique
- Therefore, spectroscopy can be used to identify elements in matter of unknown composition



- Example emission spectra of elements present in the sun
- The **visible spectrum** is shown for reference (top panel) accompanied by the emission spectra of hydrogen, neon and iron
- These show the characteristic frequencies at which these elements emit radiation

Spectroscopy

- In the 1920s, **Cecilia Payne** studied the spectra of stars, and devised a way to figure out the temperature and true chemical composition of star
- She concluded that the atmospheres of stars were:
- 90% hydrogen (by number of atoms)
- 10% helium
- Tiny traces of **heavy elements** (everything else)

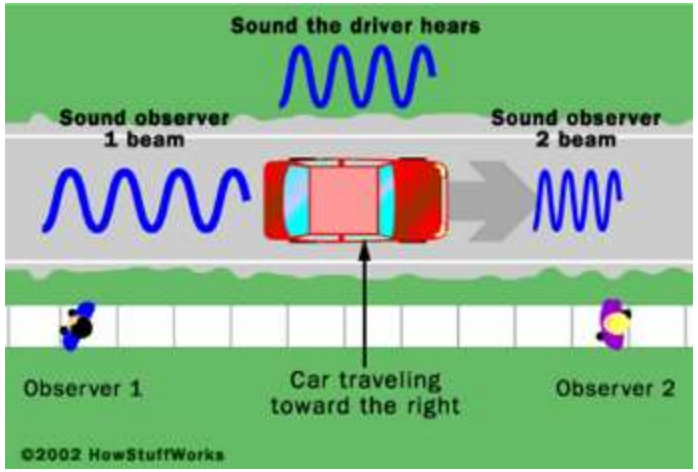
Solar Composition

Element	% by Volume	% by Mass
Hydrogen	90.946	70.682
Helium	8.913	27.509
Oxygen	0.077	0.954
Carbon	0.033	0.303
Neon	0.011	0.170
Nitrogen	0.010	0.108
Magnesium	0.004	0.068
Iron	0.003	0.137
Silicon	0.003	0.069

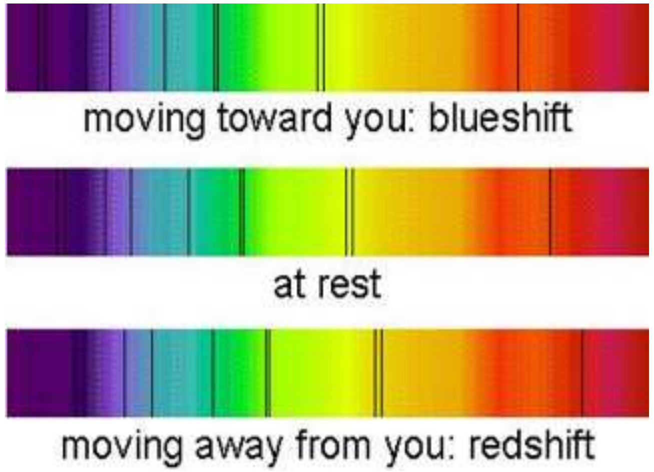
Spectroscopy-Doppler Effect and Motion of Stars

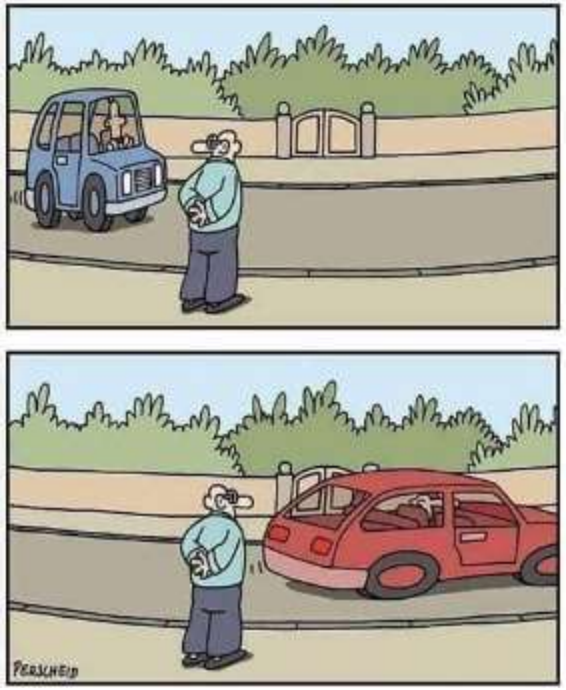
- The motion of a star can be determined by examining its spectrum and applying the **Doppler Effect** property of waves
- Electromagnetic radiation and sound

Sound



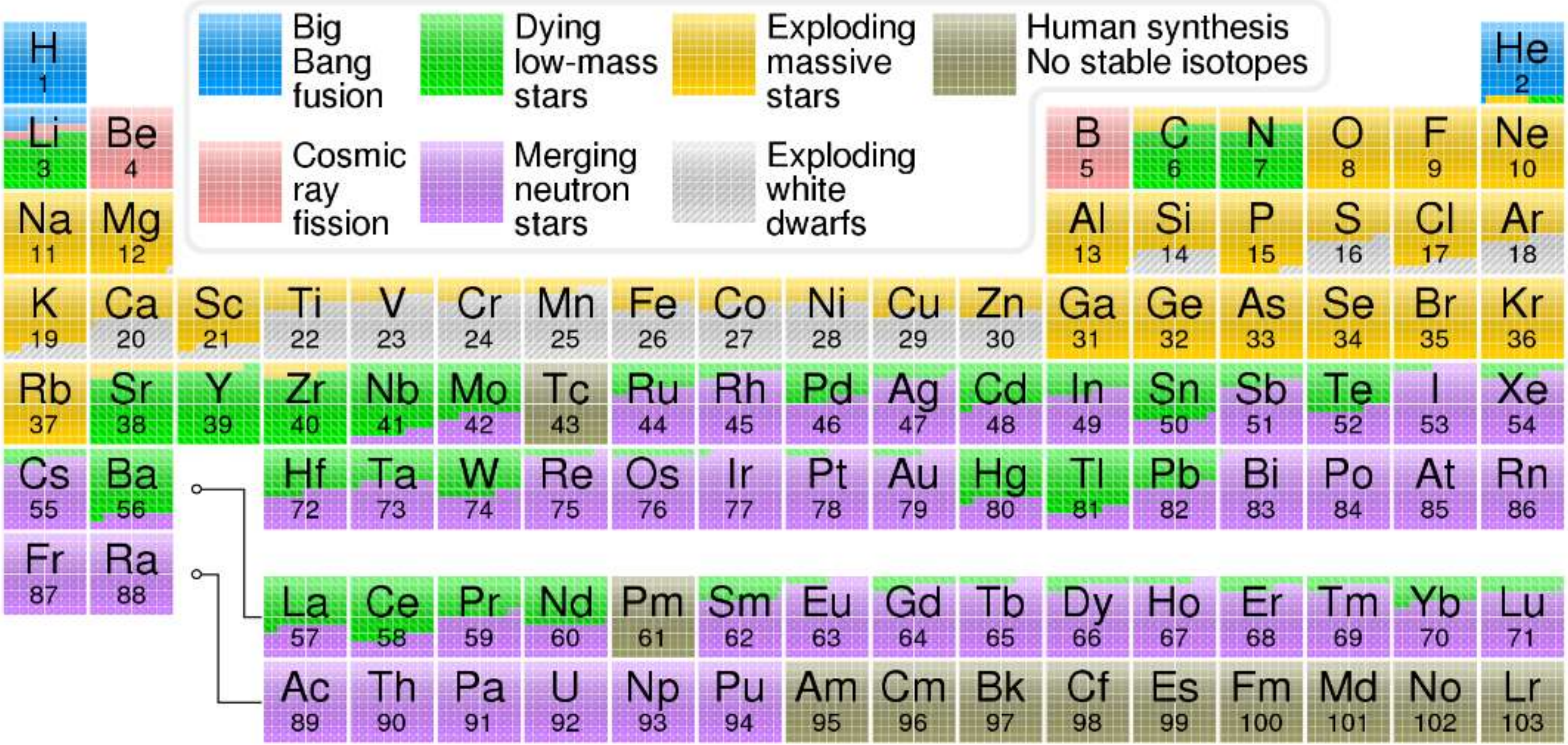
EMR





Red Shift

Composition of Stars-Elements



Next Session

How do we know some things about stars