Test 1 Results

- Remember course grade is based on number of points including review questions, tests, extra credit (some wiggle room)
- 260+ A
  225-259 B
  180-224 C
  150-179 D
- Lowest test score (out of 4) will be dropped
- Test 1 results average = 69
  approximate grade

		#exams
80-110	A	8
64-80	B	4
51-63	C	7
41-50	D	
0-40	F	3

Short Answers

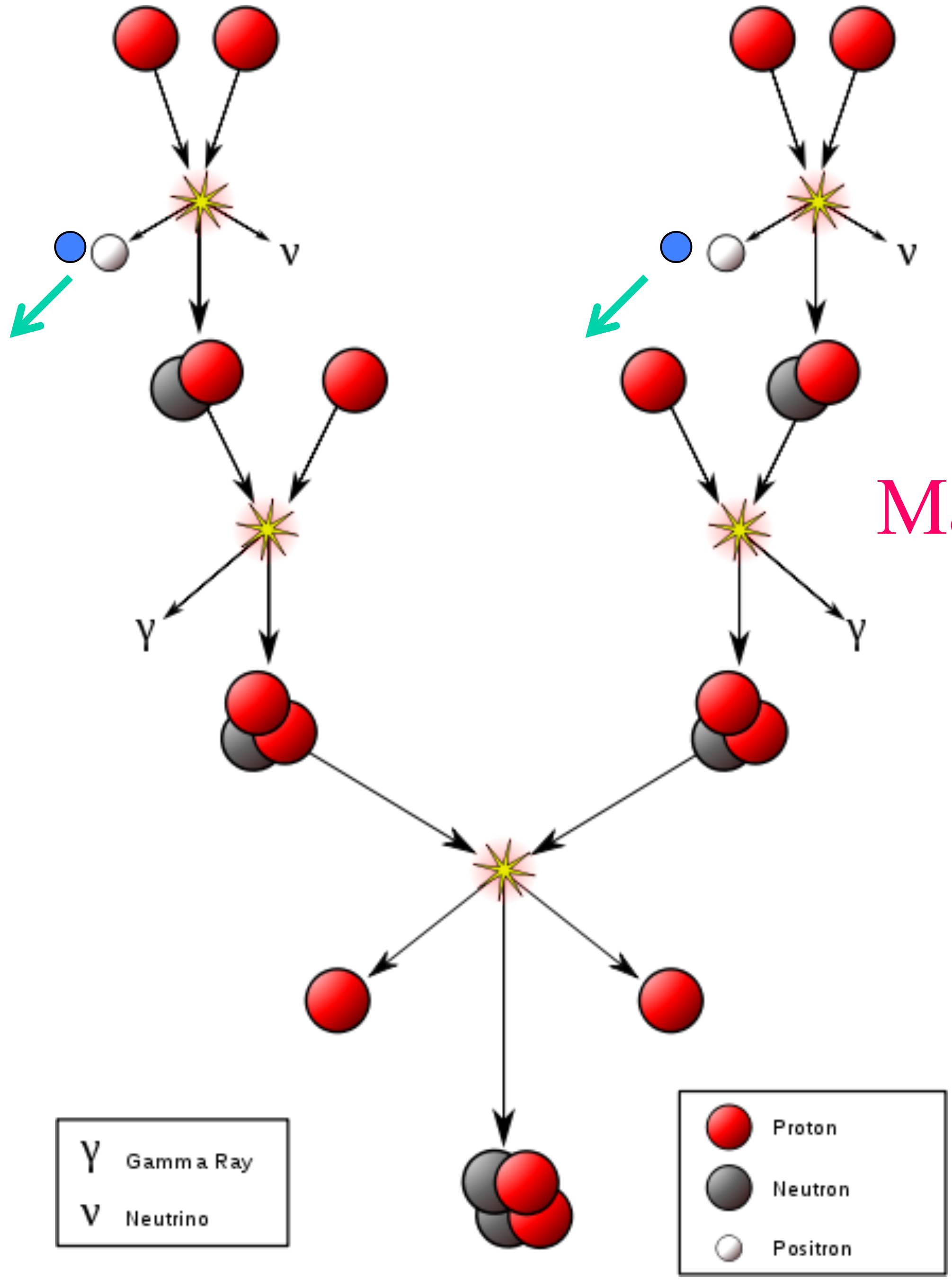
- Kepler's Law …
  – Ellipitcal orbits…. Sun and earth rotating around each other … pulled by Gravity
  - Period**2 ~ Distance**3 $1/R^2$ Law Moving more slowly, further apart
  – Equal areas swept in equal times - $1/R^2$ Law : Moving faster, closer together

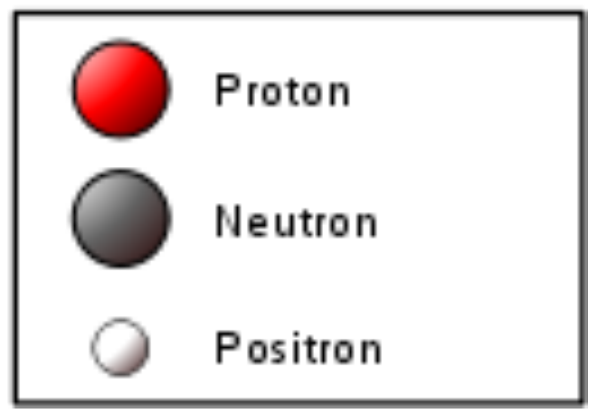
- Name 3 astronomical observations by Galileo…and why were they important
  - Moons of Jupiter … NOT left behind as planet orbited Sun NEW observation!
  - Phases of Venus … First direct observation against Ptolemic theory for Copernicus
  - Sunspots -- Sun rotated! NOT perfect or static

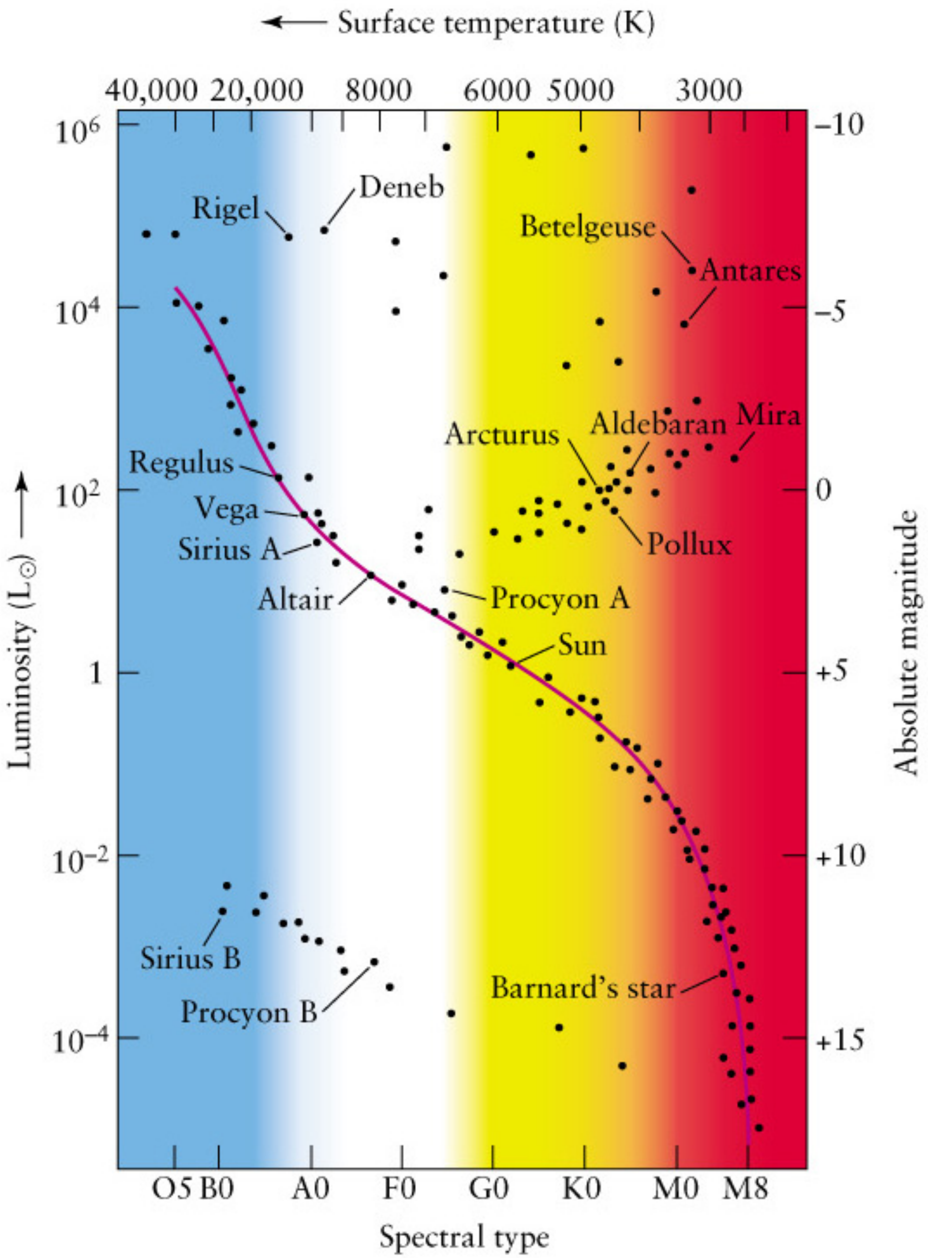
- What is the difference between mass and weight?
  - Mass is a measure of matter
  - Weight is a measure of FORCE (due to gravity)

Proton-proton cycle 3 steps

Matter Converts to energy

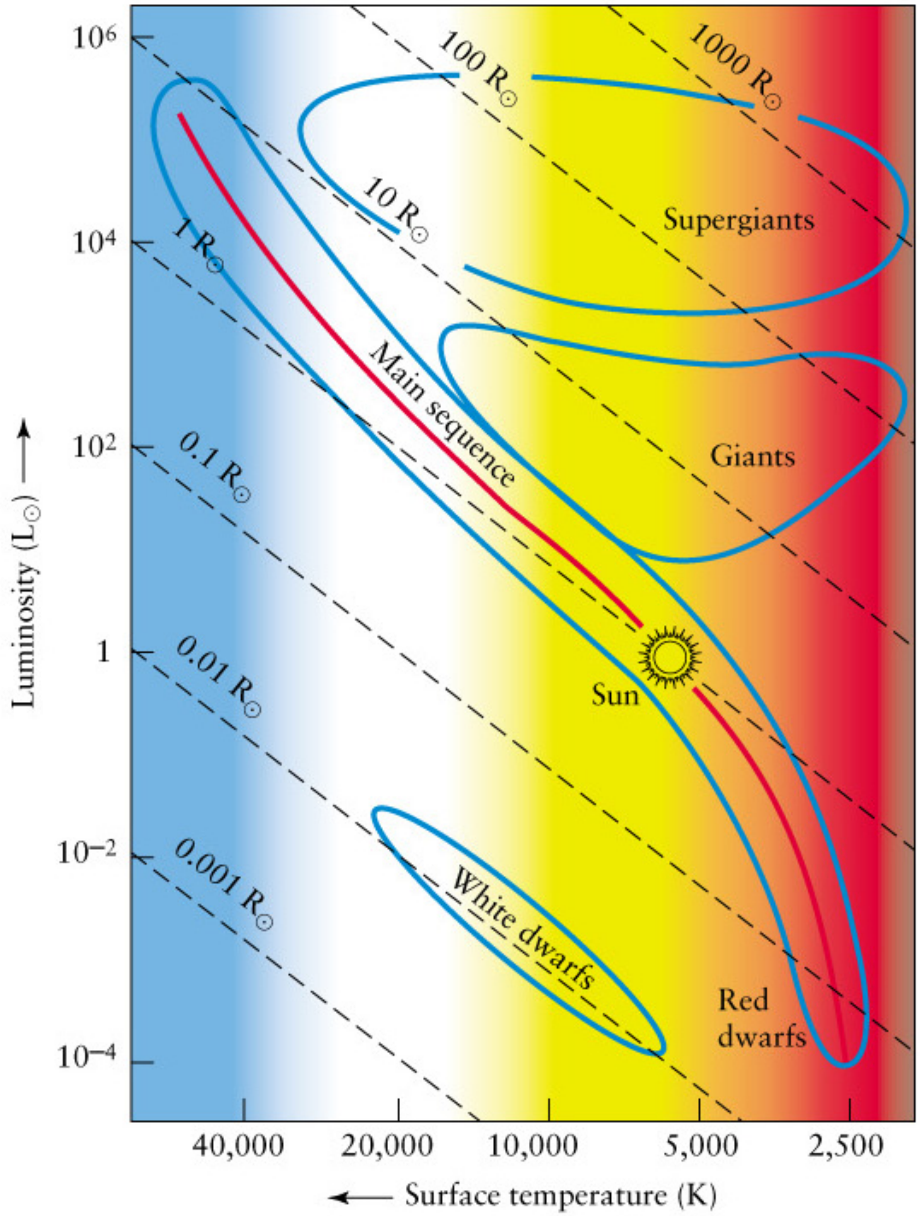






Hertzprung-Russell Diagram

Plot Luminosity versus surface temperature



Hertzprung-Russell Diagram

Stars with larger sizes are brighter then a smaller star with the same surface temperature

Hertzprung-Russell Diagram

- Most stars are on a “line” called the MAIN SEQUENCE with

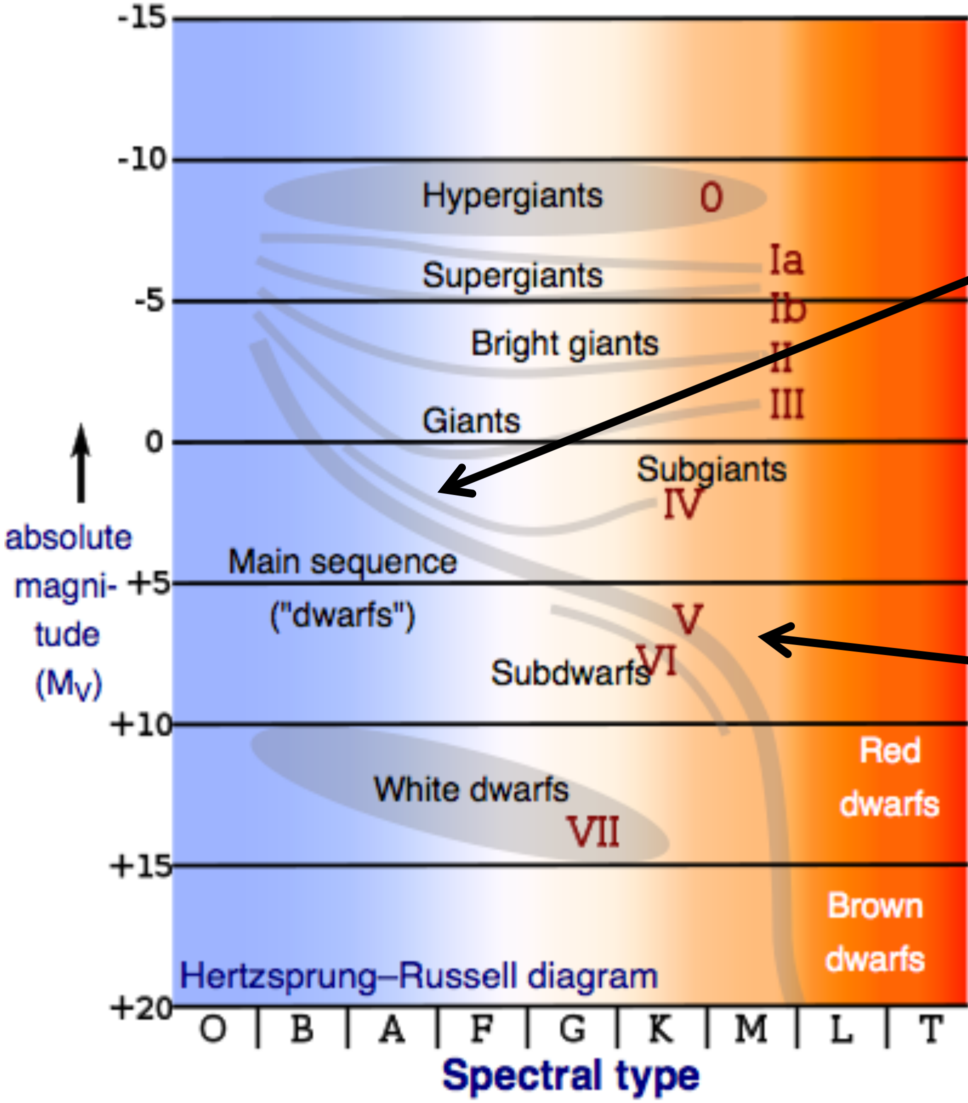
  hot surface temp ←→ large radius

  medium temp ←→ medium radius

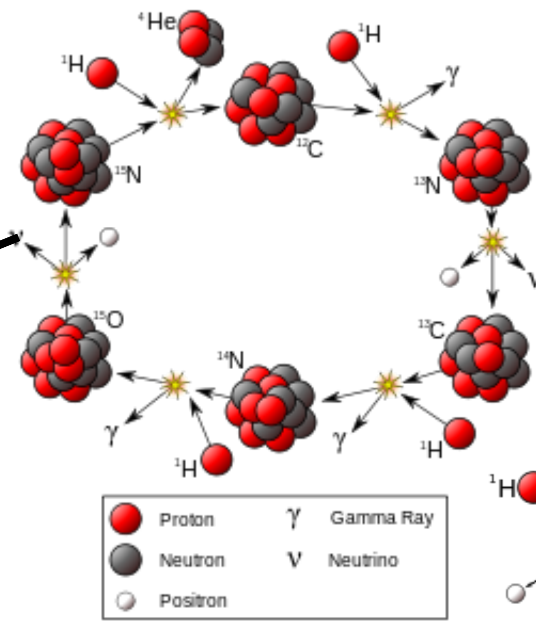
  cool surface temp ←→ small radius

- There are also stars with cool surface temperature but very large radius: RED GIANTS
- Stars with hot surface temperature but very small radius: WHITE DWARVES

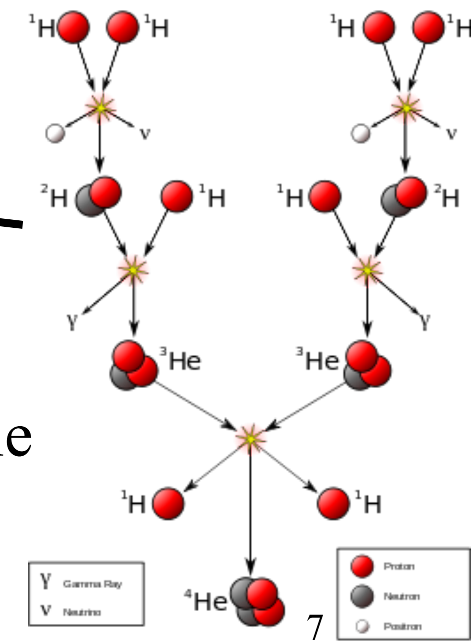
H-R Diagram and Star Formation



Hydrogen Fusion (main sequence)



CNO (carbon-nitrogen) cycle



p-p cycle

Relations of Star Properties

- The Mass, Radius and Luminosity of a star are closely interlinked:

  energy/area

  – L(*Energy*) = $4\pi\sigma R^2 T_{eff}^4$ or $E/4\pi R^2 = \sigma T_{eff}^4$

  – Mass-Luminosity relation: $$\frac{L}{L_\odot} = \left(\frac{M}{M_\odot}\right)^a$$

  where a = 3.5 for main sequence stars

  (don't have to memorize)

  – Ratio of Mass and Radius is almost linear (only changes factor of 3 within 2.5 orders of magnitude of M.

Key Properties of Main Sequence Stars

Mass/M_{Sun}	Luminosity/L_{Sun}	Effective Temperature (K)	Radius/R_{Sun}	Main sequence lifespan (yrs)	Core Temperature
0.10	3×10^{-3}	2,900	0.16	2×10^{12}	5,000,000
0.50	0.03	3,800	0.6	2×10^{11}	
0.75	0.3	5,000	0.8	3×10^{10}	
1.0	1	6,000	1.0	1×10^{10}	15,000,000
1.5	5	7,000	1.4	2×10^{9}	
3	60	11,000	2.5	2×10^{8}	
5	600	17,000	3.8	7×10^{7}	
10	10,000	22,000	5.6	2×10^{7}	
15	17,000	28,000	6.8	1×10^{7}	
25	80,000	35,000	8.7	7×10^{6}	
60	790,000	44,500	15	3.4×10^{6}	40,000,000

Higher mass → faster rate of fusion

Spectroscopic Parallax

- If we use well-understood close stars to determine the overall brightness scale of a specific class of star, then measuring the spectrum can be used to give the distance for stars > 500 LY away

1. Determine Surface Temperature + spectral class of star
2. Determine where on HR diagram should go
3. Read off absolute luminosity from HR diagram
4. Measure apparent luminosity and calculate distance

- works best if many close-by stars

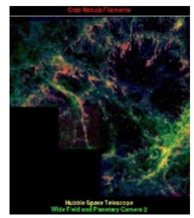
Stars: Birth, Life and Death

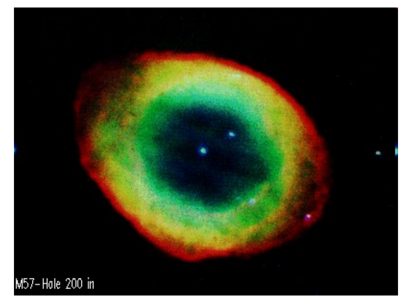
- Stars are formed from interstellar material which is compressed by gravity
- Spend >90% of their lives burning Hydrogen into Helium
- How they "die" depends on mass
  → large stars blow up Supernovas
- Understand stars' lifecycles by studying their properties and also groups of stars

Nebula

Historic term for any extended patch of light

- galaxy
- comets
- star clusters
- supernova remnants
- material ejected from Red Giants
- gas clouds
- dust clouds





Star Clusters

Stars are usually near other stars - CLUSTER

- formed at the same time
- similar chemical composition
- about the same distance from us

Can classify by appearance and use to:

- study stellar lifetimes
- measure distances

Open Star Clusters

Can see individual stars by eye or with modest telescope

- Usually some bright, hot stars
- 100-1000 stars in region of about 50 LY with few LY separating stars
- Have significant amount of heavy elements like Carbon and Oxygen

Understood as group of recently formed stars

Open Star Clusters - Pleiades

"Seven Sisters" being chased by Orion the hunter (Greek)

Subaru cluster (Japan)

Subaru Telescope Hawaii

Globular Star Clusters

"Fuzzy cotton ball" by eye or with modest telescope

- Usually dim red stars
- Dense with 100,000 stars in 50-300 LY region with less than LY separating stars
- No heavy elements. Just Hydrogen and Helium
- Often outside plane of galaxy

Understood as group of old stars formed in early history of the galaxy

Interstellar Medium

Interstellar space is filled with

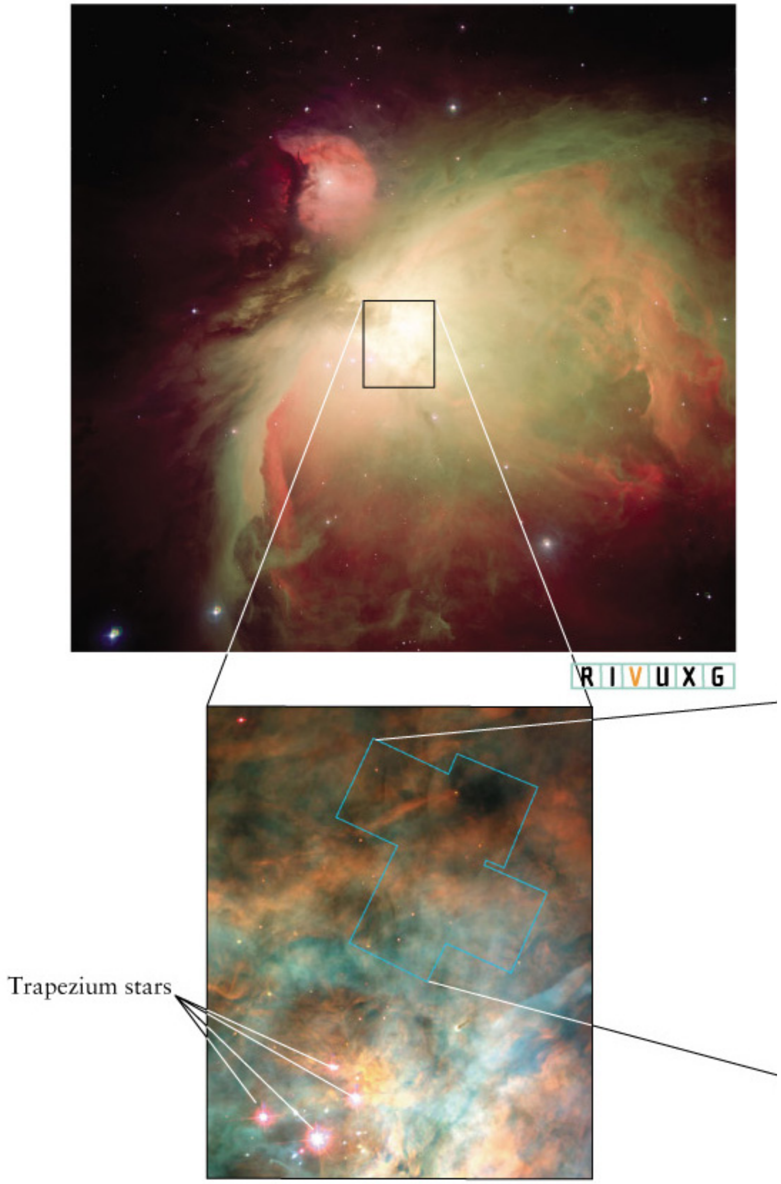
- Gas (mostly H and He)
- Dust (silicates, ices)
- Usually cold (100^{O} K or -300^{O} F)
- Usually almost perfect vacuum with 1 atom/cm^3 (1 g water = 10^{23} atoms)

Local concentrations can be compressed by gravity and form stars. Called Giant Molecular Clouds as even complicated molecules have been observed. Need about 1,000,000 times the mass of the Sun in 100 LY volume to initiate star formation

Emission Nebula

If gas cloud heated up by being near stars, will emit light and spectrum tells:

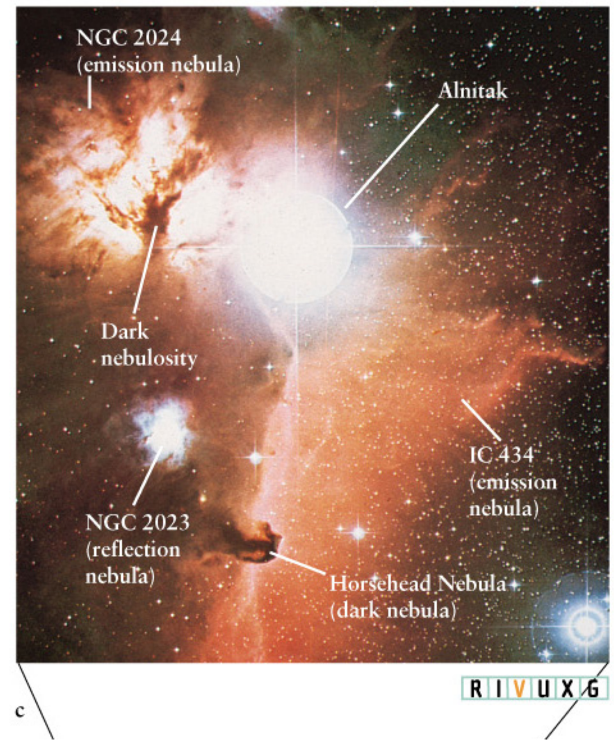
- Chemical composition
- Temperature
- Density
- Velocity (by Doppler shift)

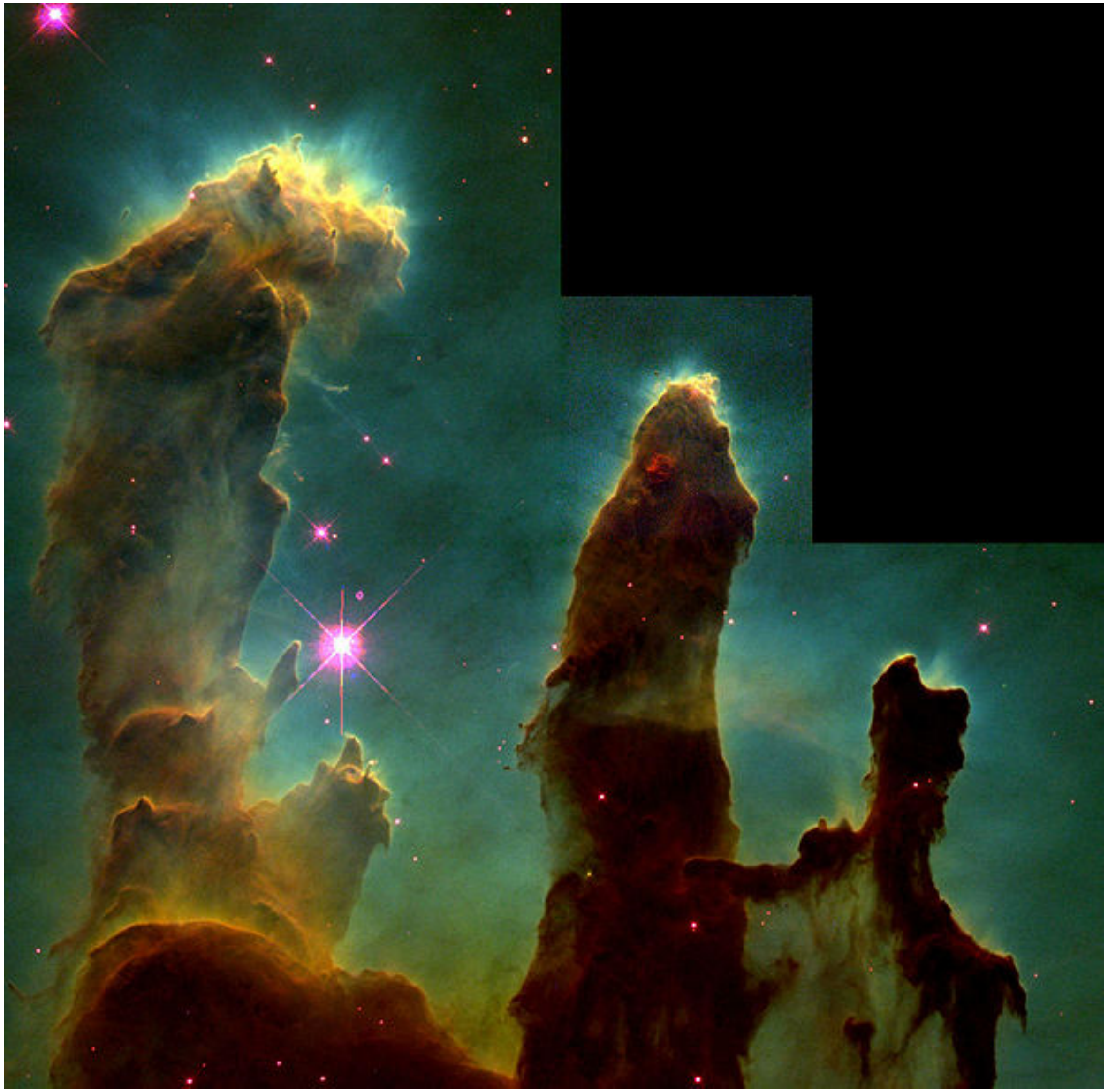


Dust Clouds

If dense gas and dust (very small particles) between stars and us see as dark image → Horsehead nebula

- IR can often see through
- regions were new stars are being formed





Star Forming Region Eagle nebula

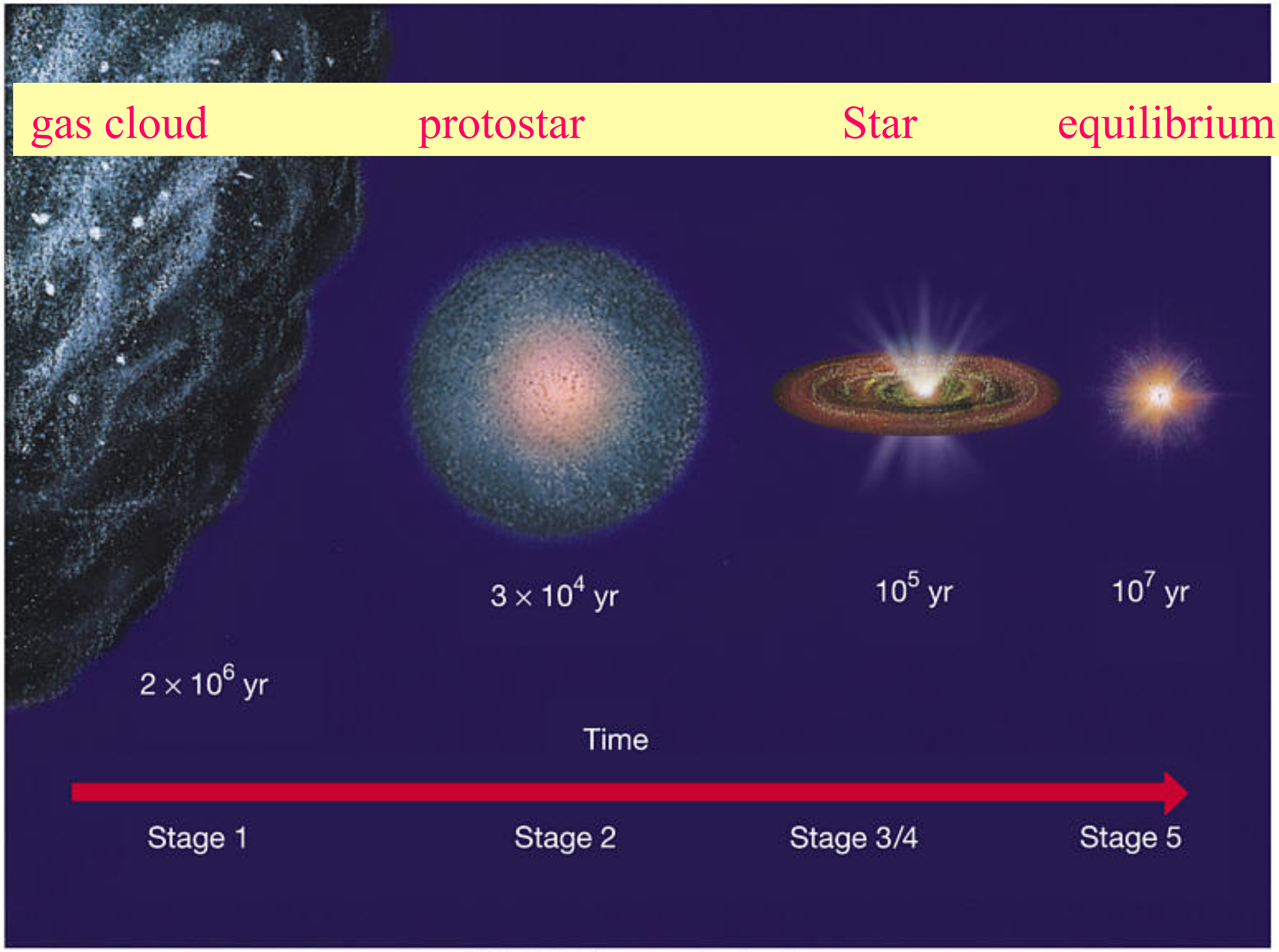
Star Formation

STEPS

1. Collapsing Gas Cloud
2. Protostar: hot ball but no fusion
3. Star: nuclear fusion but not final equilibrium
4. Main Sequence Star: final equilibrium with excess gas blown away

Star Formation

gas cloud protostar Star equilibrium



Gravity and Star Formation

Gravity causes the material (gas and dust) in a cloud to be attracted to each other

- Compresses into smaller volume
- Increases temperature and density
- If the temperature at the center becomes large enough (5 million degrees) then H to He fusion can occur:

- Star is born

Gravity II

Fusion provides a new source of energy

- Core stops compressing. Have equilibrium with thermal (electromagnetic) pressure=gravitational pressure
- "Surface" defined as excess gas blown away
- Main sequence star Luminosity depends on **MASS**

More Mass

More gravity

More fusion

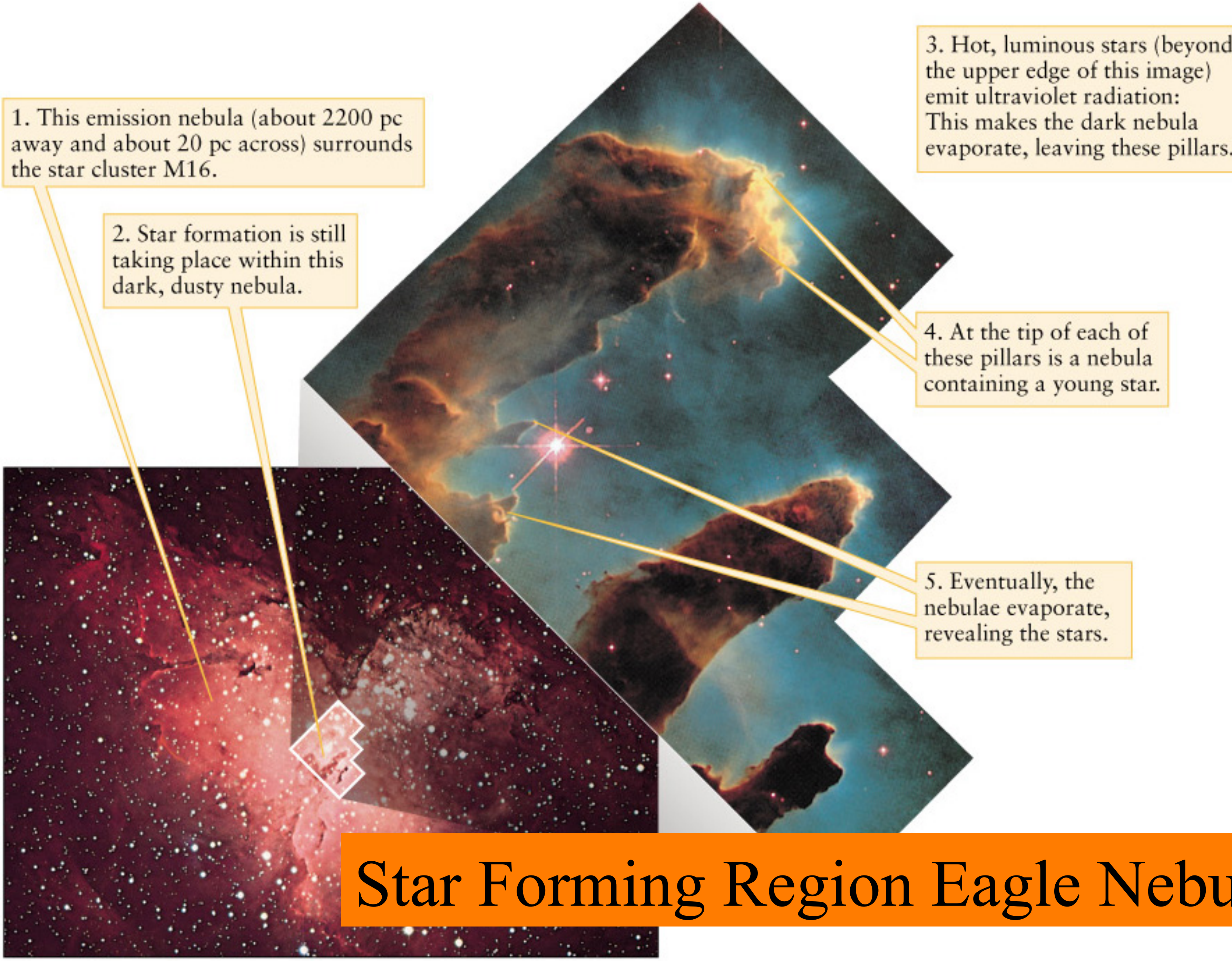
Higher Surface Temp

Brighter Star

Catalysts for Star Formation

- Stars are formed inside giant clouds of gas. New stars help initiate formation of stars in nearby regions
- Material ejected from forming stars
- Pressure from light radiation from new stars (especially large ones)
- Supernova explosions (which can occur a few million years after a large star is formed) both ejects material and sends shock wave out

Star Forming Region Eagle Nebula



Catalysts for Star Formation