Properties of Stars

BRIGHTNESS

Brightness of a star depends on _____and how much light it emits.

- **Apparent Brightness or** _____ The brightness of a star as it appears to our eyes; does not take distance into account.
- _____ the total amount of power that a star emits into space.
  - Stellar Luminosities span a _____ range!
  - Stellar luminosities are stated in comparison to the Sun's luminosity, which we write as L_{Sun} for short.

Stars

Examples of Stellar Luminosities

- Proxima Centauri (the nearest neighbor) is about 0.0006 times as luminous as the Sun, or _____
- Betelgeuse (bright left shoulder of _____): 38,000 L_{Sun}

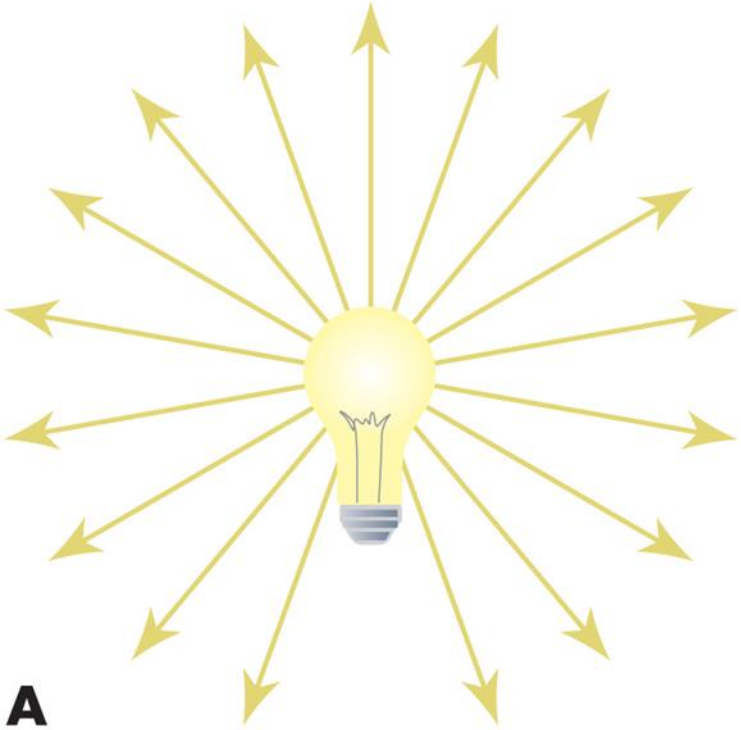
Two important Lessons:

1. Stars have a wide range of luminosities and our Sun is somewhere in the _____.

   Range = $(10^{-4}L_{Sun} - 10^{6}L_{Sun})$

2. _____ stars are more common than bright stars.

Brightness



A

B

b: © Goodshoot/ PunchStock RF

Brightness decreases with distance.

Properties of Stars

STELLAR TEMPERATURES

Unless otherwise stated, when you hear “temperature” in terms of a star, it is referring to _____ temperature.

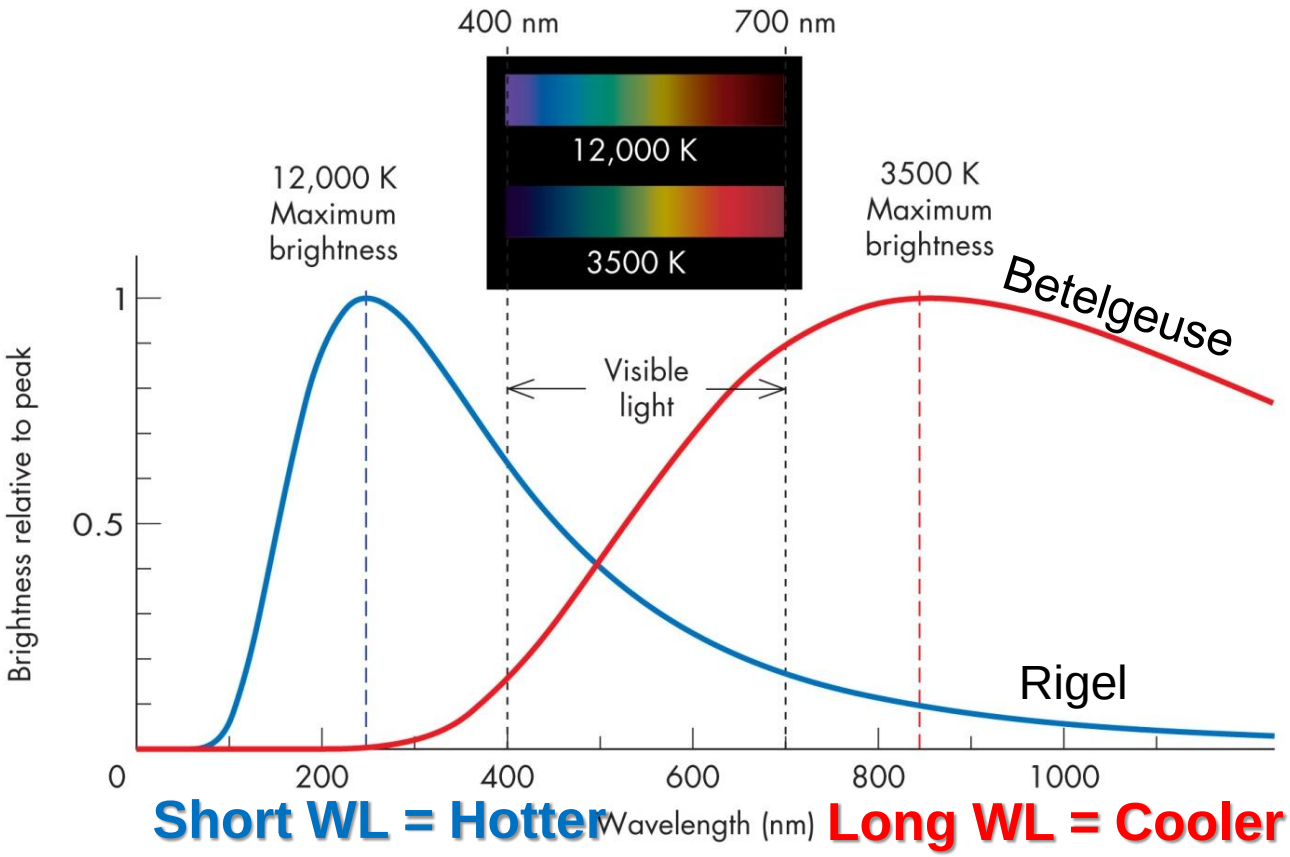
- ***Why?*** *Surface temperature is directly measurable; interior temperatures are inferred from mathematical models.*

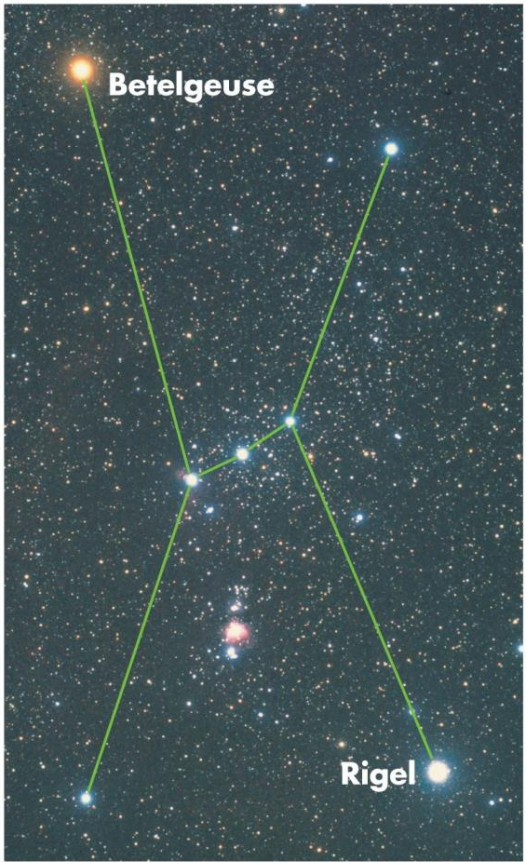
Color and Temperature

Thermal Radiation (heat) at the _____ depends on the average energy emitted from the surface.

- *Temperature can be deduced from the color of its emitted light.*
- ***In general, hot stars emit _____ light; cooler stars emit red light.***

Color and Temperature





Betelgeuse is red compared to _____. This plot of wavelengths vs brightness shows that the stars peak at different wavelengths.

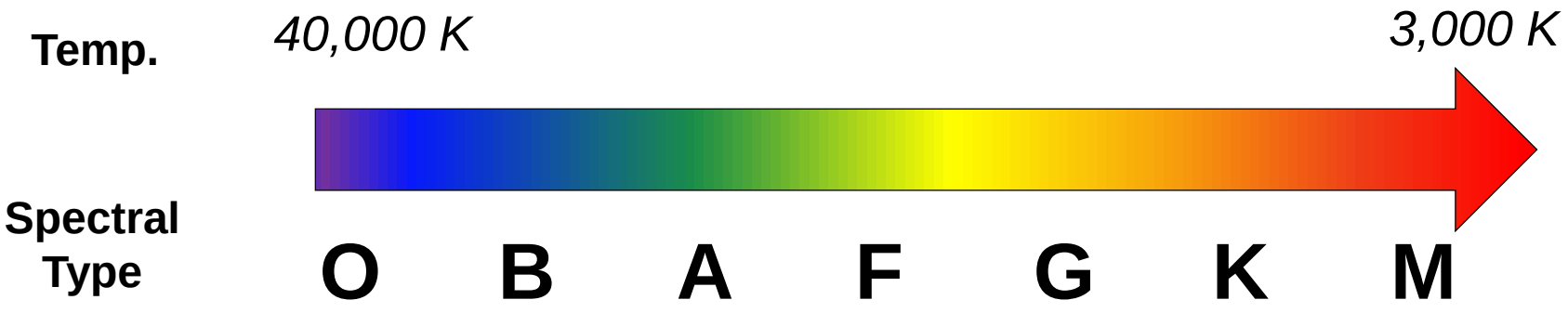
Properties of Stars

STELLAR TEMPERATURES, *continued*

Astronomers classify stars according to _____ temperature by assigning a **spectral type** (determined from spectral lines)

Spectral Types: (O, B, A, F, G, K, M)

Each is then further subdivided into #'s _____. The larger the number, the _____ the star. Sun is a G2

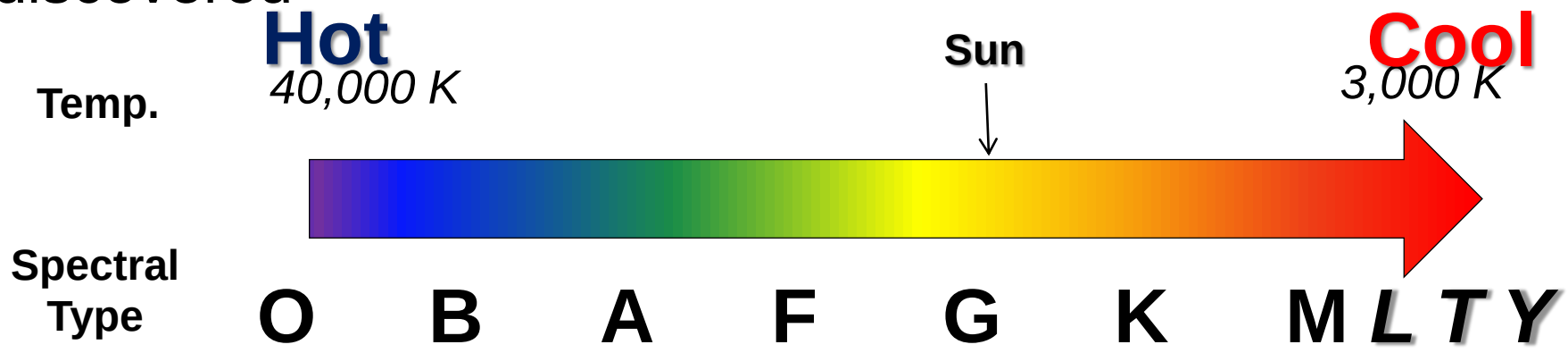


Properties of Stars

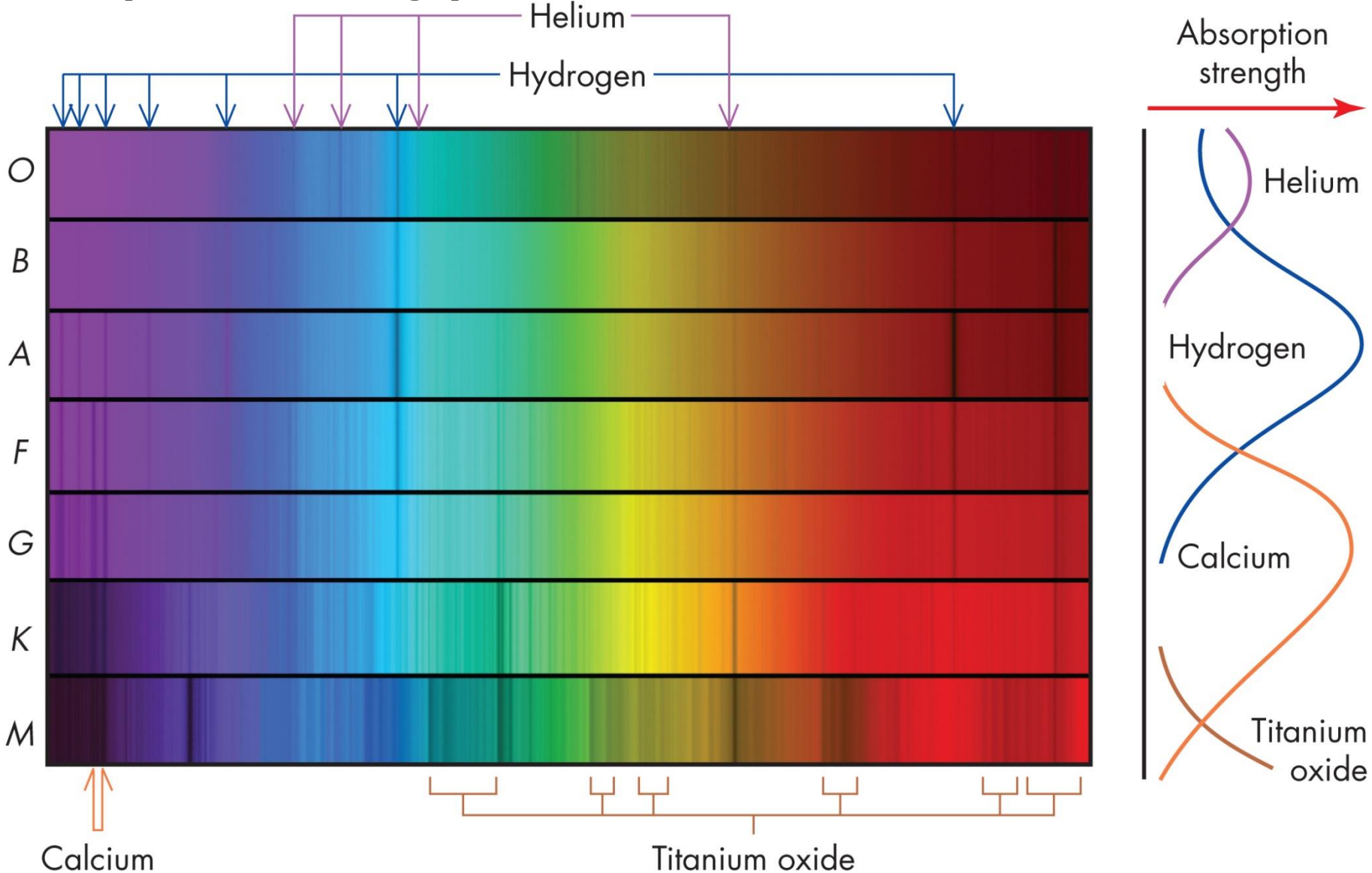
Courtesy of Harvard College Observatory

STELLAR TEMPERATURES, *continued*

Types L, T, and Y were later added to the Spectral Classifications after even _____ stars were discovered



Spectral Types



Spectral Types

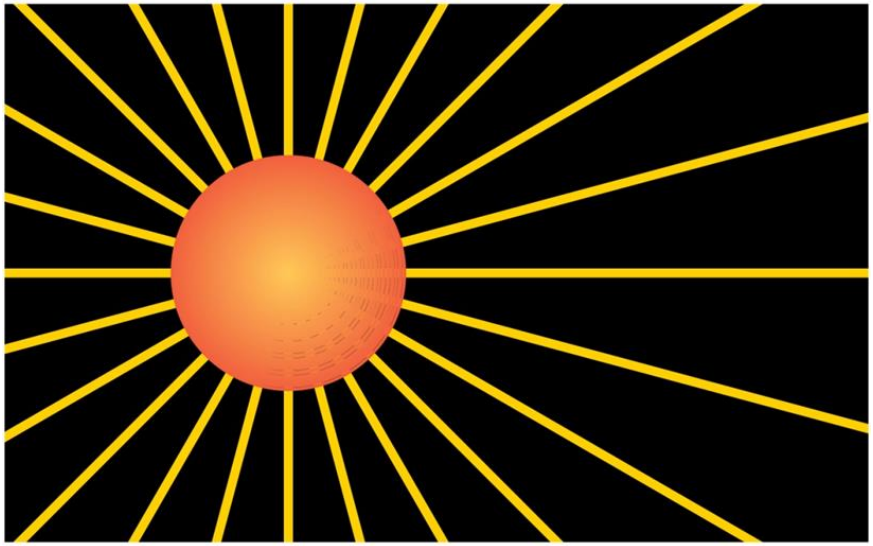
Table 13.3 Summary of Spectral Types

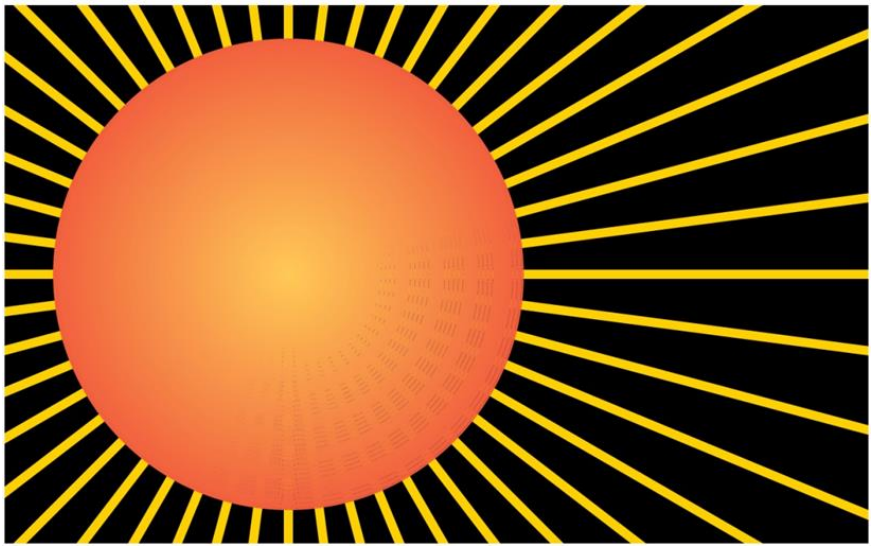
Spectral Type	Temperature Range (K)	Features	Representative Star
O	Hotter than 30,000	Ionized helium, weak hydrogen	
B	10,000–30,000	Neutral helium, hydrogen stronger	Rigel
A	7500–10,000	Hydrogen very strong	Sirius
F	6000–7500	Hydrogen weaker, metals (especially ionized Ca) moderate	Canopus
G	5000–6000	Ionized Ca strong, hydrogen even weaker	The Sun
K	3500–5000	Metals strong, CH and CN molecules appearing	Aldebaran
M	2000–3500	Molecules strong, especially TiO and water	Betelgeuse
L	1300–2000	Metal hydrides, water, and reactive metals strong, but no TiO	
T	700–1300	Strong lines of water and methane	
Y	<700	Absorption line at 1.55 μm, possibly of ammonia	

Properties of Stars

RADIUS

If two stars have the same _____, but one is more luminous than the other, the more luminous star must have a larger surface area, and therefore a larger radius than the dimmer star.





Properties of Stars

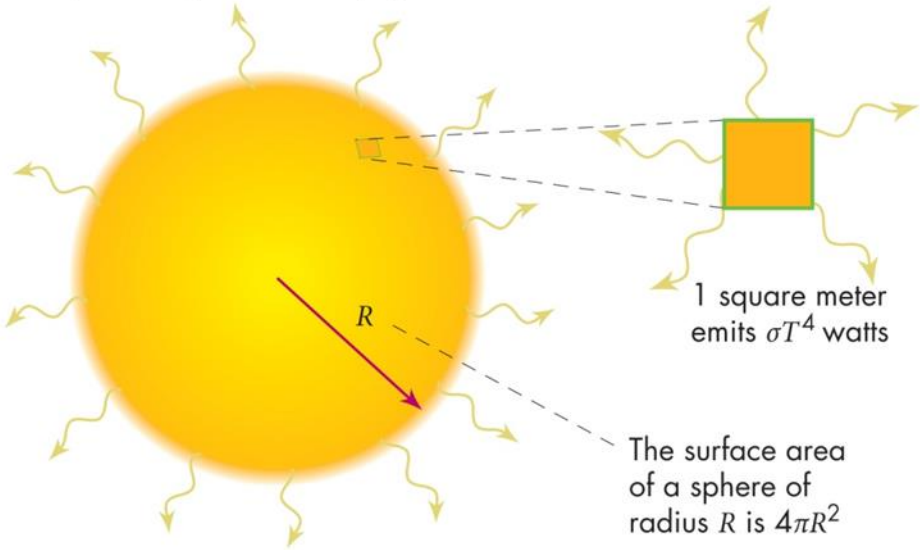
RADIUS

Stefan-Boltzmann law:

A star's luminosity depends on its _____ and temperature.

$$L = \sigma T^4 \times 4\pi R^2$$

- L: Luminosity—total energy radiated per second by the star
- σT^4: Energy emitted per second by 1 square meter
- $4\pi R^2$: Number of square meters in surface area of the star



Properties of Stars

RADIUS , continued

Telescopes can be used to measure the size of stars, but if a star were the size of the Sun and 50 ly away, it would require a telescope _____ meters in diameter!

Solution*: Use two or more telescopes separated by large distances (an _____) to measure angular distances of stars.. and radii.*

Properties of Stars

RADIUS, continued

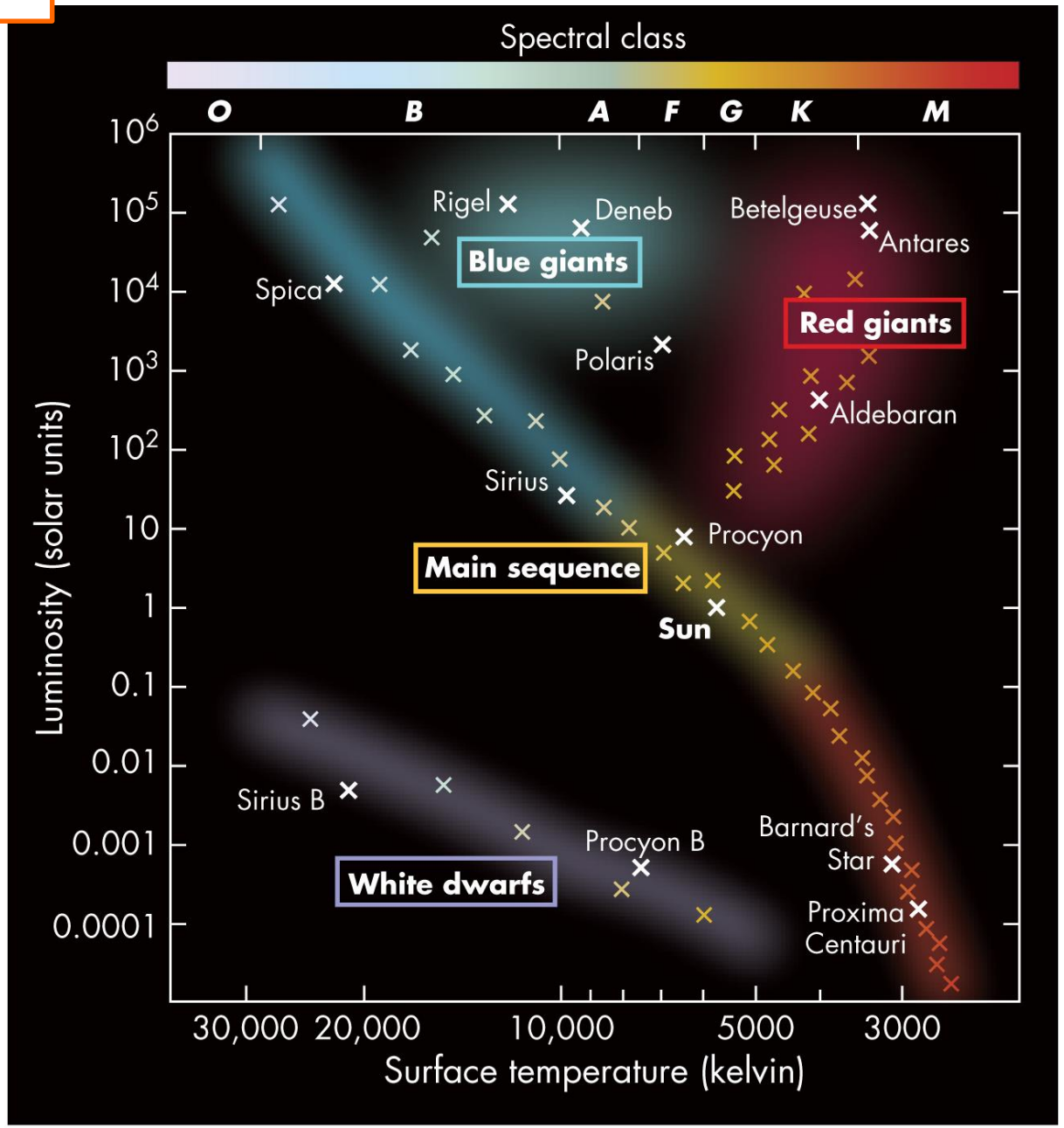
The Stefan Boltzmann law and interferometer observations show that stars differ enormously in radius.

- Some, like Betelgeuse, are hundreds of times larger than the Sun and are called _____.
- Smaller stars (including our Sun) are called _____.

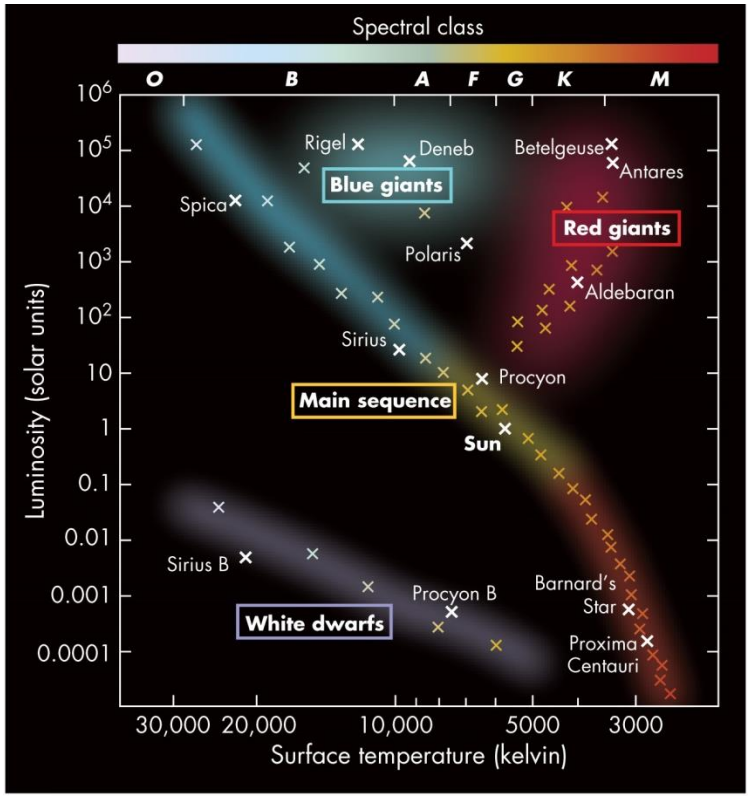
The H-R Diagram

- There are many varieties of stars, but what creates the variety and what does it mean?
- The Hertzsprung Russell _____ shows the relationship between stellar properties.
  - *In 1912, astronomers Ejnar Hertzsprung and Henry Norris Russel independently found that if stars are plotted according to their luminosity and their temperature(or spectral type), most fall in a few specific areas of the diagram.*

H-R Diagram


Spectral class
O
B
A
F
G
K
M
Luminosity (solar units)
10^6
10^5
10^4
10^3
10^2
10
1
0.1
0.01
0.001
0.0001
Rigel
Deneb
Betelgeuse
Antares
Blue giants
Spica
Red giants
Polaris
Aldebaran
Sirius
Procyon
Main sequence
Sun
Sirius B
Procyon B
Barnard's Star
White dwarfs
Proxima Centauri
30,000
20,000
10,000
5000
3000
Surface temperature (kelvin)

H-R Diagram

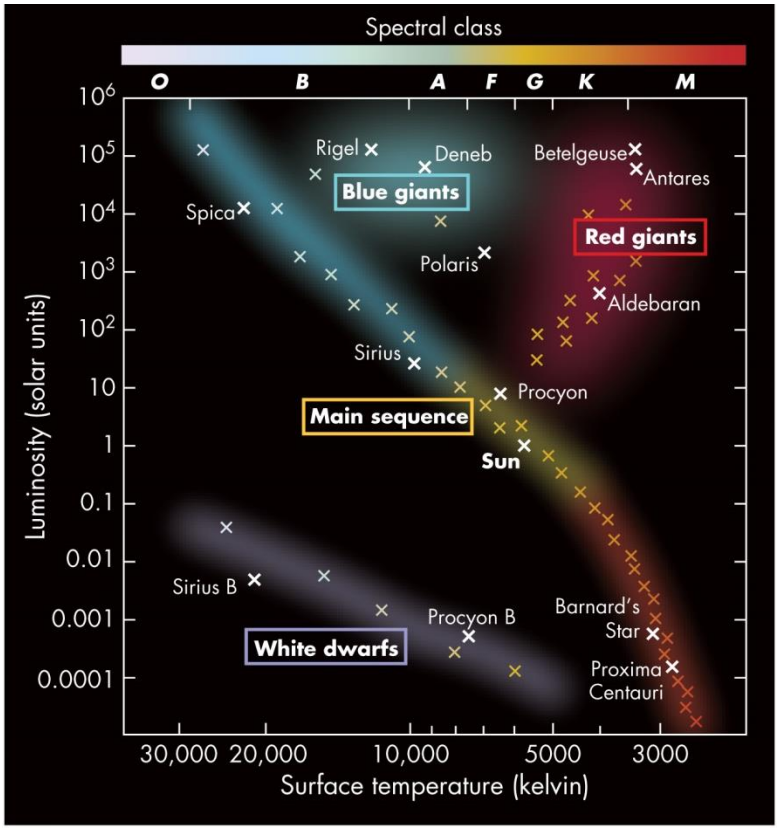


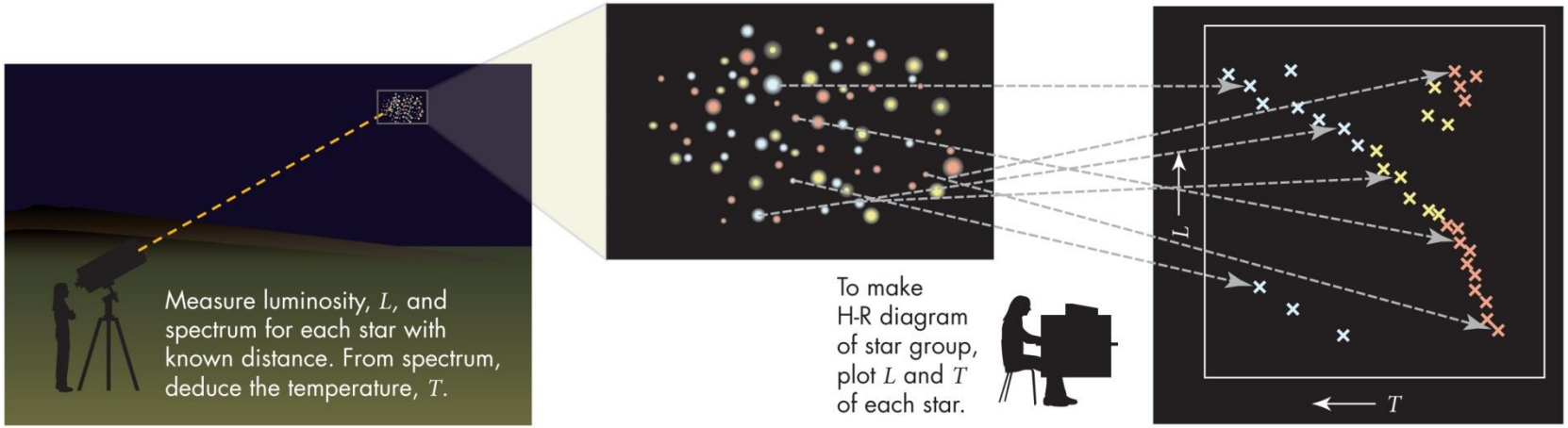
Video: HR Diagram Animation

H-R Diagram

Main Sequence- the approximately _____ line on the HR diagram along which the majority of stars lie.

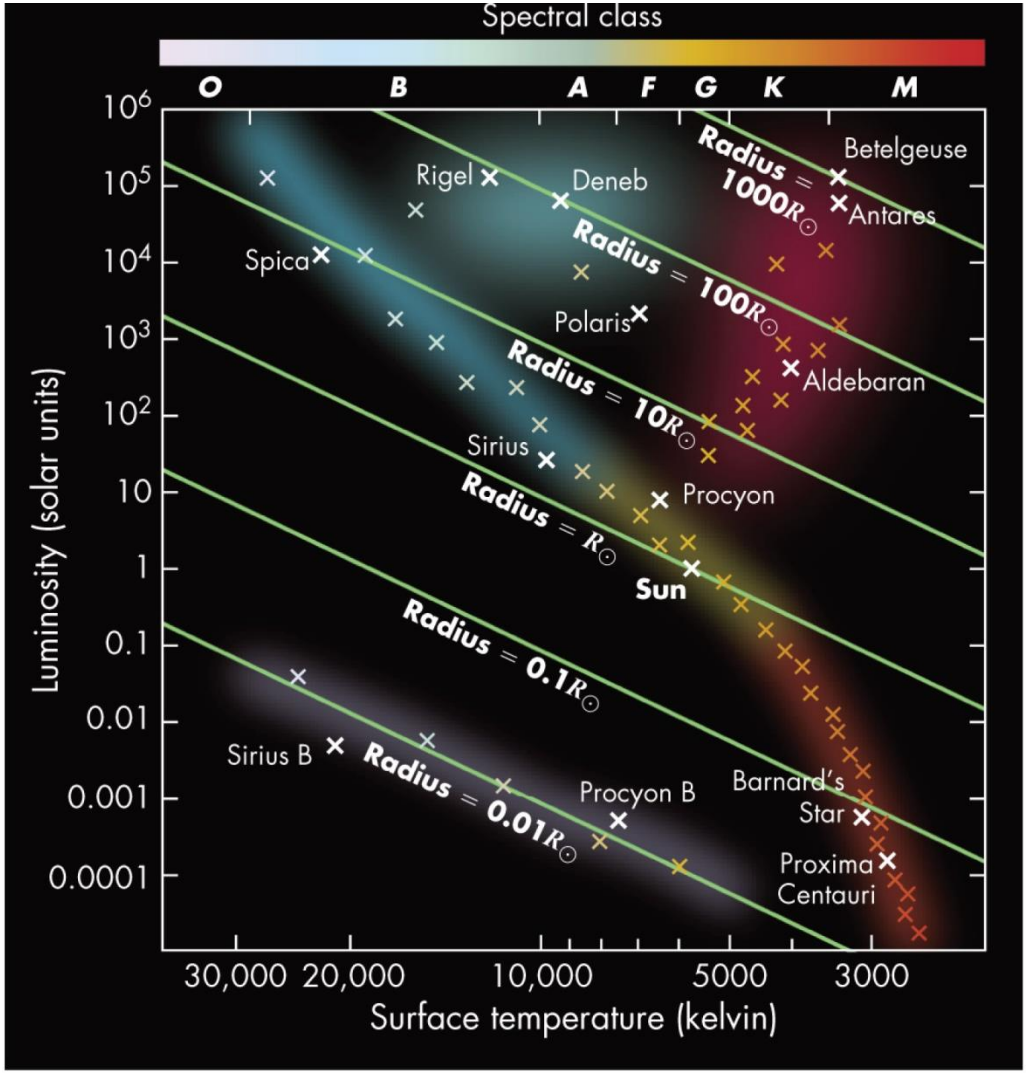
Note: Our Sun is a main sequence star





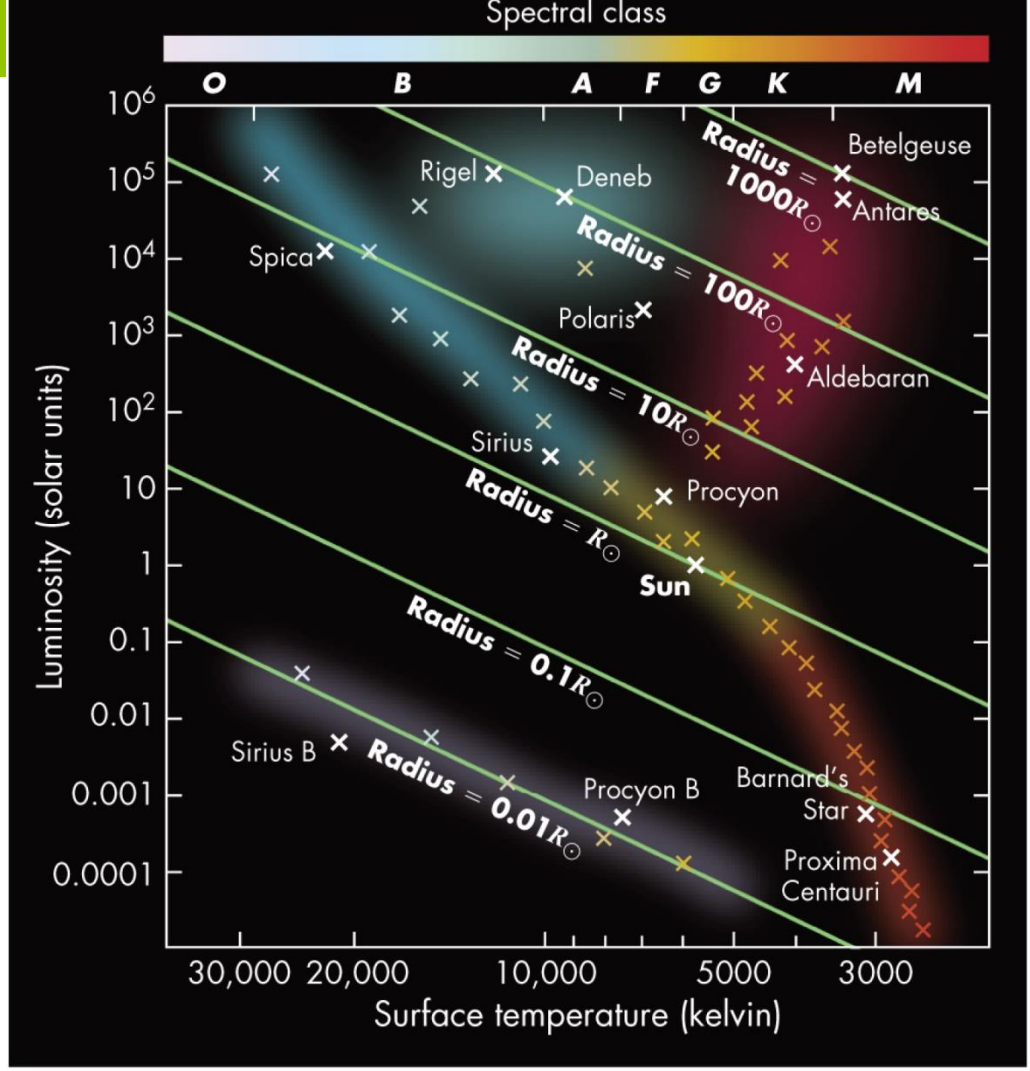
H-R Diagram

Stellar Radii depends on _____ and surface _____, so it can be determined with the HR Diagram.



Patterns in the H-R Diagram

- **Main sequence-** 90% of stars fall within this prominent streak
- _____ - upper right (large and bright)
- _____ - larger and brighter than main sequence, but smaller and dimmer than supergiants.
- _____ - near lower left; appear white in color because of high temperature

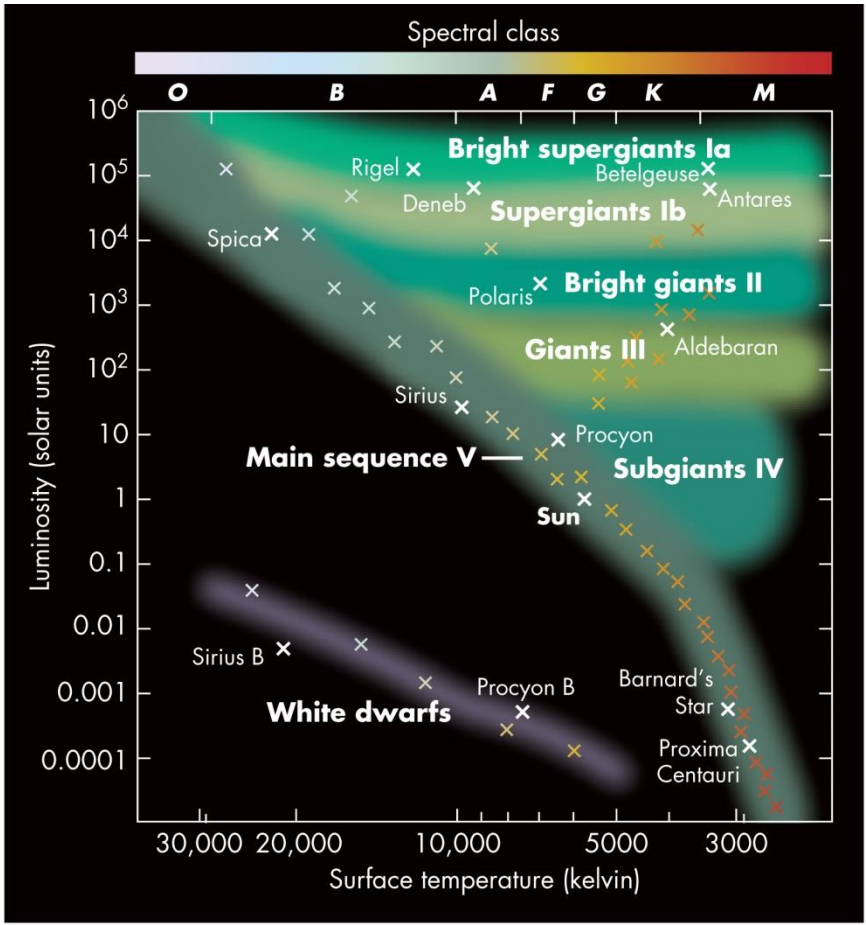


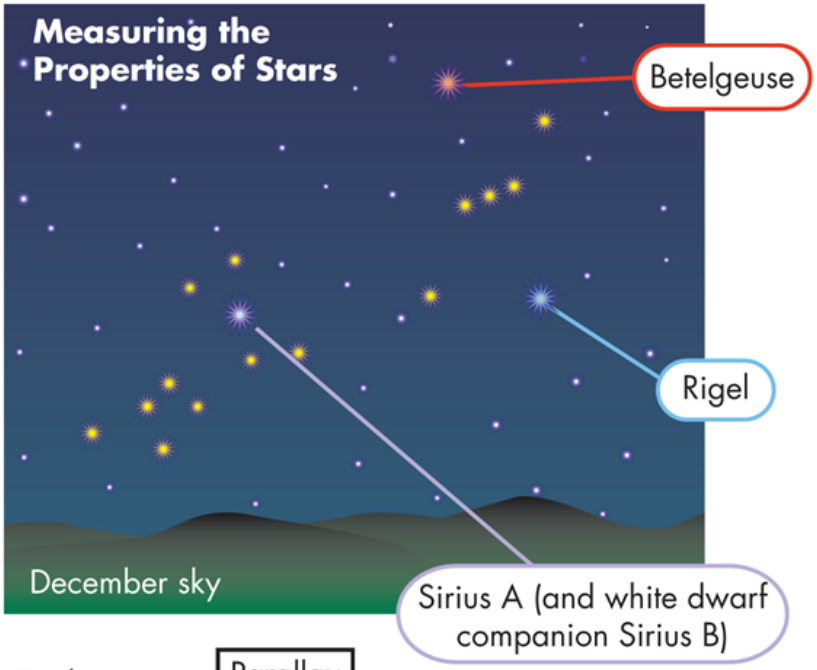
Patterns in the H-R Diagram

Luminosity Classes: I – IV; added to _____ type to give a more complete description of a star's light.

Example: our Sun is a G2V while Rigel is a B8Ia

Class	Description
Ia	Bright Supergiants
Ib	Supergiants
II	Bright Giants
III	Ordinary Giants
IV	Subgiants
V	Main Sequence





Wien's law

Find temperature from star's color:

$$T = \frac{2.9\times10^{6}\ \text{K nm}}{\lambda_{max}}$$

Inverse square law

$$L = 4\pi d^2 B$$

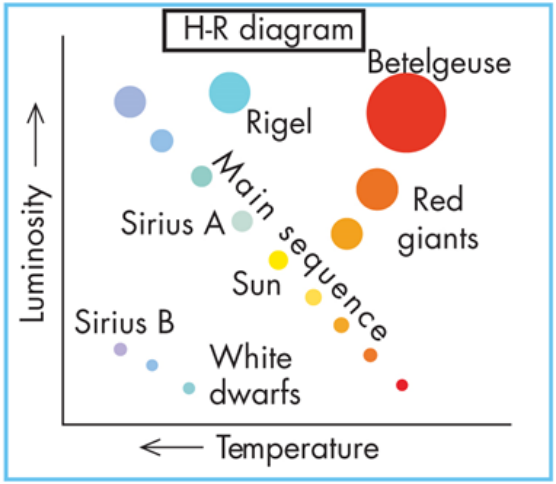
(B: measured brightness)

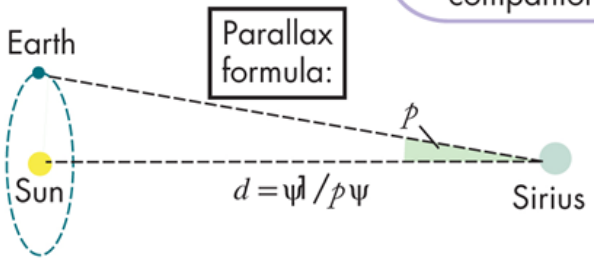
Stefan-Boltzmann law

Solve for radius

$$L = 4\pi R^2 \sigma T^4$$

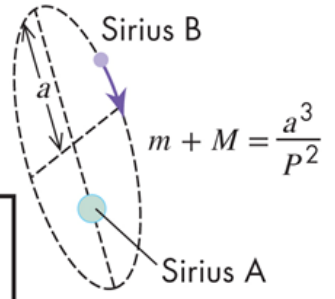
(L: from brightness or spectrum; T: from color)





Composition can be found from spectral lines corrected for temperatature.

Kepler's law (modified)



Stellar Lifecycle

- The existence of main sequence stars, red giants, and white dwarfs suggests to astronomers a picture of how stars _____.
- **Stellar Evolution-** a star's lifecycle from "_____" to "_____".
  - **Driven by gravity-** what begins as a gentle tug grows into a crushing force that heats up a stars interior.
  - Energy from _____ constantly replaces the energy the heat that flows out of a star, establishing a balance with gravity as long as nuclear fuel lasts.
  - *A star dies when its fuel is* _____

Stellar Lifecycle

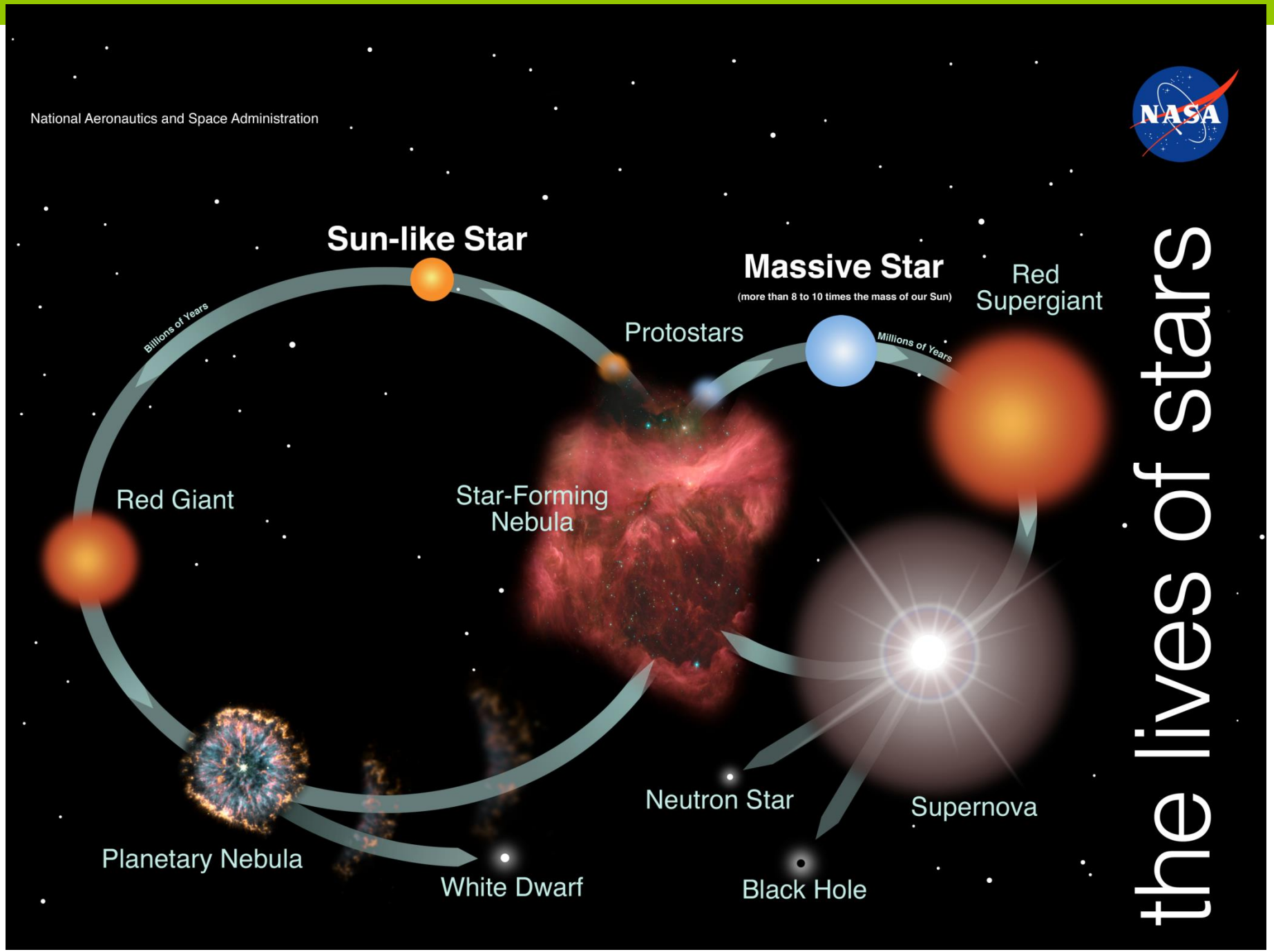
- All stars form when _____ causes a molecular cloud to contract until the center becomes hot enough for nuclear fusion to occur.
  - ***Gravitational Equilibrium-*** *outward pressure of gas is balanced by the inward force of gravity.*
- *When the _____ is used up, their structure changes because gravity is no longer counterbalanced.*
- ***A star's life story depends on its _____****(how much material it contains).*
  - *Mass determines how strong gravity is and also how much fuel it has.*

Stellar Lifecycle

2 Groups:

1. ***Low Mass Stars****- follow same _____ as the Sun*

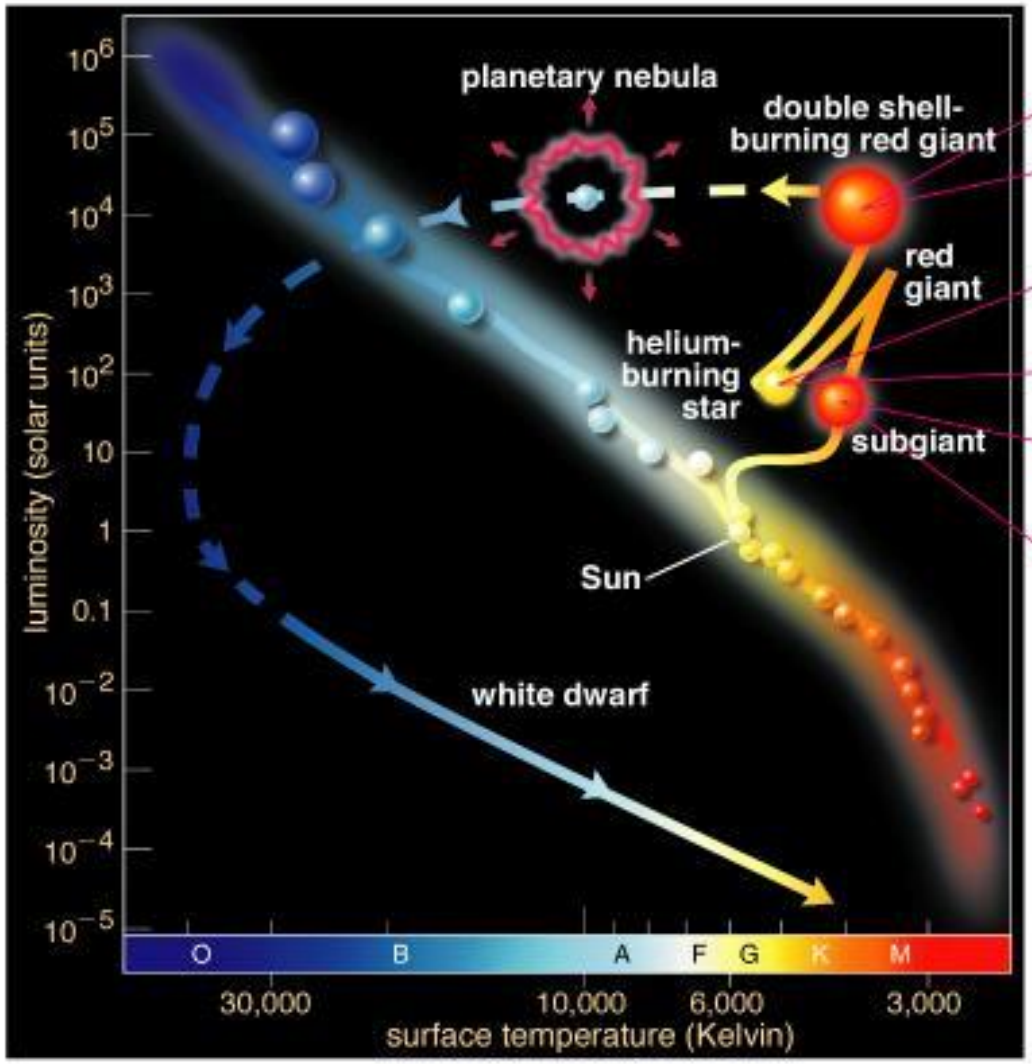
2. ***High Mass Stars****- powerful gravitational pull causes _____ collapse after exhausting all their fuel.*

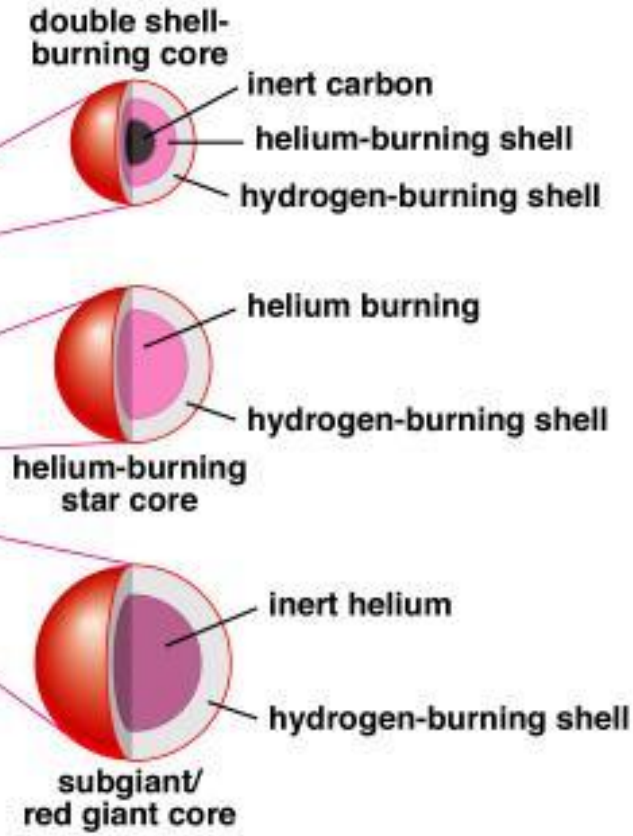

National Aeronautics and Space Administration
NASA
Sun-like Star
Billions of Years
Red Giant
Planetary Nebula
White Dwarf
Massive Star
(more than 8 to 10 times the mass of our Sun)
Protostars
Millions of Years
Red Supergiant
Star-Forming Nebula
Neutron Star
Supernova
Black Hole
the lives of stars

Lifecycle of Low Mass Stars

1. Interstellar Cloud- cold, dark mass of gas
2. Hydrogen → Helium fusion begins in core
   - If plotted, stars in this phase are Main Sequence stars.
3. After consuming about _____ % of hydrogen in the core, the core will shrink, become hotter, and generate energy faster
4. Outward flowing energy will cause expansion and cooler outer layers. **(_____ Giant)**
5. Even hotter core fuses helium **(_____ Giant).**
6. When helium is used up, it will grow into a larger red giant **(planetary nebula**) and outer layers will be driven into space.
7. **White** _____ tiny core but HOT!

Lifecycle of Low Mass Stars





Lifecycle of High Mass Stars

High mass stars have a mass that is _____ times greater than the Sun.

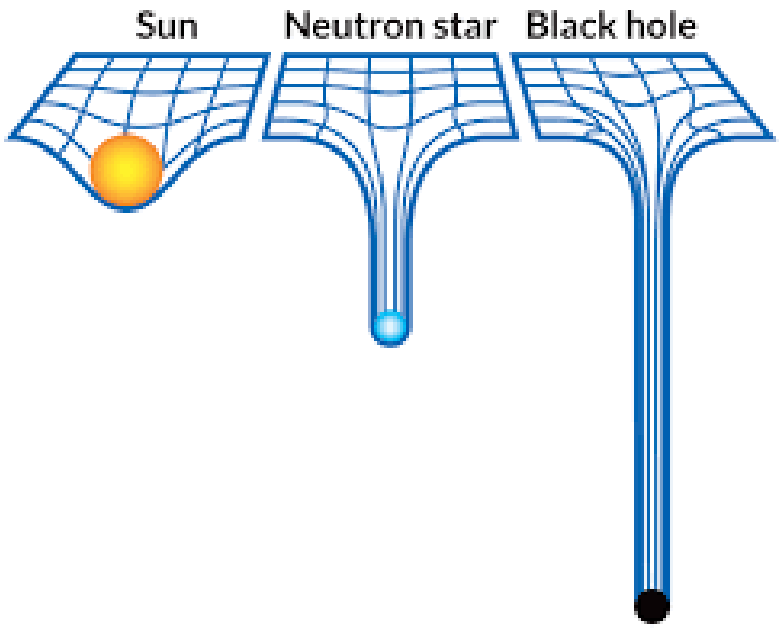
- **Early life is similar to a _____ mass star** (originates from the collapse of an interstellar cloud, but its greater mass causes it to have higher temperatures)
- **High mass stars burn _____ faster and therefore have shorter life-spans.**

Lifecycle of High Mass Stars

1. Early life like low mass star
2. As a main sequence star, high mass stars are much hotter, bluer, and more luminous than low mass stars.
3. When hydrogen is exhausted, the star swells and grows cooler, becoming a **Pulsating _____ Giant.**
4. Intense gravitational compression of core causes temperature to rise and fuel to be burned more furiously.
5. Higher temperature permits star to fuse progressively heavier elements (H→ He→ C→ O→ Si→ Fe**)**
   - *Iron does not release energy when it is fused*
6. _____*(Cataclysmic explosion)*- heavy elements flow into space when core collapses under the intense gravity
7. _____ **Star** (ball of neutrons) or **Black Hole**

Black Holes

When a star that was initially more massive than about _____ Solar Masses reaches the end of its life and collapses, it creates a core so compact that no radiation (light) can escape.



Additional Resources

- Crash Course: Low Mass Stars
  - https://www.youtube.com/watch?v=jfvMtCHv1q4
- Crash Course: High Mass Stars
  - https://www.youtube.com/watch?v=PWx9DurgPn8
- Crash Course: Black Holes
  - https://www.youtube.com/watch?v=qZWPBKULkdQ