Properties of Stars & Star Formation

Physics 090
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Measuring Properties of Stars

- Distance
  - Parallax method for nearby stars
- Brightness (Intensity)
  - Easy to measure – is it bright or dim?
- Luminosity
  - Get from brightness and distance
  - Physical relationships for special objects (e.g., Cepheid Variables)

Measuring Properties of Stars

- Composition and Surface Temperature
  - Spectrum shape
- Radius
  - Get from L and T, Stefan-Boltzmann Law
- Masses
  - Binary stars
  - Physical relationships for typical ("main-sequence") stars.

Analysis of stellar spectrum

- Color, absorption lines, detailed shape gives you temperature and chemical composition
- Spectral Class: Primarily based on temperature.

	Type	Surface Temp (K)
"blue"	O	> 30,000
	B	10,000 – 30,000
	A	7,500 – 10,000
"white"	F	6,000 – 7,500
	G	5,000 – 6,000
	K	3,500 – 5,000
"red"	M	2,200 – 3,500
	L	1,300 – 2,200
"brown dwarfs"	T	< 1,300 (recent)
The Sun:	G2	T = 5,800 K

Subtypes :
G0 (hottest) to
G9 (coldest)

Sizes of stars

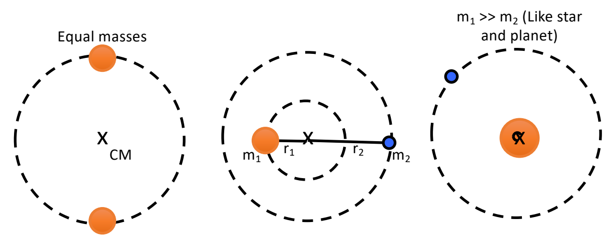
- Stefan-Boltzmann Law: Derived in upper-level thermodynamics.

$$L = 4\pi R^2 \sigma T^4$$
$$(\sigma = constant)$$

- Takeaway: relates L and T to R!

Binary Stars gives Mass

- Over 50% of the "stars" you see are actually multiple systems bound by gravity. Most are double. Many triple and higher.
- Yet another application of Kepler's and Newton's laws.



Trends for Main-Sequence Stars

- Once all stellar properties were measured, trends emerged. Eventually derived.
- All stellar properties can be scaled to mass ("scaling relations")
- These relations are true only for main-sequence stars (nuclear physics built into these expressions)

$$L \propto M^4$$
$$R \propto M$$
$$T \propto M^{1/2}$$

- The mass-luminosity relation implies that massive stars live short lives. They have more fuel, but burn through it faster!

Some Properties of MS Stars

Type	Mass (Sun)	T (K)	Luminosity (Sun)	R (Sun)
O5	40	40,000	500,000	18
B0	18	28,000	20,000	7.4
B5	6.5	15,000	800	3.8
A0	3.2	10,000	80	2.5
F0	1.7	7,400	6	1.4
G0	1.1	6,000	1.3	1.1
K0	0.8	4,900	0.4	0.8
M0	0.5	3,500	0.03	0.6
M5	0.2	2,800	0.008	0.3

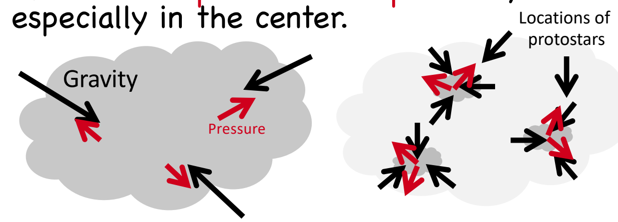
- The Sun is a G2 star. Majority of stars in galaxy are K and M (average mass = ½ the Sun). Still, the Sun is a garden-variety star.

Stars and Star Formation

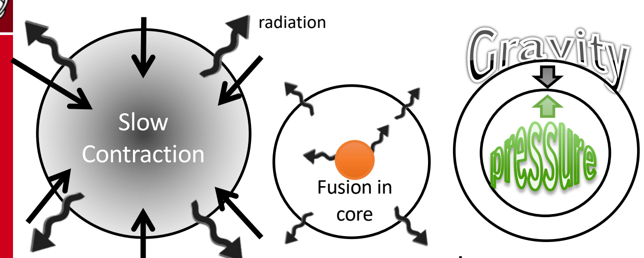
- Gravity's constant battle against pressure.
  - Gravity wants to brings everything together.
  - (Thermal) Pressure wants to spread everything out.
- Start with a giant cloud of gas. If massive enough, own self gravity can cause collapse.
- Cloud fragments into multiple stars all forming simultaneously.
- As regions condense, collisions raise temperature up. Eventually hot enough to be stars.

Heading Toward Stars

- As cloud contracts, fragments into pieces ("protostars"). Their own gravity takes over and forces them into free-fall collapse.
- As the density of the protostar grows, so does the temperature and pressure, especially in the center.



A Star is Born



Gravitational contraction releases energy, no fusion yet.

Nuclear energy in center provides pressure and energy when T > 10^7 K

Hydrostatic Equilibrium: Stable balance between pressure from nuclear fusion and gravity.

A Star is Born

- When the temperatures get sufficiently high in the center (> 10^7 K), quantum nuclear reactions start to take place:
  - A STAR IS BORN!
- Star settles onto the main sequence; contraction ceases. L and T stabilize.
- Nuclear reactions provide a counterbalance against gravity's never-ending pull.
- Star is in "hydrostatic equilibrium"