Announcements

- Webwork due on Wednesday
- Keep in mind: Poor test scores with high homework scores are recoverable. Poor test scores with poor homework scores will definitely hurt.
- Lab Group A meeting tonight!
- Test 3 one week from Friday
- Polling: `rembold-class.ddns.net`

APOD!

Let's Review. . .

We can determine the age of a star cluster by:

A. Estimating the number of stars in the cluster
B. Finding the average luminosity of its stars
C. Looking at the average temperature of the cluster
D. Determining where it leaves the main sequence

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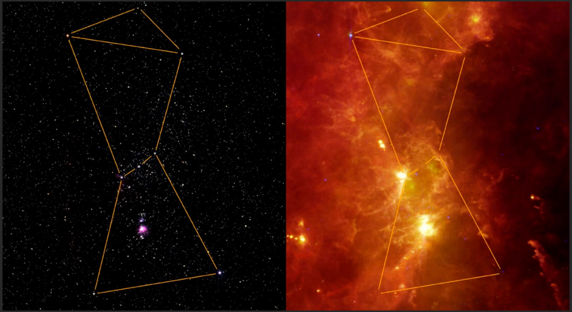
Making a Star: Gather Your Ingredients

- Ch 21.1 and 21.2
- Stars are formed in giant molecular clouds
    - Dense, cold, dusty regions of interstellar space
    - "Dense" is relative here...

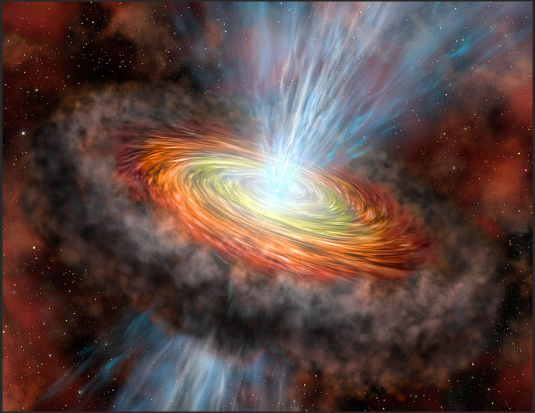
Bring it in. . .

- Need gravity to be greater than any internal gas pressure
  - Easiest with dense, cold regions
  - Hence the molecular clouds
- Densest regions attract the most gas
  - Breaks a cloud up into various smaller clouds
  - Each smaller, dense cloud can continue to contract to become a protostar



Protostars

- Molecular cloud moves towards random regions of density
- Gravity further isolates and condenses dense regions
- The resulting cloud fragment is generally called a protostar
  - Not yet hot enough to start nuclear fusion!
  - Can still be bright due to the energy loss of inward moving gas




UK Astrophysical
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Matthew Bate
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Yo Momma So Fat. . .

- For a cloud of some density and temperature, how much mass do we need to "win" and collapse to form protostars?

$$M_{min} = 18M_{\odot}\sqrt{\frac{T^3}{n}}$$

where

- T is the temperature of the gas cloud
- n is the gas density in terms of particles per cubic centimeter
- M_{min} is the minimum mass needed for the cloud to collapse and start creating stars
- $M_{\odot}$ is the mass of the Sun

Example

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Suppose I observed a massive molecular cloud, with the below properties:

- $T = 25\,\mathrm{K}$
- $n = 500\,\mathrm{particles/cm^3}$
- $M = 75 M_\odot$

Should I expect this molecular cloud to collapse into protostars?

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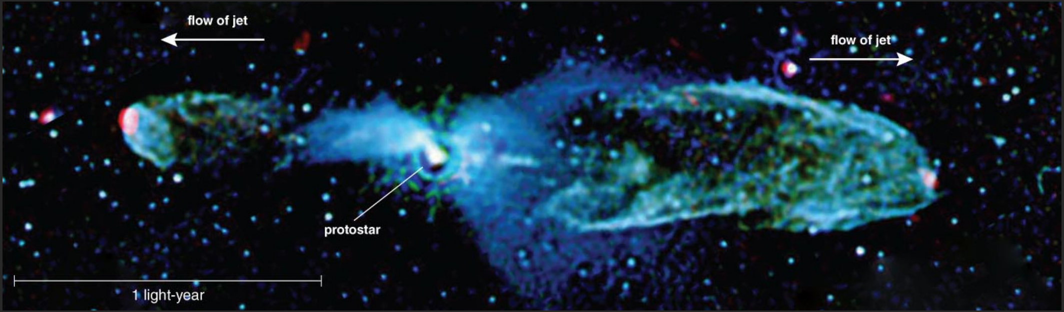
Should I expect this molecular cloud to collapse into protostars?

NO!

$M_{min} = 100.62 M_\odot$

Jets!

- Life as a protostar is often violent!
- Rapid rotations lead to disk flattening
- We commonly see jets emanating from the poles
  - Help shed angular momentum?
  - Influenced by strong magnetic fields



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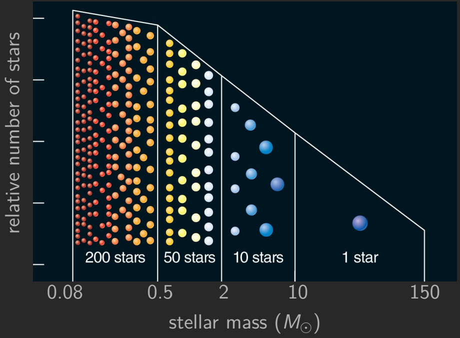
Onward toward the Main Sequence!

- More massive stars do everything faster!
- Protostar lifetimes
  - O or B type: a million years or so
  - G type: 30 million years
  - M type: >100 million years
- Makes it possible for some massive stars to ignite, shine, run out of fuel and die before a smaller baby star even starts fusion!

What's being born?

- High mass stars are rare
- Low mass stars are much more common



Star classifications: Spectral types

Dwarfs

O B A F G K M D T Y L

Colors do not represent the actual visual color of the star.

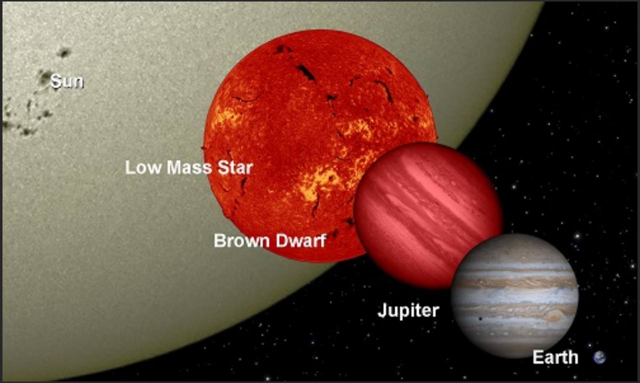
	Star system	Distance in light-years	Stellar type (s)	Observed planets
1	Alpha Centauri	4.24-4.37	M, G, K	1
2	Barnard's Star	5.96	M	
3	Wolf 359	7.78	M	
4	Lalande 21185	8.29	M	
5	Sirius	8.58	A, D	
6	Luyten 726-8	8.73	M, M	
7	Ross 154	9.68	M	
8	Ross 248	10.32	M	
9	Epsilon Eridani	10.52	K	2
10	Lacaille 9352	10.74	M	
11	Ross 128	10.92	M	
12	EZ Aquarii	11.27	M, M, M	
13	Procyon	11.40	F, D	
14	61 Cygni	11.40	K, K	
15	Struve 2398	11.53	M, M	
16	Groombridge 34	11.62	M, M	
17	Epsilon Indi	11.82	K, T, T	
18	DX Cancri	11.83	M	
19	Tau Ceti	11.89	G	5
20	GJ 1061	11.99	M	
21	YZ Ceti	12.13	M	
22	Luyten's Star	12.37	M	
23	Teegarden's Star	12.51	M	
24	SCR 1845-6357	12.57	M, T	
25	Kapteyn's Star	12.78	M	
26	Lacaille 8760	12.87	M	
27	Kruger 60	13.15	M, M	
28	DEN 1048-3956	13.17	M	
29	UGPS 0722-05	13.26	T	
30	Ross 614	13.35	M, M	
31	WISE 1541-2250	13.70	Y	
32	WISE 0350-5658	13.70	Y	
33	Wolf 1061	13.82	M	
34	Van Maanen's Star	14.07	D	
35	Gliese 1	14.23	M	
36	Wolf 424	14.31	M, M	
37	TZ Arietis	14.51	M	
38	Gliese 687	14.80	M	
39	LHS 292	14.80	M	
40	Gliese 674	14.81	M	1

The Highs and Lows of Life

- Upper limit of star mass
  - Largest observed about $150M_\odot$
  - May be some a bit larger
  - Luminosity actually gets so high it starts blowing parts of the star itself away
- Lower limit
  - Need at least $0.08M_\odot$ to ignite nuclear fusion reliably
  - Radiate primarily in the infrared
  - Slowly cool due to missing an energy source
  - Called Brown Dwarfs

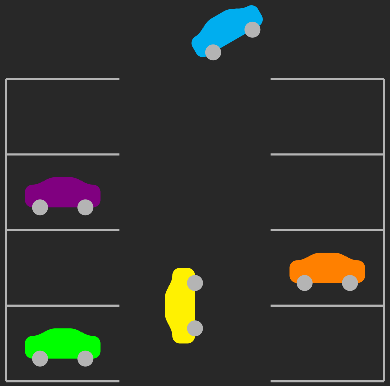
The Brown Dwarfs

- Occupy the space between large planet and tiny star
- Glow reddish
- Without fusion to provide an energy source, why does gravity not crush them?
  - Degeneracy Pressure



Parking Lot Degeneracy Pressure

- Pauli Exclusion Principle limits numbers of particles in certain states
- “Backs up traffic” as particles have to search and work harder to find space



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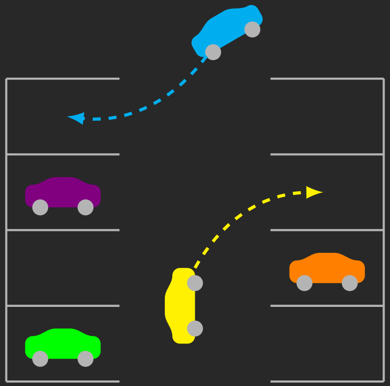

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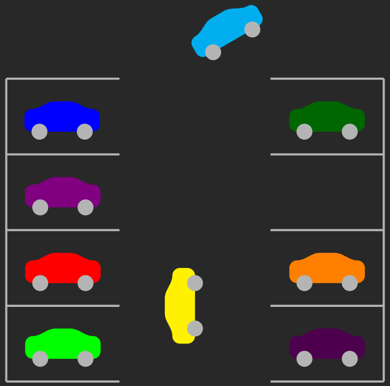

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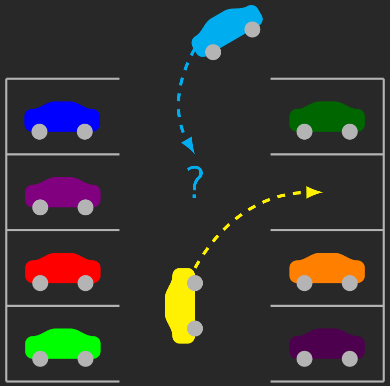

A Massive Undertaking

- A star's mass is likely its most influential property
- Determines:
  - Luminosity
  - Temperature
  - Lifetime
  - And its ultimate fate!
- Catagorize:
  - Low-mass: stars born with a mass $< 2M_\odot$
  - Intermediate-mass: stars born with mass between 2 and 8 $M_\odot$
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- We'll look at low mass star lifetimes first, then look at intermediate and high mass lifetimes together