AST1002

Stellar Alchemy

Chapter 14
Star Stuff

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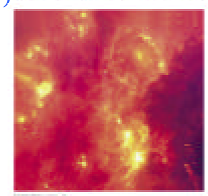
Star Stuff

- Stars form in cold molecular clouds (mostly H_2 but also perhaps some CO, H_2O)
- Gravity collapses a piece of the cloud which heats up and begins to glow as a protostar



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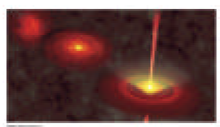
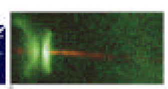
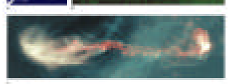
Star Stuff

- Conservation of angular momentum causes the cloud the spin faster and flatten into a disk
- Magnetic fields cause jets of material to form







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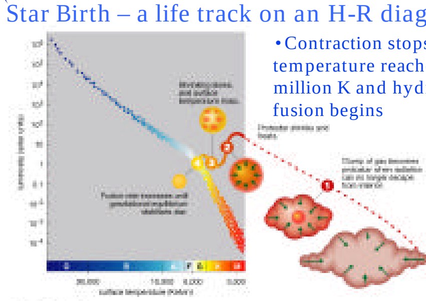
Star Stuff

- Star Birth – a life track on an H-R diagram



- Contraction stops when temperature reaches 10 million K and hydrogen fusion begins

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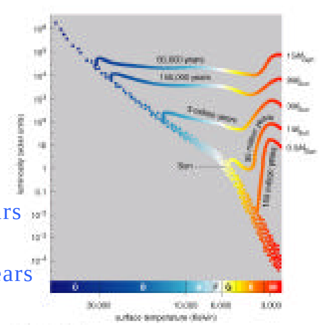
Star Stuff

- Mass controls formation time
  - 15 M_{sun} 60,000 years
  - 1 M_{sun} 50 million years
  - 0.5 M_{sun} 150 million years



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Star Stuff

- Stellar Birth Weights
  - Many stars will form from a molecular cloud
  - Wide range of masses

10 – 100 M_{sun}	1 star
2 –10 M_{sun}	10 stars
0.5 – 2 M_{sun}	50 stars
Less than 0.5 M_{sun}	200 stars

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Star Stuff

- Stellar Birth Weights
  - Upper limit about 100 M_{sun}
    - Radiation pressure blows star apart
  - Lower limit about 0.08 M_{sun}
    - Electron degeneracy pressure limits contraction
    - Temperature less than 10 millon K
    - No hydrogen fusion
  - Brown dwarfs and giant planets

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Star Stuff

- Gravitational equilibrium
  - A continuous balance between gravity and pressure
  - If pressure does not balance gravity the star will shrink or expand

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Star Stuff

- Three kinds of pressure
  - Thermal pressure maintained by energy generation
  - Radiation pressure maintained by energy generation
  - Degenerate pressure
    - No two particles can have the same position and velocity

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Star Stuff

- Life cycles of stars
  - Low mass stars
    0.08 M_{sun} to 2 M_{sun}
  - Intermediate mass stars
    2 M_{sun} to 8 M_{sun}
  - High mass stars
    above 8 M_{sun}

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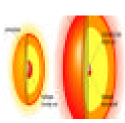
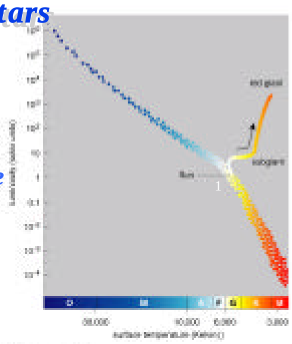
Low Mass Stars

1. Remain on the **main sequence** while H fusion (into helium) goes on ***in the core***





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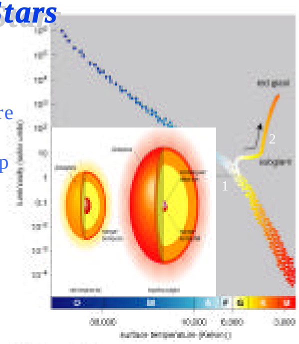
Low Mass Stars

2. H shell burning
   - H shell generates energy, Helium core shrinks, Luminosity goes up
   - Outer layers expand
     - Star becomes a giant
     - Takes 1 billion years for the sun



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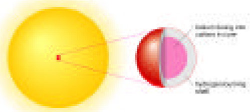
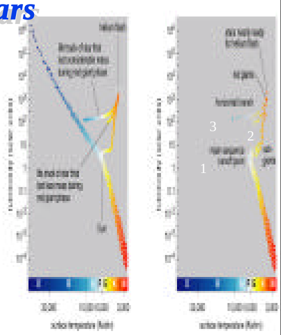
Low Mass Stars

3. Helium fusion
   - 3 ^{4}He -> ^{12}C
   - H burning shell expands and cools
   - Star moves to horizontal branch





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Low Mass Stars

3. Helium fusion
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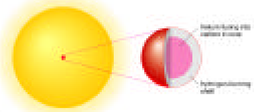

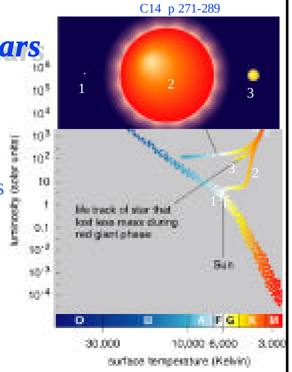

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Low Mass Stars

4. Double shell burning (H, He)

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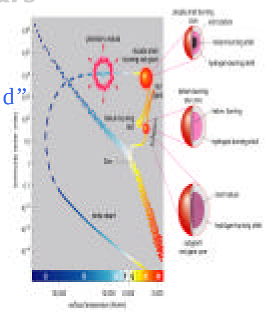
Low Mass Stars

4. Double shell burning (H, He)
   - Strong "stellar wind"



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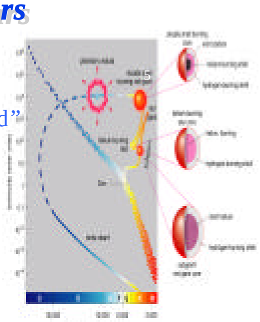
Low Mass Stars

4. Double shell burning (H, He)
   - Strong "stellar wind"
5. Ejects Planetary Nebula



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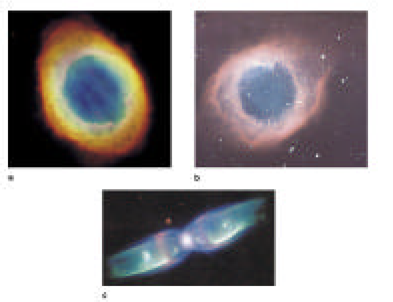
Low Mass Stars



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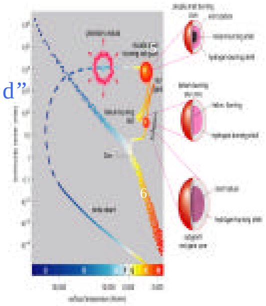
Low Mass Stars

4. Double shell burning (H, He)
   - Strong “stellar wind”
5. Ejects Planetary Nebula
6. Leaves white dwarf



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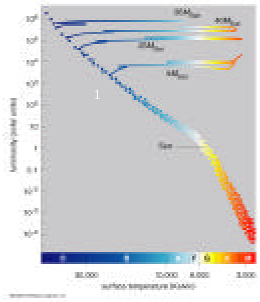
Medium and High Mass Stars

1. Main Sequence
   - H fusion in core
   - Radiation pressure may be more important than thermal pressure



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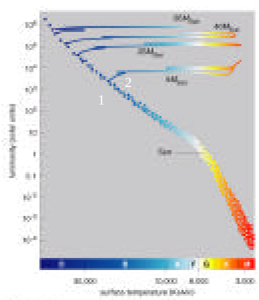
Medium and High Mass Stars

1. Main Sequence
   - H fusion in core
   - Radiation pressure may be more important than thermal pressure
2. H shell burning



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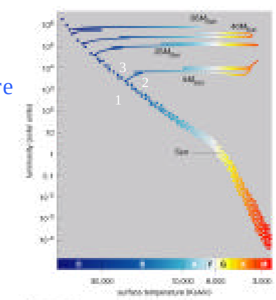
Medium and High Mass Stars

1. Main Sequence
   - H fusion in core
   - Radiation pressure may be more important than thermal pressure
2. H shell burning
3. H shell, He core burning



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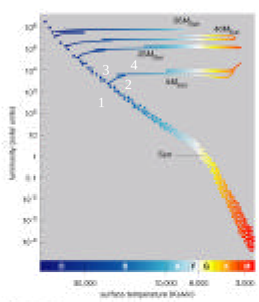
Medium and High Mass Stars

1. Main Sequence
   - H fusion in core
   - Radiation pressure may be more important than thermal pressure
2. H shell burning
3. H shell, He core burning
4. H, He shell, C core burning



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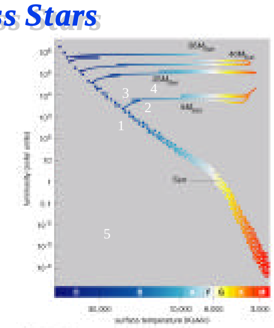
Medium Mass Stars

1. Main Sequence
   - H fusion in core
   - Radiation pressure may be more important than thermal pressure
2. H shell burning
3. H shell, He core burning
4. H, He shell, C core burning
5. Blow off upper layers; become white dwarf



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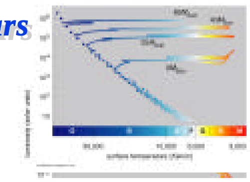
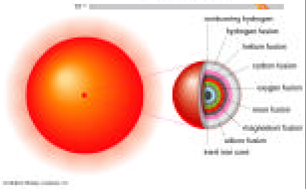
High Mass Stars

- Multiple fusion layers
  - Carbon
  - Oxygen
  - Neon
  - Magnesium
  - …
  - Iron





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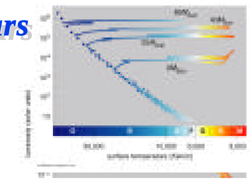
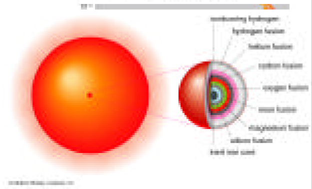
High Mass Stars

- Multiple fusion layers
  - Carbon 100 years
  - Oxygen 100 days
  - Neon 100 hours
  - Mg 100 mins
  - …
  - Iron 100 secs





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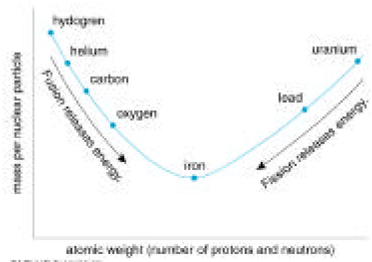
Star Stuff

- The Limit is Iron!



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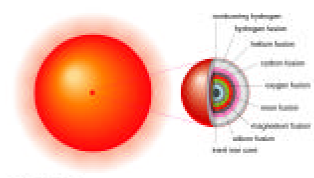
Star Stuff

- Core eventually collapses as Iron builds up



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Star Stuff

- Core eventually collapses as Iron builds up
- Protons and electrons merge to form neutrons (and neutrinos)

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Star Stuff

- Core eventually collapses as Iron builds up
- Protons and electrons merge to form neutrons (and neutrinos)
- Gravitational energy released …

Supernova

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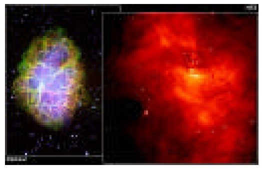
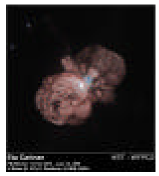
Star Stuff

- Supernova
  - Up to 10 billion L_{sun}
  - Leaves a neutron star (or maybe a black hole)
  - And a supernova remnant
  - And emits a burst of neutrinos





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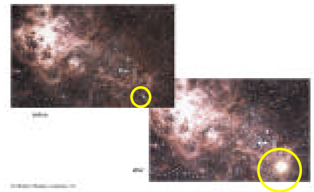
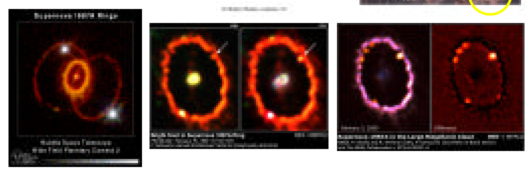
Star Stuff

- SN1987A
  - A shock wave expands





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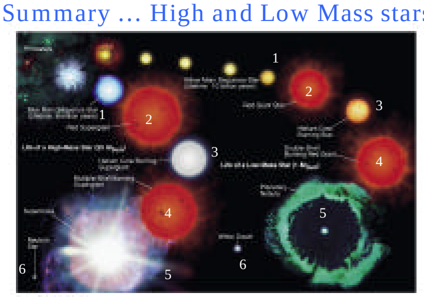
Star Stuff

- Summary … High and Low Mass stars



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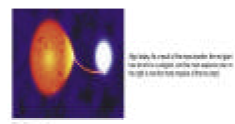
Star Stuff

- Close Binary evolution
  - The "Algol" paradox
  - Today:
    - 0.8 m_{sun} subgiant
    - 3.7 m_{sun} main-sequence star
  - How can this be?



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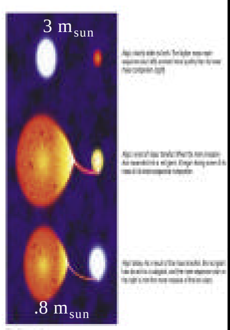
Star Stuff

- Close Binary evolution
  - The "Algol" paradox
    - The sub-giant was once the more massive star
    - The 3.7 m_{sun} main-sequence star was once the less massive star



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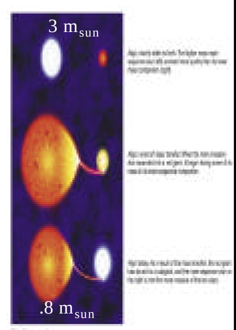
Star Stuff

- Close Binary evolution
  - The "Algol" paradox
    - The sub-giant was once the more massive star
    - The 3.7 m_{sun} main-sequence star was once the less massive star
  - What Next?



Questions and/or Comments?

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