


AST1002




Stellar Alchemy

Chapter 14
Star Stuff


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Star Stuff

- Stars form in cold molecular clouds (mostly H₂ but also perhaps some CO, H₂O)
- Gravity collapses a piece of the cloud which heats up and begins to glow as a protostar



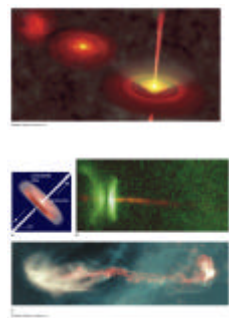
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Star Stuff

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



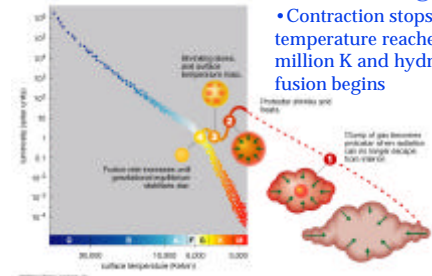
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Star Stuff

- Star Birth – a life track on an H-R diagram
- Contraction stops when temperature reaches 10 million K and hydrogen fusion begins



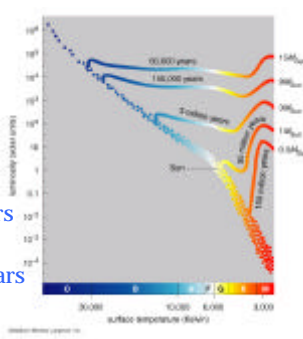
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Star Stuff

- 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

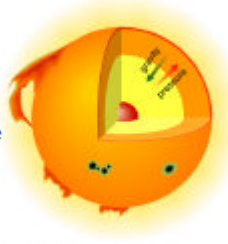
- Stellar Birth Weights
 - Upper limit about $100 M_{\text{sun}}$
 - Radiation pressure blows star apart
 - Lower limit about $0.08 M_{\text{sun}}$
 - Electron degeneracy pressure limits contraction
 - Temperature less than 10 million K
 - No hydrogen fusion
- Brown dwarfs and giant planets

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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

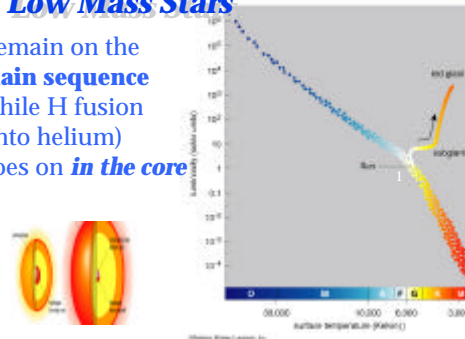
- Life cycles of stars
 - Low mass stars $0.08 M_{\text{sun}}$ to $2 M_{\text{sun}}$
 - Intermediate mass stars $2 M_{\text{sun}}$ to $8 M_{\text{sun}}$
 - High mass stars above $8 M_{\text{sun}}$

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Low Mass Stars

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

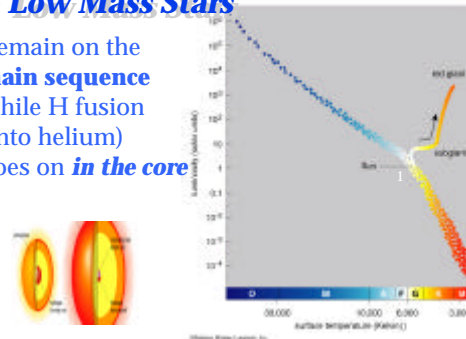


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Low Mass Stars

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

- $3\ ^4\text{He} \rightarrow\ ^{12}\text{C}$
- 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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- H burning shell expands and cools
- Star moves to horizontal branch

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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

- Double shell burning (H, He)
 - Strong "stellar wind"
- Ejects Planetary Nebula
- Leaves white dwarf

The diagram shows the evolutionary tracks of low-mass stars (0.5 to 8 solar masses) on a plot of luminosity (10³⁰ to 10³⁴ W) versus surface temperature (30,000 to 3,000 K). It includes tracks for the main sequence, red giant branch, and planetary nebula phase. Three inset diagrams illustrate the internal structure of a star at different stages: 1. Main sequence (H fusion in core), 2. Red giant (H shell burning), and 3. Planetary nebula (H and He shell burning).

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Medium and High Mass Stars

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

The diagram shows the evolutionary tracks of medium and high-mass stars (8 to 100 solar masses) on a plot of luminosity (10³⁰ to 10³⁴ W) versus surface temperature (30,000 to 3,000 K). It highlights the main sequence phase where radiation pressure becomes significant.

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Medium and High Mass Stars

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

This diagram is similar to slide 20 but highlights the second stage of evolution: H shell burning, which occurs as the star moves off the main sequence.

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Medium and High Mass Stars

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

This diagram highlights the third stage of evolution: H shell, He core burning, showing the star's path towards the end of its main life.

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Medium and High Mass Stars

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

This diagram highlights the fourth stage of evolution: H, He shell, C core burning, representing the final stages of nuclear fuel consumption.

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Medium Mass Stars

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

This diagram highlights the final stage of evolution: Blow off upper layers; become white dwarf, showing the star's path towards the end of its life.

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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

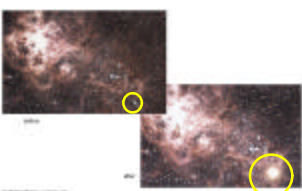
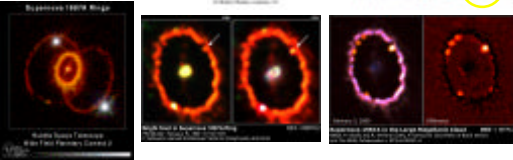



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Star Stuff

- SN1987A
 - A shock wave expands

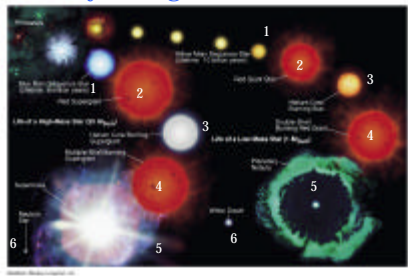



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Star Stuff

- Summary ... High and Low Mass stars

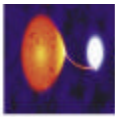


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Star Stuff

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

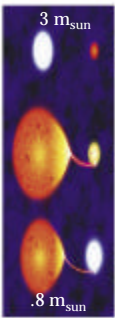


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Star Stuff

- 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

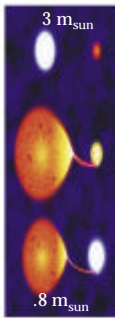


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Star Stuff

- 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?



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Questions and/or Comments?

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or visit <http://www.astro.ufl.edu/~oliver/>