Course Updates

- Reading: Chapter 12
- Avoid Google Chrome browser: causes issues with homework site.
- Homework on Chapter 12 due Wednesday 11:59PM
- Second midterm on November 3, covers chapters 6,9,10,11,12 + nuclear weapons
- Bring scantron form 882E or 882ES (buy it from the bookstore)
- Practice midterm handed out in class on Friday.

Review of HR Diagram

- HR Diagram is a plot of temperature versus luminosity of stars
- Adult stars lie on the , a thin diagonal strip in the chart
- Dying, stars are on the top right
- Dead, stars are on the bottom left

The Stellar Life Cycle

What will eventually happen to all the stars in the universe?

(A) The cycle will continue forever, and the stars will remain about the same through cosmic time
(B) The cycle will continue forever, but each generation of stars will contain less metals
(C) The cycle will continue forever, but the stars get cooler each generation
(D) The cycle will eventually stop, and the universe will go dark

Star Birth

The images of stellar birth are among the most spectacular captured by the Hubble Space Telescope.

What do the colors mean?

In visual images of star forming regions:

- regions are locations where stars are forming, but have not yet begun sustained hydrogen fusion ( )
- regions are where stars that have recently formed light up the surrounding gas

Molecular Clouds

Stars form when a cloud of gas gets cold enough to form hydrogen , $H_2$.

What is a molecule?

- A molecule forms when more than one share their electrons
- Most famous example: $H_2O$, two hydrogen atoms plus one oxygen atom
Molecular Clouds

Water is a most crucial molecule for life on Earth

H₂ is molecular hydrogen:
Two pure hydrogen atoms from the big bang

What is the difference between \(^{2}\text{H}\) and \(\text{H}_2\)?

(A) \(^{2}\text{H}\) is an entirely different element from \(\text{H}_2\).
(B) \(^{2}\text{H}\) has exactly one neutron; the H in \(\text{H}_2\) probably doesn’t.
(C) \(^{2}\text{H}\) has exactly two neutrons; the H in \(\text{H}_2\) probably doesn’t.
(D) They are two different ways of saying the same thing.

How does a star forming cloud look?

How does a star forming cloud look?

Visible Light

Infrared Light

The Stellar Life Cycle

Basic stages in the life of a star

1. Molecular Cloud—a huge region in space with diffuse molecular hydrogen gas
2. Protostar—a dense object with a thin disk of gas around it
3. Main-sequence star—sustained hydrogen fusion; most of the life of the star is spent here
4. Giant phase—no more hydrogen burning in the core; helium burning starts
5. Death—fast and explosive (supernova) or slow and wind-driven
Resisting gravity
How do objects resist gravity? Through non-gravitational forces.
• —keeps you from falling through the ground
• —keeps clouds and stars from collapsing by puffing them up
• Degeneracy pressure—matter is anti-social
  • Electrons, protons, and neutrons simply resist being packed into spaces much tighter than the nucleus of an atom
• When all these fail, you cannot resist gravity.

Star Formation
A hydrogen atom is very of atomic hydrogen
  • Their heat energy at getting cool—clouds collapse into stars.
  • Their heat energy resist gravity.

Hydrogen Atom

Star Formation
A hydrogen molecule is very at getting cool—clouds of molecular hydrogen lose heat through
  • Their heat energy resist gravity.

Star Formation needs molecules
A hydrogen atom is very bad at getting cool—clouds of atomic hydrogen do not collapse into stars.
  • Their heat energy can resist gravity.

Star Formation needs molecules
A hydrogen molecule is very good at getting cool—clouds of molecular hydrogen lose heat through vibration.
  • Their heat energy cannot resist gravity.

Collapse of a molecular cloud
Into a star cluster

The Fight Against Gravity is Life-Long
It’s like a tennis match

The Fight Against Gravity is Life-Long
In the end, gravity is just a little bit better than anything a star can produce

Human-Star Comparison

<table>
<thead>
<tr>
<th>Event</th>
<th>Star Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud collapses</td>
<td>0 15</td>
</tr>
<tr>
<td>Protostar heats up, slows collapse</td>
<td>15 30</td>
</tr>
<tr>
<td>Protostar too big, starts to recollapse</td>
<td>30 30</td>
</tr>
<tr>
<td>Fusion ignites, puffs up the star</td>
<td>30 30</td>
</tr>
<tr>
<td>Hydrogen supply runs out, core collapses</td>
<td>40 40</td>
</tr>
<tr>
<td>Helium burning starts</td>
<td>40 40</td>
</tr>
</tbody>
</table>

Motion Along the HR Diagram
How does the brightness and color of a protostar change as it grows?
Motion Along the HR Diagram

What is happening as the protostar moves onto the main sequence?
- The star is always moving towards bluer colors.
- Luminosity is going up and down. Why?

Why is the luminosity going up and down?

Remember that

\[ \frac{L}{L_{\text{sun}}} = \left( \frac{R}{R_{\text{sun}}} \right)^2 \left( \frac{T}{T_{\text{sun}}} \right)^4 \]

(A) The star’s temperature is going up and down
(B) The star’s radius is going up and down
(C) The star’s radius is only going down
(D) The star’s radius is only going up

Growth track for the sun

Growth track for other stars

Mass limits for the stars

The smallest stars are 8% of the mass of the sun because smaller gaseous objects
(A) Aren’t hot enough at the core to start fusion
(B) Simply do not exist
(C) Do not have enough hydrogen to start fusion
(D) Would be called planets instead

The largest stars are about 150 solar masses because beyond 150 solar masses
(A) Light itself pushes away any excess gas
(B) The stars rapidly boil away any excess gas
(C) The protostar turns directly into a neutron star
(D) The protostar turns directly into a black hole

Initial mass function

Smaller mass stars are much more common.

The first stars

- The first stars exceeded the 150 solar mass limit
- They did this because they didn’t have any
- Without metals, pressure isn’t as effective—light blows right through hydrogen and helium