The Formation of Stars Like the Sun

Gravity & Heat

* In an interstellar medium, equilibrium is maintained by the balance of the opposing forces of gravity (directed inward) & heat (outward pressure)

* Effects of gravity and heat:

  * Gravity pulls the atoms together
  * Heat is the random motion of the atoms
* How does star formation begin?
  
  When part of an interstellar medium collapses under its own weight

* As the # of atoms increases in an accidental cluster, the gravitational attraction increases, and the clump becomes strong enough for the atoms not to disperse. The effect of heat is not stronger than the effect of gravity. The gravity causes it to contract, forming a star.

* The clump must have a mass comparable to that of the sun to prevent dispersal.

* Star formation is triggered when a sufficiently massive pocket of gas is squeezed by some external event.
The 7 Stages of Star Formation

There are 7 evolutionary stages that an interstellar cloud goes through before becoming a mainsequence star like our Sun:

Stage 1: An interstellar cloud
Stages 2 & 3: A contracting cloud fragment
Stages 4 & 5: Protostellar evolution
Stages 6 & 7: A Newborn star
Stage 1: An Interstellar Cloud

*Dense interstellar cloud begins to collapse, and fragments into smaller clumps*

*Temperature goes up, pressure goes up, fragmentation stops, but contraction continues*

*This process takes a few million years*
Stages 2 & 3: A Contracting Cloud Fragment

*In stage 2, the fuzzy gaseous blob is still about 100 times the size of our solar system.

*The fragment shrinks due to contraction, and when the fragment’s diameter is about the size of our solar system, stage 3 occurs.

*In stage 3, we first see the protostar: dense, opaque region at the object’s center. The object for the first time resembles a star.
Stages 4 & 5: Protostellar Evolution

*The mass is now the size of Mercury’s orbit, and the temp. is a few thousand kelvins
  - We can now calculate the luminosity using the radius-luminosity-temperature relationship

*H-R diagram shows the physical properties in stage 4
  - The surface temp. and luminosity are represented by a single point on the diagram

-*Evolutionary track*- Motion of that point around the diagram as the star evolves

*Contraction slows due to internal heat diffusing*
**Hertzsprung-Russel Diagram**

**Luminosity Class**

I  Supergiants
II  Bright giants
III Giants
IV Sub- giants
V  Main sequence (dwarfs)
VI  Sub- dwarfs
VII White dwarfs

Note: it's a 2D classification scheme on the HR diagram!

...sometimes plotted as B- V
Protostellar Evolution, continued

*Stage 5: It is now 10 times the size of the Sun
*Violent surface activity due to protostellar winds occurs
*This portion of the evolutionary track is called the *T*
  *Tauri phase*
* Evolution slows: luminosity goes down, as does contraction
-After 10 million years, the protostar evolves into a true star.

-Stage 6 = The radius of the star will be larger than an avg. sun, but b/c it has a lower surface temperature which means that its luminosity is only about 2/3 of its actual solar value.

-What occurs in Stage 6?
Protons begin fusing into helium in the core and the star is formed.

-How do we know that stage 6 exists?
Around newly formed stars there are “cocoons” of dust, which absorb the radiation that the star emits and reemits them as infrared radiation which allows us to view it through infrared observation.
• **Hot stars are said to heat their surrounding clouds in the fact that:**

• 1) Dust cocoons are predicted to disperse quite rapidly once their central star form.

• 2) The composition of the cocoons are found in the cores of molecular clouds.
• Over 30 million years the **stage-6** star contracts to normal size. The central density rises to $10^5 \text{ kg/m}^3$, the central temp rises to 15 million K and the surface temp rises to 6000 K.

• Star reaches the main sequence in **stage-7**, where gravity and pressure are balanced and the rate of nuclear energy generated in the core matches the rate at which energy is released.

• The entire process takes **40-50** million years, but in terms of a star’s lifetime it is still less than 1%. The star will remain on the H-R diagram almost unchanged for the next **10** billion years.
Stars of Other Masses

• The Zero-Age Main Sequence

• “Failed” Stars
The Zero-Age Main Sequence

• This is the point at which stars settle and begin the process of hydrogen burning.

• The ZAMS is not an evolutionary track; it is a waypoint on the H-R diagram.
  – Once on the main sequence, a star stays in the same location; it doesn’t change classifications.
“Failed” Stars

- Brown Dwarfs – Never begin burning hydrogen because they are too small and don’t generate enough heat.

- Minimum mass of gas needed to generate nuclear fusion is 0.08 solar masses – 80 times the mass of Jupiter.
11.5 Star Clusters!

- Star cluster = Groups, dozens to millions, of stars that form at the same time, from the same cloud of interstellar gas.

- Star clusters provide information about stellar evolution, because they are similar in age and chemical composition and are similar distances from earth.

- Mass is the only distinction between stars in a star cluster.
- **Open Cluster** = Loosely bound collection (100-1000) of stars that span over a few parsecs.

- H-R Diagram of Pleiades cluster allows scientists to estimate the age of the cluster to be less than 20 million years old, the lifetime of an O-type star.
• **Association** = Small grouping of young stars (typically less than 100), that spans few tens of parsecs.

• Associations survive for only few tens of millions of years as oppose to open clusters which last for millions/billions of years.

• It is believed that the main difference between associations and open clusters is the way the stars were formed: how many stars in the original cloud ended up in actually forming stars.
• **Globular cluster** = Sphere-like collection (100,000-1,000,000) of stars that spans 50 parsecs.

• Globular clusters lack upper main-sequence stars, they contain no main sequence stars greater than 80% mass of the sun.

• The A-type stars in the H-R diagram are a lot further in the evolutionary process of stars.

• Globular clusters are estimated to be at least 10 billion years old, and are speculated as the survivors of clusters formed long ago.
• Infrared observations have demonstrated that stars really are found within star-forming regions.
The End!!!

Greg doesn’t want to ask any questions, so we aren’t going to!