Chapter 9
Perspective: Origins

Guidepost

In the next chapter we will look at the origins of our solar system. But to understand that, we need to look more closely at the stars, our galaxy and the origins of the Universe. Afterwards we should be able to answer the following:

1. How are stars born, and how do they die?
2. What are galaxies, and how do they form and evolve?
3. How did the Universe begin?
4. How are the atoms in our bodies formed?

The Birth of Stars

Stars may appear to be permanent, but astronomers know that stars are born and stars die.

Although space seems empty, it is filled with thinly spread gas and dust, called the interstellar medium. The medium is mostly hydrogen, with ~1% being dust (heavier atoms such as carbon and iron).
The medium is collected into masses called nebulae.

The Birth of Stars (2)

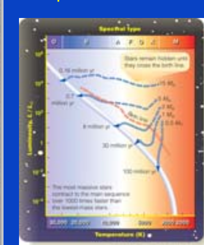
If a nebula grow denser due to gravitational attraction or a shock wave passing through them, stars might be born within the gas cloud. Shock waves may originate via supernova explosions, galactic collisions, or other energetic processes.

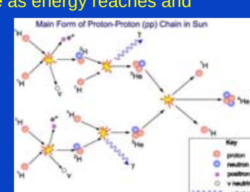
The Birth of Stars (3)

Protostars form within the cloud, but these are hard to see as they do not yet emit energy at visual wavelengths. But their heat shows them via infrared radiation.

The Birth of Stars (4)

Hydrogen fusion begins in the dense core of the protostar, and the star will soon shine as energy reaches and escapes its surface.



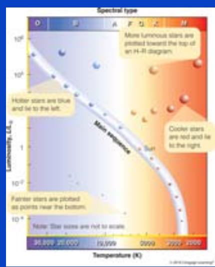


Higher Mass Stars evolve more quickly.

http://www.atnf.csiro.au/outreach/education/senior/astrophysics/stellarevolution_mainsequence.html

Stellar Evolution and the Hertzsprung-Russell Diagram

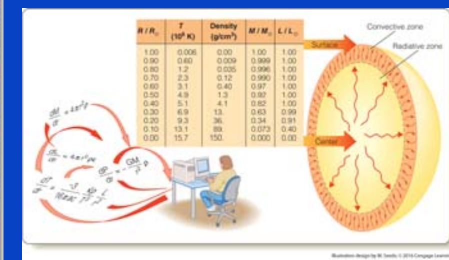
A graph of temperature vs. luminosity shows that stars tend to group according to their size.



The Sun appears with a group of stars that are called the Main Sequence. These stars all plot on a diagonal line. These stars all fuse hydrogen in their cores, generating energy.

Stellar Evolution and the Hertzsprung-Russell Diagram (2)

Stars on the Main Sequence radiate energy outward from their cores, with the energy coming from hydrogen fusion.

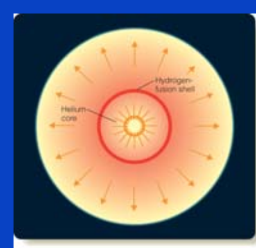


Stellar Evolution and the Hertzsprung-Russell Diagram (3)

The amount of energy radiating outwards has to balance the weight of gases above each zone in a star.

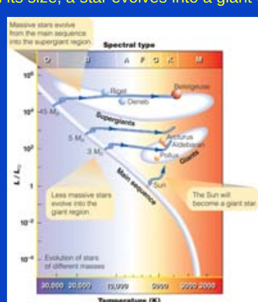
Stellar Evolution and the Hertzsprung-Russell Diagram (4)

At some point, all the hydrogen has been fused within the core of the star and helium fusion begins. At this point the star moves off of the main sequence.



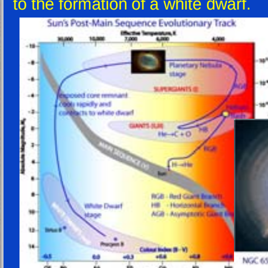
Stellar Evolution and the Hertzsprung-Russell Diagram (5)

Depending on its size, a star evolves into a giant or super giant star.



Stellar Evolution and the Hertzsprung-Russell Diagram (6)

Our Sun will follow an evolutionary path that will eventually lead to the formation of a white dwarf.

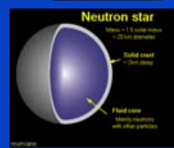


A white dwarf is effectively an exposed core of a star, collapsing due to its own weight and quickly getting dimmer.

http://www.atnf.csiro.au/outreach/education/senior/astrophysics/stellarevolution_deathlow.html

Stellar Evolution and the Hertzsprung-Russell Diagram (7)

Stars that are more massive than the Sun will form Supergiant stars. These stars will produce a supernova and a neutron star or black hole depending on their final mass.



http://funandmagic.com/photolinks2.htm
http://www.atnf.csiro.au/outreach//education/senior/astrophysics/stellarevolution_deathhigh.html

Stellar Evolution and Heavy Elements

Supernova explosions are the catalysts that create heavier elements. As stars are born, live, die and new stars take their place, the concentration of heavier elements is slowly increasing.

Stellar Evolution and Heavy Elements (2)

Our solar system had to have formed from the leftover remnants of just such an explosion.

Our Home Galaxy

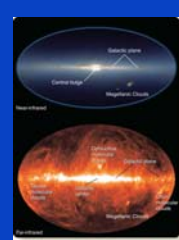
The Milky Way is familiar to most stargazers. It is in fact our own home galaxy. A galaxy is “a very large collection of stars, gases and dust orbiting a common center.”

Our Home Galaxy (2)

The Milky Way is a barred-spiral galaxy. Molecular clouds are concentrated along the spiral arms – locations for new star formation.

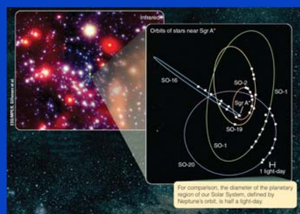
Our Home Galaxy (3)

The Milky Way that we see is the edge of the spiral. Looking towards the galactic center it has a central bulge.



Our Home Galaxy (4)

Careful study of stars near the galactic core indicate that there is a massive black hole at the center of our galaxy with a mass of at least 4 million solar masses.



The Universe of Galaxies

But we are not alone in the Universe. There are many galaxies as this Hubble Deep Field image shows.

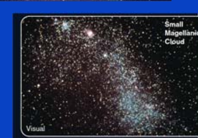
The Universe of Galaxies (2)

Galaxies come in three main shapes:

- Elliptical galaxies have no disk, no spiral arms, and almost no gas and dust
  - Range from huge giants to small dwarfs
- Spiral galaxies: disk-shaped
  - Typically have spiral arms and contain gas and dust
  - Variations: barred spiral and lenticular galaxies
- Irregular galaxies: generally shapeless and tend to be rich in gas and dust

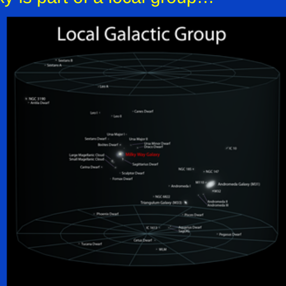
The Universe of Galaxies

Examples of each galaxy type:



The Universe of Galaxies (2)

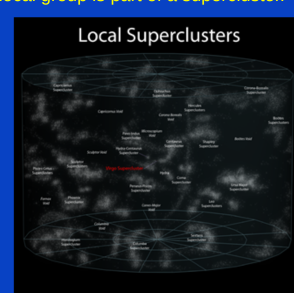
Our galaxy is part of a local group…



https://en.wikipedia.org/wiki/Local_Group#/media/File:5_Local_Galactic_Group_%28ELitU%29.png

The Universe of Galaxies (3)

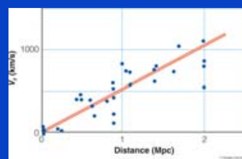
… and our local group is part of a supercluster.



https://commons.wikimedia.org/wiki/File:7_Local_Superclusters.png

Hubble's Law and the Origin of the Universe

Edwin Hubble made an important discovery in the 1920s by studying "nebulae" – what we now call galaxies.



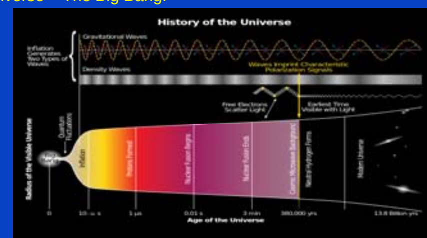
The greater the distance to a galaxy, the faster it was moving away from us. This is now called Hubble's Law.

http://www.phys-astro.sonoma.edu/brucemedalists/hubble/

Hubble's Law and the Origin of the Universe (2)

The fact that the farther away a galaxy is the faster it is moving indicates that the Universe is expanding.

Hubble's discovery soon led to a hypothesis for the origin of the Universe – The Big Bang.

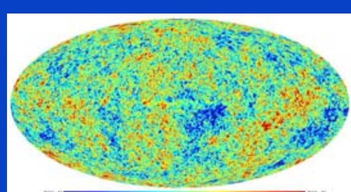


https://en.wikipedia.org/wiki/Big_Bang

Evidence for the Big Bang

Evidence for the Big Bang includes:

- The expansion of the Universe (Hubble's result)
- The relative abundance of simple elements (H & He)
- Cosmic microwave background radiation



http://space.mit.edu/home/tegmark/wmap.html