

# STARS

Pewaukee Astronomy Club  
January 9, 2010

## Definition - Star

A massive, **luminous** ball of plasma [atoms missing electrons] that is held together by **gravity**. ([en.wikipedia.org/wiki/Star](http://en.wikipedia.org/wiki/Star))

A **self-luminous celestial** body consisting of a mass of gas held together by its own **gravity** in which the energy generated by **nuclear reactions** in the interior is **balanced** by the outflow of energy to the surface, and the inward-directed gravitational forces are balanced by the outward-directed gas and radiation pressures. ([www.thefreedictionary.com/star](http://www.thefreedictionary.com/star))

## Key Points

- **Celestial** – Waaaaaay out there. Can't find or make one on earth.
- **Luminous** – Emits all kinds of energy, but the most famous ones send visible light.
- **Massive** – Really, REALLY big and "heavy" by earth standards.
- **Gravity** – Holds it together. Related to massive.
- **Nuclear reactions** – Energy source.
- **Balance** – When aspects get out of balance, something dramatic happens.

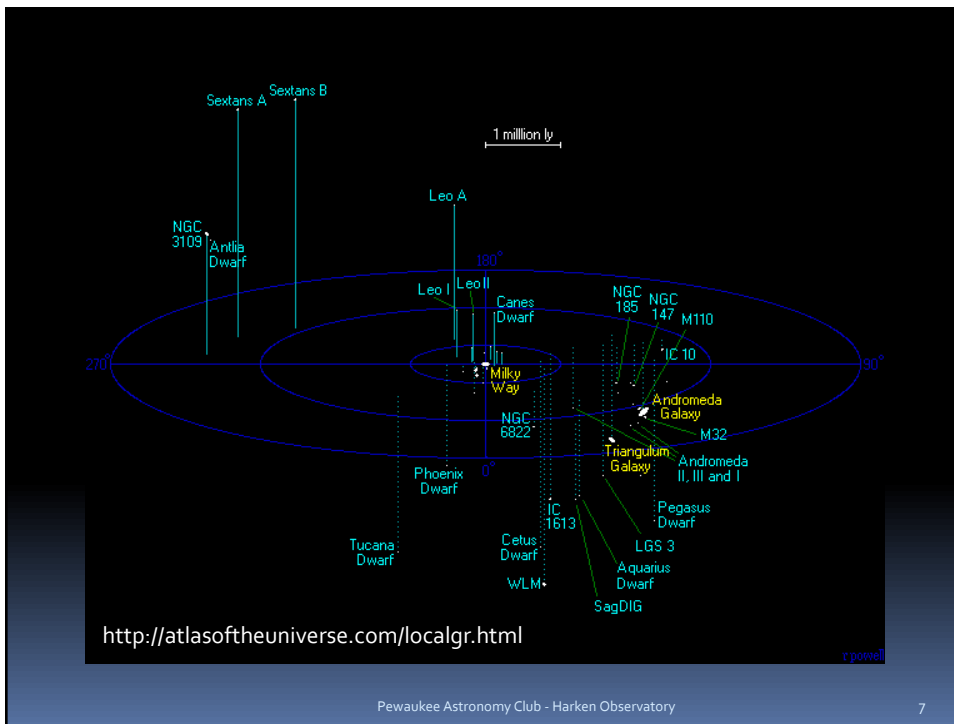
## Key Points

- Every thing we "know" about stars is from observation. No one has visited, or even could visit, a star the way we visited the moon.
- We can discover basic laws of physics and combine them with observations to figure out what must be happening on a star.
- Tomorrow we may decide we had it all wrong!

# Birth

## Creation of Stars

- First, create a bunch of atoms. (Details, details...)
- Distribute the atoms (89% hydrogen, 9% helium, 2% everything else) throughout the universe, forming the interstellar medium.
- Gravity and shocks waves from exploding stars concentrate the medium into Giant Molecular Clouds (GMC).
- The GMC's gravity pulls it into a proto-star.



- Roughly to scale
- 1LY = 5,878,612,843,200 miles
- Milky Way is 100,000 LY diameter & 200-400 billion stars
- Andromeda (M31) is 141,000 LY & 1 trillion stars
- Triangulum is 50,000 LY & 30-40 billion stars

**Stars only occur as part of a galaxy!**

Inter Galactic Space

Intergalactic space is a vacuum  
Perhaps 1 atom / cubic meter  
Air is  $10^{13}$  atoms / cubic meter

Milky Way

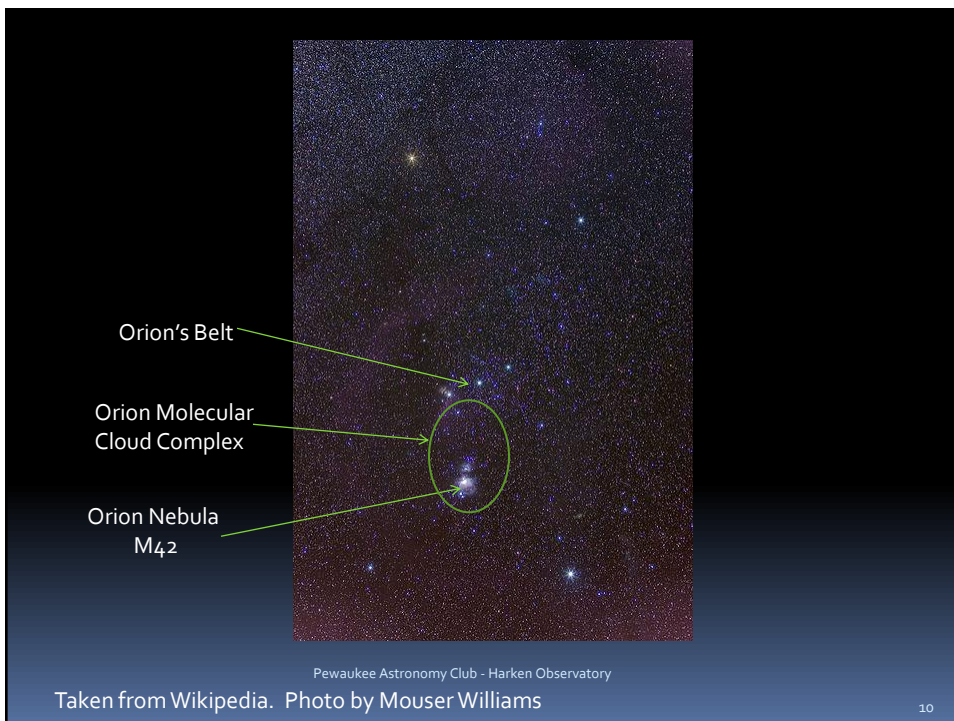
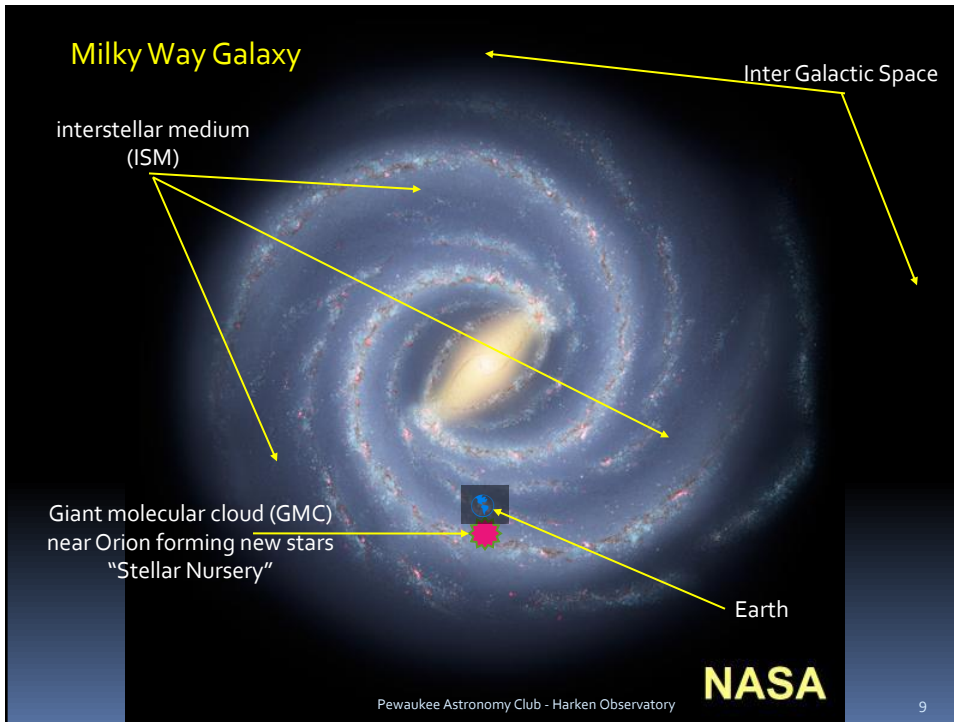
2.5 million LY

50 LY

Andromeda M31

Triangulum M33

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Orion - Barnard 30 – “Clouds” are areas of star formation.  
<http://www.spitzer.caltech.edu/Media/mediainages/copyright.shtml>

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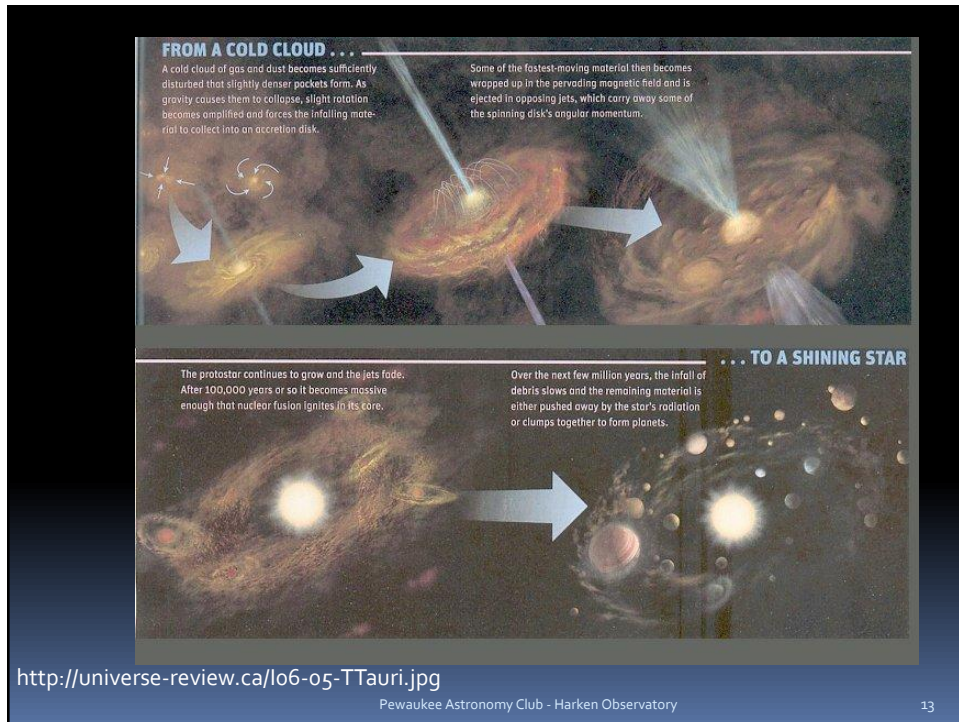
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## A star is born

- The particle clouds condense due to each particle's **gravity** pulling on its neighbor.
- Sometimes two gas clouds collide.
- Sometimes there is an external shock wave such as an exploding nearby
- The “thin” nebula becomes enough atoms close enough together (protostar, t tauri) to collapse and start nuclear fusion
- Sometimes it fizzles out – brown dwarf

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## Inner planets solid, outer gas

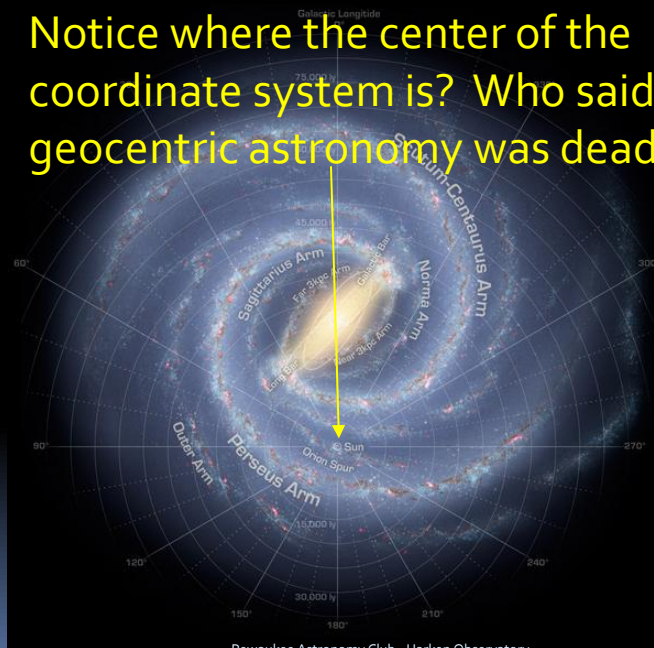
- The particles clouds condensed due to each particle's gravity pulling on its neighbor.
- Hottest in the dense center, forming the super hot sun
- Warm near the middle, condensing out iron, nickel, etc. making rocks
- Cooler farther out, condensing gases into gas giants like Jupiter
- Pluto is very far and a rock - suspicious

# Fun Fact

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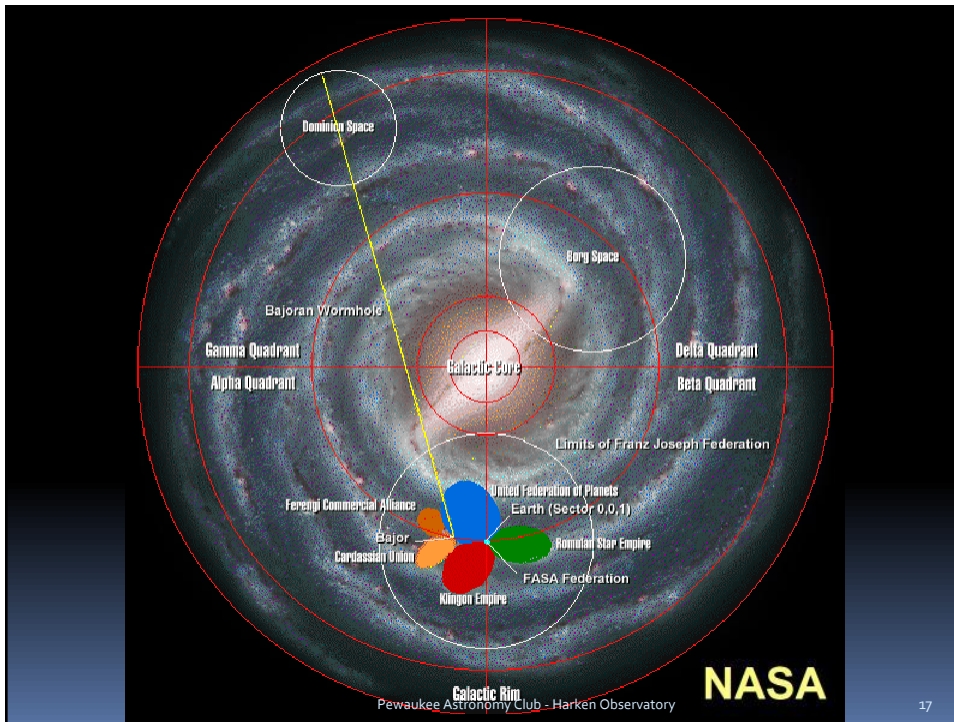
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Notice where the center of the coordinate system is? Who said geocentric astronomy was dead!



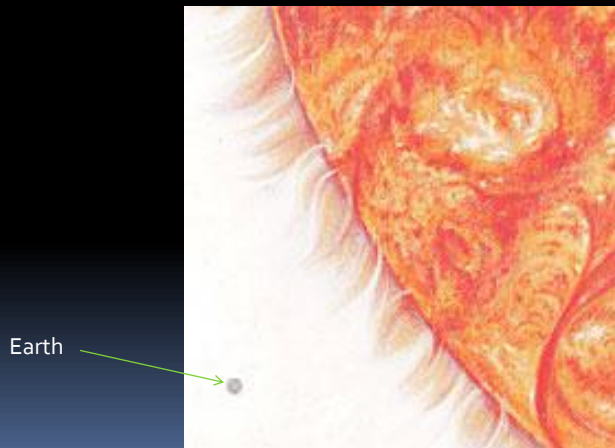
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## Sun Facts

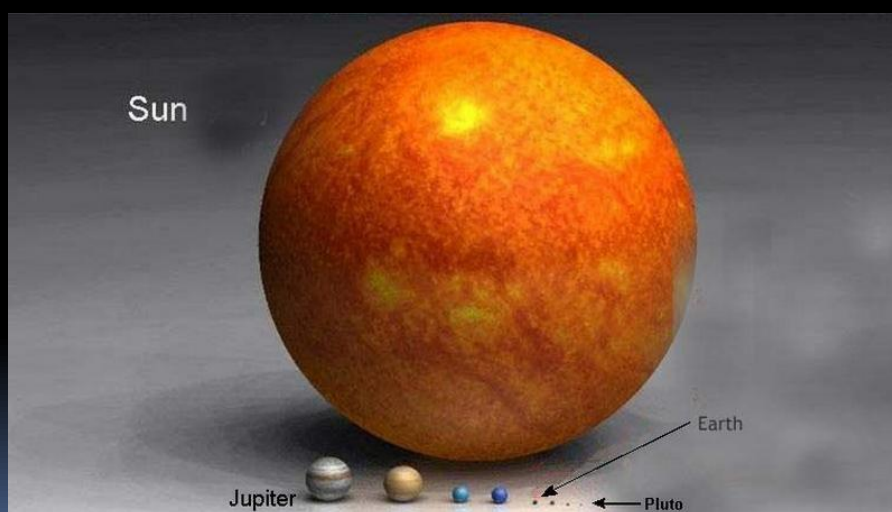
- Radius 432,000 miles (695,500 kilometers), approximately 109 times Earth's radius



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## Solar System

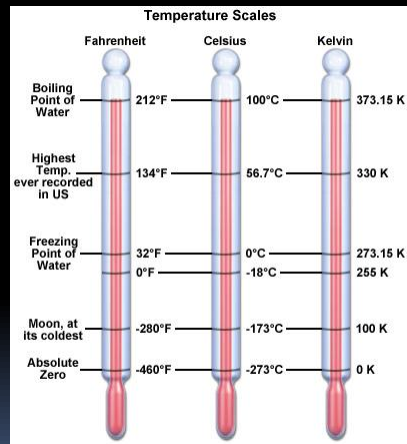


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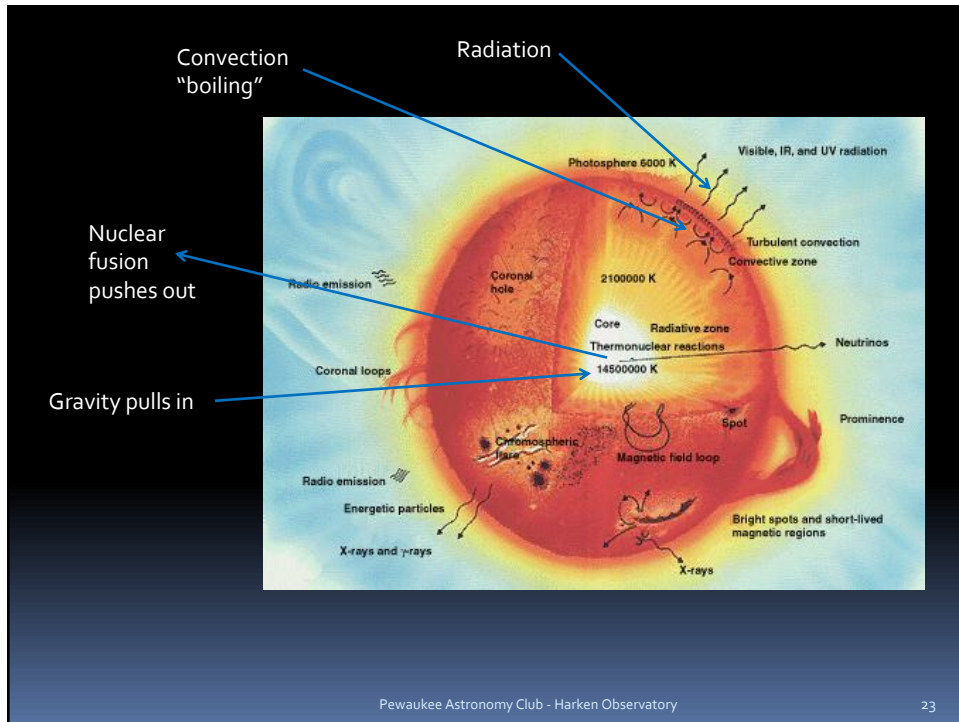
# Temperature Scales

- In the US we use degrees Fahrenheit
- The rest of the world uses Celsius (Centigrade)
- Scientists use Kelvin
- Once you get hot enough, does it really matter?



# Parts of the Sun

- The sun is made of layers
- The exterior we see is (in comparison) cool and less dense. Surface has a temperature of about 10,000 degrees F (5500 degrees C or 5800 K)
- Temperatures in the sun's core reach over 27 million F (15 million K)



## Internals of a Star

- **Hydrostatic Equilibrium** – All that mass creates gravity that pulls everything together. Energy from inside pushes back. Balance.
- **Radiation Transport** – Convection (energy swirling around) and radiation move energy outward.
- **Nuclear Fusion** – Hydrogen atoms combine to make helium and release energy.

## Definition - Star

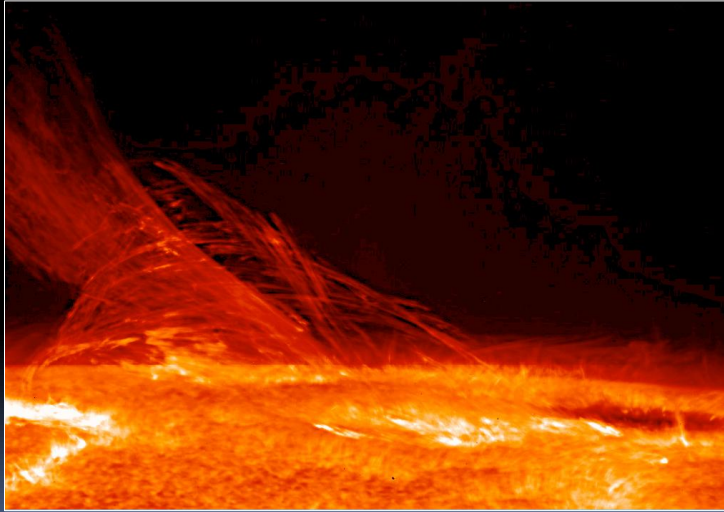
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## Core

- All of a star's energy comes from nuclear fusion in its center
- Energy (e.g. gamma rays) created in the center takes about 1 million years to get to the edge due to running into so much stuff.
- Once light gets to the edge, it escapes very quickly.

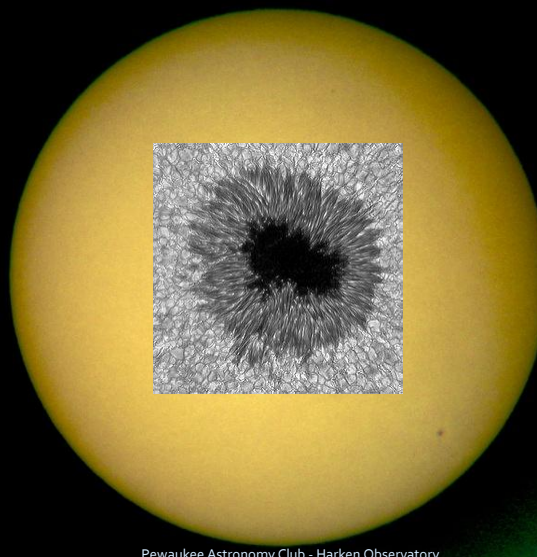
## Exterior of the Sun



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## Sun Spots



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## Sun Spins

- The sun rotates, just like the earth (on earth, this causes day and night)
- Sunspots are on the surface, so we track them. They are actually quite hot (3,000+ K), just not as hot and bright as the rest of the surface.
- The axis rotates once every 27 days at the equator, once every 31 days at the poles

## Inside the Sun

- The sun has 99.8 percent of the mass in the solar system which is  $2 \times 10^{27}$ . That's 333,000 times as massive as Earth.
- Average density is about 90 pounds per cubic foot. That's about 1.4 times the density of water and less than one-third of Earth's average density.
- The interior is very dense. At its center, the sun's density is 14 times lead's.
- The center core is where nuclear fusion takes place

# Relatives

## Stellar Evolution

- There are many sizes and colors of stars
- Stars change size and color over time
- By human standards, change is (usually) very slow – billions of years
- The exact starting place and sequence of events mostly depends on the star's size when it was formed

## Some Observations

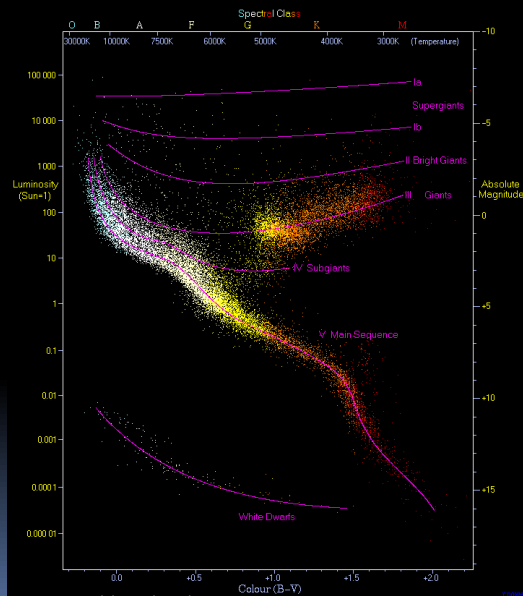
- When you get farther away from something, it appears smaller even though it didn't really change size. (visual perspective)
- A bright thing close up looks dim when far away. (apparent brightness, absolute brightness, luminosity)
- A spectrometer can determine chemical composition by analyzing light, even if that light is from far away. (You can analyze something without touching it)
- The amount of energy (light, heat, etc.) radiated is proportional to temperature. (Stefan-Boltzmann Law)

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## Hertzsprung-Russell (H-R) Diagram

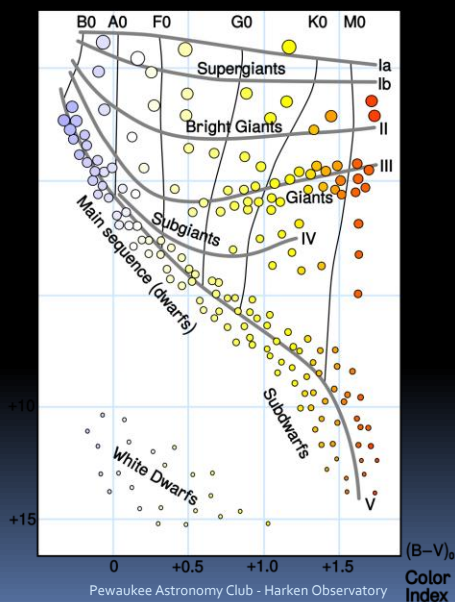
- Ejnar Hertzsprung - 1910
- Henry Norris Russell
- Lots going on here
- Vertical is Brightness
- Horizontal is Temperature & Color
- Natural clustering
- Sun is near the center
- Small diameter is lower left, big is upper right, diagonal bands



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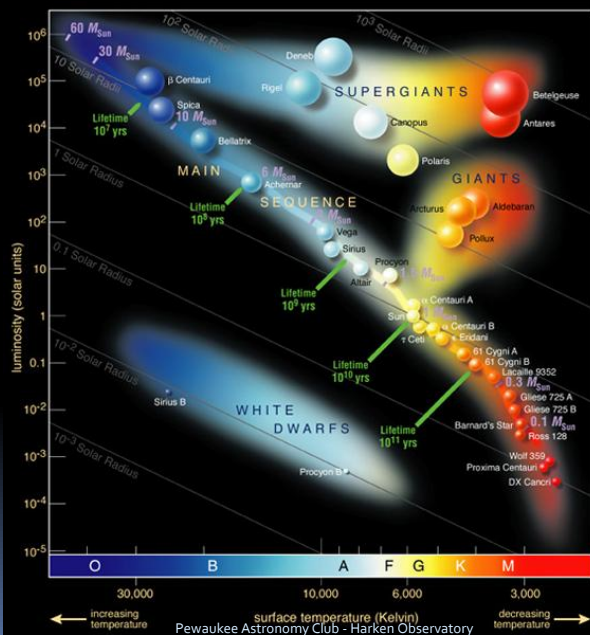
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# Hertzsprung-Russell (H-R) Diagram




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# Hertzsprung-Russell (H-R) Diagram



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### Main Sequence Stars



	O	B	A	F	G	K	M
Spectral Type:	O	B	A	F	G	K	M
Temperature:	40 000K	20 000K	8500K	6500K	5700K	4500K	3200K
Radius (Sun=1):	10	5	1.7	1.3	1.0	0.8	0.3
Mass (Sun=1):	50	10	2.0	1.5	1.0	0.7	0.2
Luminosity (Sun=1):	100 000	1000	20	4	1.0	0.2	0.01
Lifetime (million yrs):	10	100	1000	3000	10 000	50 000	200 000
Abundance:	0.00001%	0.1%	0.7%	2%	35%	8%	80%

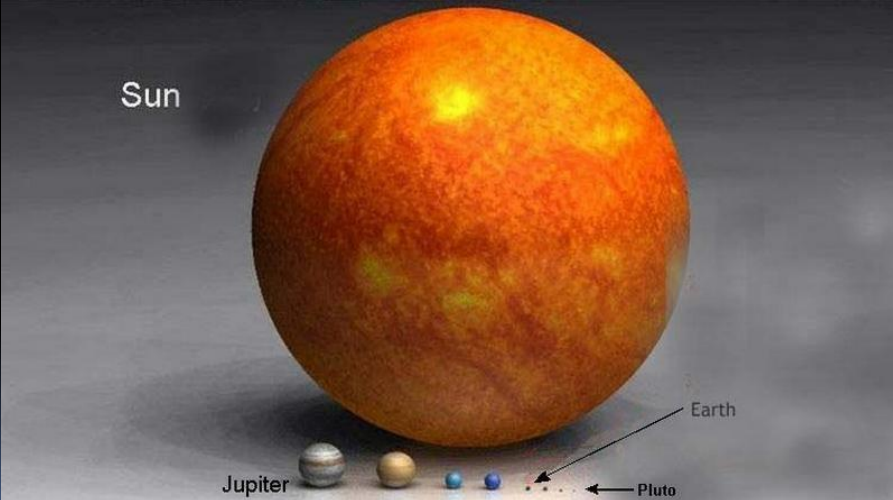
  

<h4>Giant Stars</h4> <p>Low mass stars near the end of their lives.</p> <p>Spectral Type: Mainly G, K or M          Temperature: 3000 to 10 000K          Radius (Sun=1): 10 to 50          Mass (Sun=1): 1 to 5          Luminosity (Sun=1): 50 to 1000          Lifetime (million yrs): 1000          Abundance: 0.4%</p>	<h4>White Dwarfs</h4> <p>Dying remnant of an imploded star.</p> <p>Spectral Type: D          Temperature: Under 80 000K          Radius (Sun=1): Under 0.01          Mass (Sun=1): Under 1.4          Luminosity (Sun=1): Under 0.01          Lifetime (million yrs): -          Abundance: 5%</p>	<h4>Supergiant Stars</h4> <p>High mass stars near the end of their lives.</p> <p>Spectral Type: O, B, A, F, G, K or M          Temperature: 4000 to 40 000K          Radius (Sun=1): 30 to 500          Mass (Sun=1): 10 to 70          Luminosity (Sun=1): 30 000 to 1000 000          Lifetime (million yrs): 10          Abundance: 0.0001%</p>
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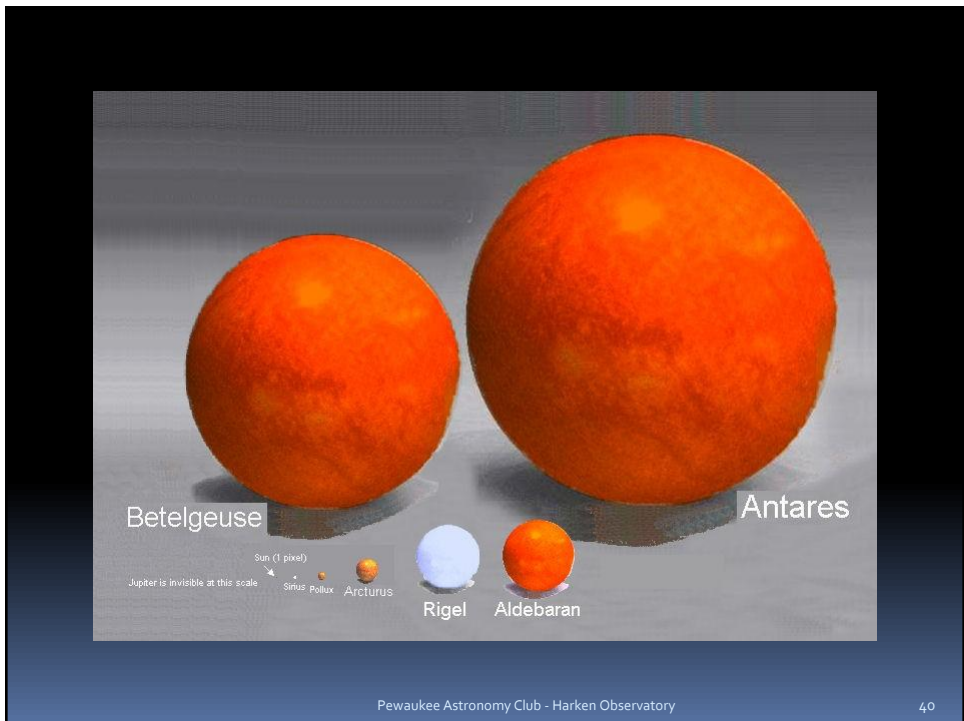
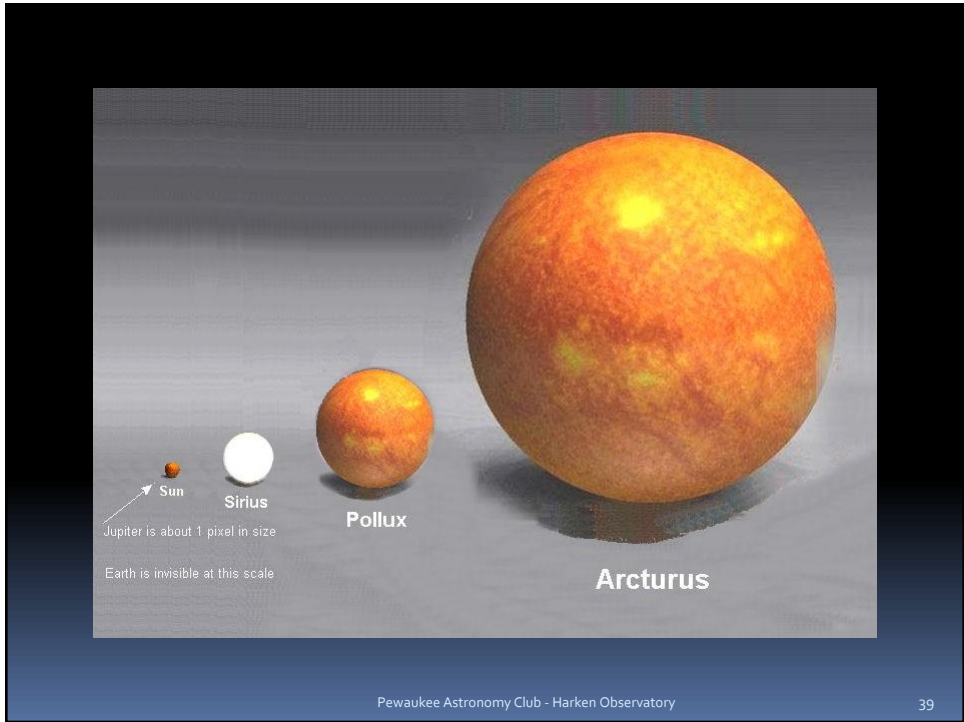
# Solar System



Sun

Jupiter      Earth      Pluto

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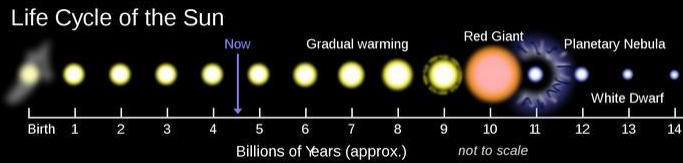


# Death

## Aging of a Star

- A star is huge, but it has only so much hydrogen and doesn't refuel.
- When the hydrogen runs out, the nuclear fusion stops. No more heat and light from the core pushing outward, so the ball collapses.
- If the original star was big enough, it ends with a huge explosion, a supernova

# Life of our Sun



- The Big Bang is believed to have happened about 14 billion years ago
- The sun was formed about 4.5 billion years ago, probably from parts of older stars that blew up

## Sources

- Atlas of the Universe  
(<http://www.atlasoftheuniverse.com/hr.html>)
- NASA – Galaxy & Star Images  
(<http://www.nasa.gov/multimedia/index.html>)
- NASA – Encyclopedia  
([http://www.nasa.gov/worldbook/sun\\_worldbook.html](http://www.nasa.gov/worldbook/sun_worldbook.html))
- University of Oregon – Astronomy 122  
(<http://zebu.uoregon.edu/~imamura/122/astro.122.html>)
- Wikipedia – Definitions & pictures  
([http://en.wikipedia.org/wiki/Barnard%27s\\_Loop](http://en.wikipedia.org/wiki/Barnard%27s_Loop))