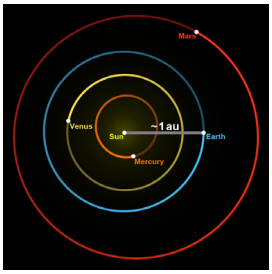
Are We Alone in the Universe?

Measuring Distance in the Universe

- The distances between planets, stars, and other solar systems is huge.
- The distances are so large that it does not make sense to use meters or kilometers.
- Astronomers have their own units for measuring the distances.

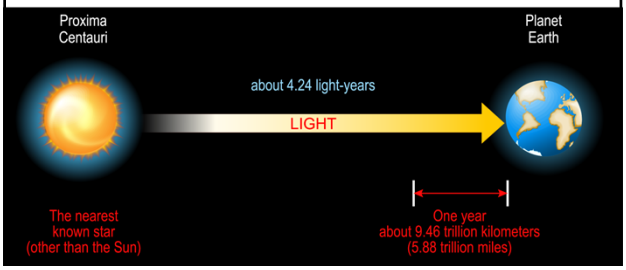
Astronomical Unit

- An astronomical unit (au) is the average distance between the Earth and the Sun.
  - 1 au = 1.495979×10^{11} m



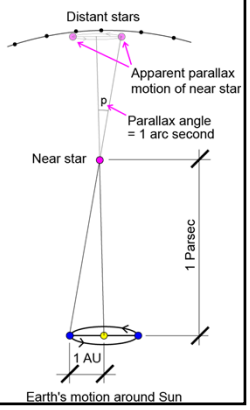
Lightyear

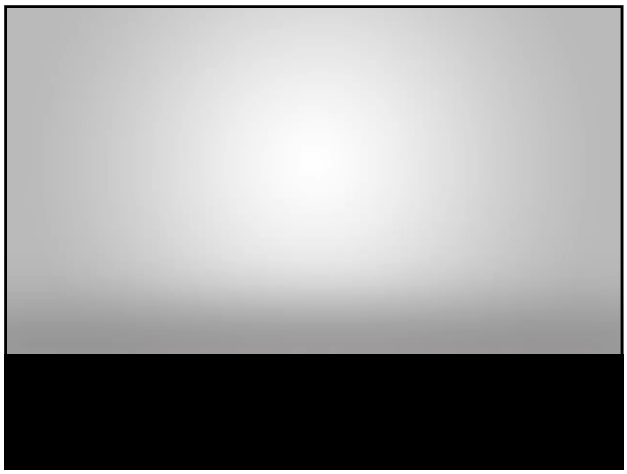
- A lightyear (ly) is the distance light travels in one year.
  - 1 ly = 9.4607×10^{15} m



Parsec

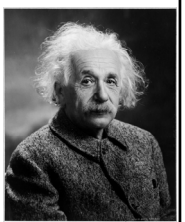
- A parsec is the distance from the Sun to an astronomical object that has a parallax angle of one arcsecond.
  - 1 parsec = $\frac{648\,000}{\pi}$ au





Early Ideas

- It was originally thought that the universe was static.
  - The size of the universe was constant.
- This idea was based on Einstein's general theory of relativity and Newton's theory of gravity.



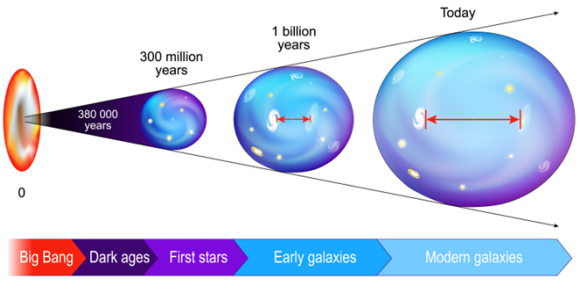
- Georges Lemaître, a Belgian scientist and priest, published a paper in 1927 arguing that the equations of Albert Einstein's general theory of relativity implied that the Universe is not static.
- Lemaître connected this prediction to what he argued was a simple relation of proportionality between the average recessional velocity of galaxies and their distance to the Earth.

- In 1929, the US astronomer Edwin Hubble published a paper showing that, in the average, galaxies recede at a velocity proportional to their distance from the observer.
- This argument convinced many experts that the Universe is not static.

The Big Bang Theory

- The Big Bang theory states that the universe is finite (has edges) and is expanding.
- About 13.8 billion years ago, everything in the universe was squished into one super-hot, super-tiny point smaller than a grain of sand.
- Suddenly, that tiny point started expanding super-fast. As it grew, it cooled down, and tiny bits of matter formed.

- Over millions and millions of years, those bits clumped together to make stars, galaxies, and planets.
- The universe is still expanding today.



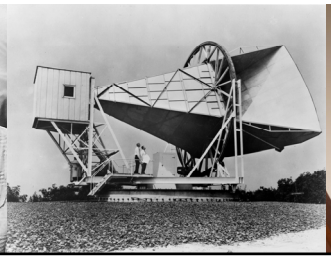
Red Shift

- If a star is moving away from us, the light gets stretched out.
- This makes it appear redder than it really is.
- Observations of distant galaxies show a redshift in the light from the stars.
- Redshift provides strong evidence for the idea that the universe is getting bigger over time, thus supporting the Big Bang theory.

Cosmic Background Radiation

- In the 1940's, scientists realized that they should be able to find the remnants of the Big Bang's energy in the far reaches of the universe.
  - These remnants would come to be known as the cosmic microwave background radiation.

- Arno Penzias and Robert W. Wilson worked on ultra-sensitive cryogenic microwave receivers, intended for radio astronomy observations. In 1964, on building their most sensitive antenna/receiver system, the pair encountered radio noise that they could not explain.


- Penzias contacted Robert H. Dicke, who suggested it might be the background radiation predicted by some cosmological theories.
- This proved to be landmark evidence for the Big Bang.

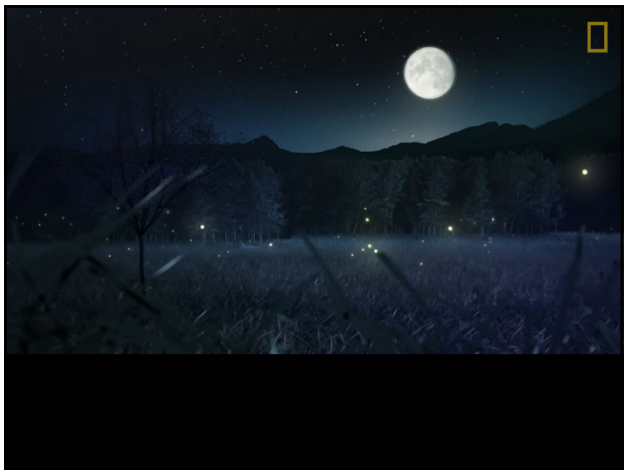
Hydrogen and Helium

- The Big Bang would have produced large amounts of hydrogen and helium due to nuclear fusion.
- Using powerful telescopes, scientists have concluded the universe consists of mainly hydrogen (74%) and helium (25%).
- This continuity throughout the universe is the third major piece of supporting evidence for the Big Bang theory.

Life Cycle of a Star

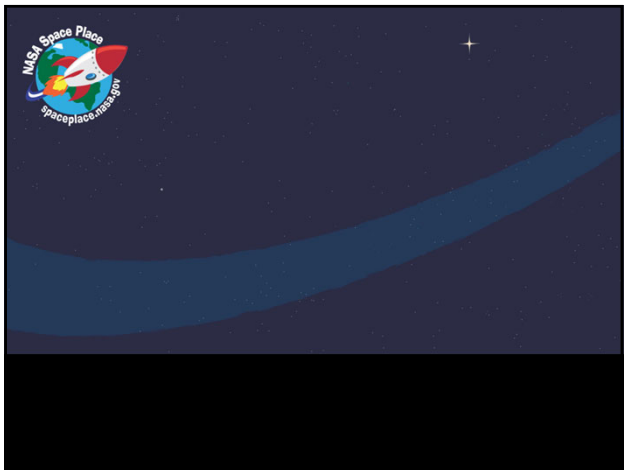
- A star's life cycle is determined by its mass.
  - The larger its mass, the shorter its life cycle.
- A star's mass is determined by the amount of matter that is available in its nebula, the giant cloud of gas and dust from which it was born.

- Stars are giant, glowing balls of plasma.
- Stars are made of hydrogen (~75%), helium (~25%) and a little dust (carbon and iron).
- They are “born” from an interstellar area of gas (mostly hydrogen) and dust (mostly carbon and silicon).

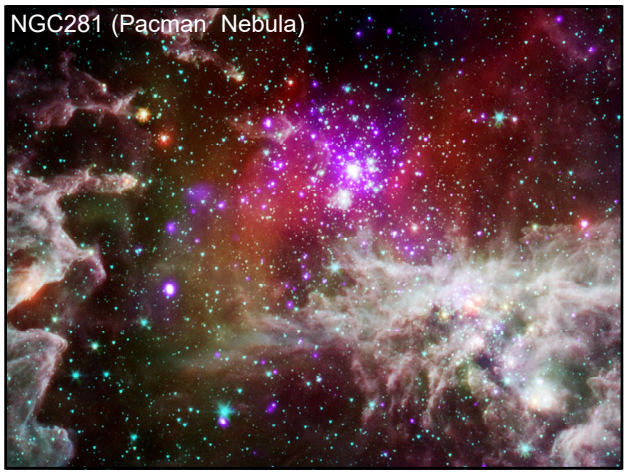


Nebula

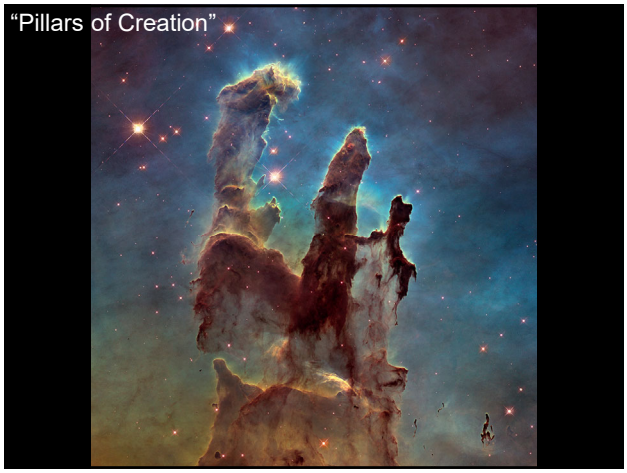
- A nebula is an interstellar cloud of dust, hydrogen gas, helium gas and other ionized gases.
  - Nebulae are the birthplace of stars.



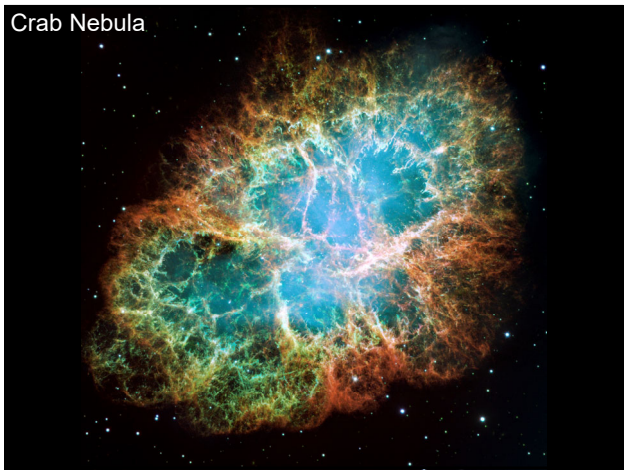
NGC281 (Pacman Nebula)



"Pillars of Creation"



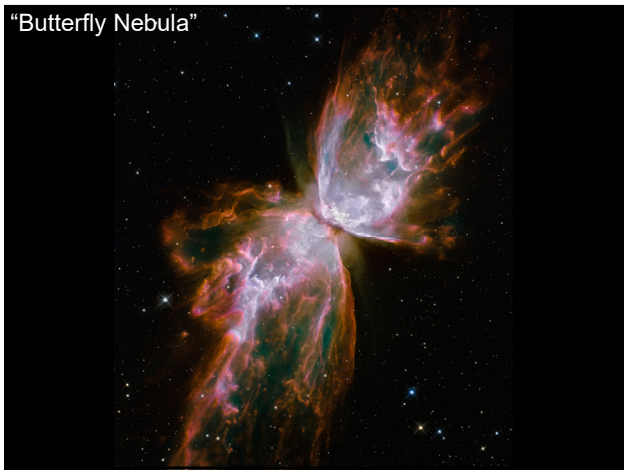
Crab Nebula



"Cat's Eye Nebula"

"Horsehead Nebula"

"Butterfly Nebula"



Protostar

- A protostar forms when some gas and dust in the nebula clump together forming a spinning ball.
- This ball of gases and dust will attract more gas due to its gravitational force.
- The ball starts to collapse under its own gravitational force, heating up.
- The ball continues collapsing and heating up until the core temperature is around 15 million degrees Celsius.

Main Sequence Star

- When the core reaches around 15 million degrees Celsius, fusion reactions start and the star starts to shine and becomes a main sequence star.
  - Approximately 90% of all stars in the universe are main sequence stars.
  - Our Sun is a main sequence star.

Red Giant/Supergiant

- The outer gas layers of the star expand, and as the star uses all its fuel, its core shrinks.
- The red giant will grow to tremendous size as helium replaces hydrogen as the fuel.
- The rest of the star's life depends on the mass of the star.

Low Mass Stars

- The expanding shell of gases spreads out into space leaving a hot core.
- The star becomes a white dwarf.
- A white dwarf slowly cools until all of its heat is gone. It then becomes a cold, lightless piece of matter called a black dwarf.

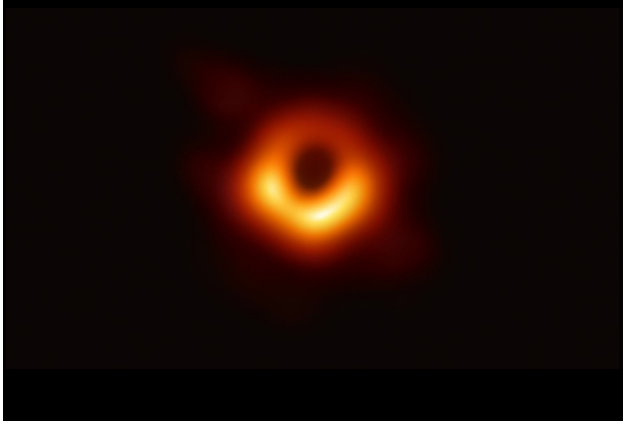
High Mass Stars

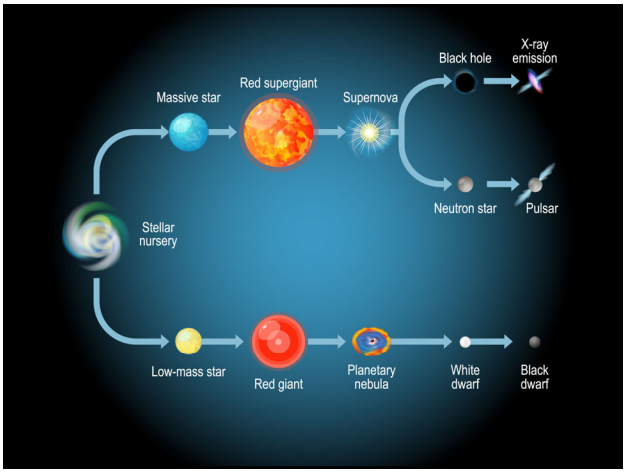
- These stars may expand and contract several times and then explode. This violent explosion is called a supernova.
- A neutron star is the very dense core left behind after a supernova.
  - A neutron star is mostly made of neutrons and can produce rapid bursts of repeating radio waves.
- If the mass is large enough, a supernova will leave behind a black hole.

Black Hole

- A black hole is an object whose gravity is so strong that even light does not escape it.
  - Stellar-mass black holes with three to dozens of times the Sun's mass are spread throughout our Milky Way galaxy, while supermassive monsters weighing 100,000 to billions of solar masses are found in the centers of most big galaxies, ours included.

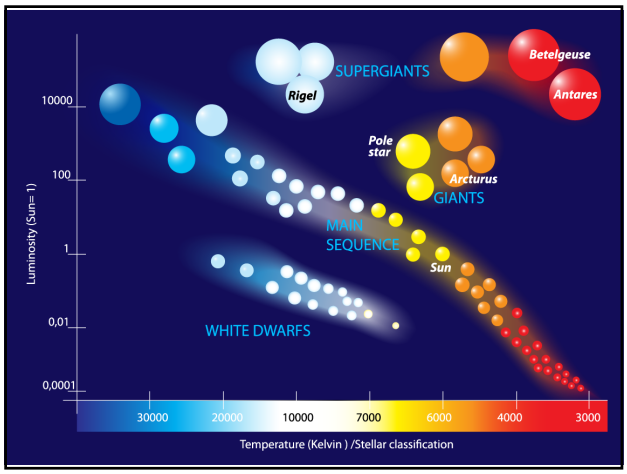
Messier 87





Color & Luminosity

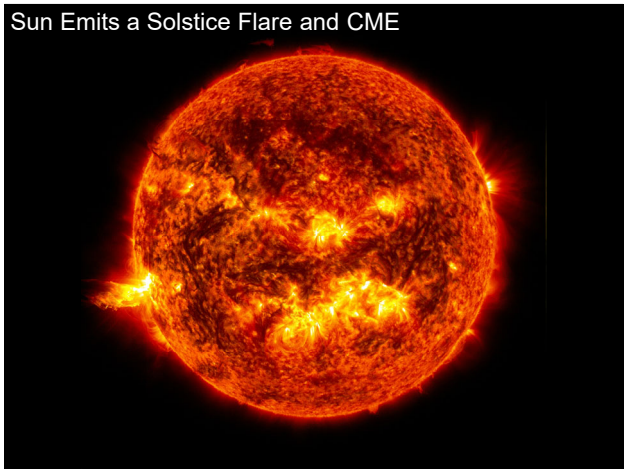
- The color of a star is related to its temperature.
  - Red stars are at the low temperature end.
  - Blue stars are at the high temperature end.
- The luminosity of a star is related to its temperature and its size.
- The Hertzsprung-Russell (HR) diagram shows the relationship between luminosity, temperature and color.



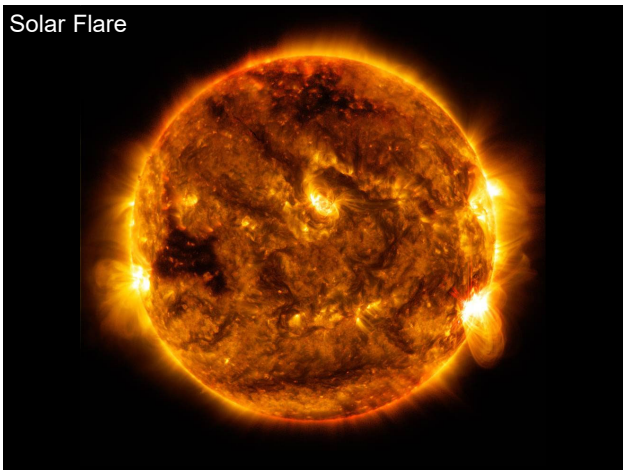
Solar Flare

- A solar flare is a sudden, powerful explosion of energy on the Sun's surface.
  - It happens when twisted magnetic field lines in the Sun suddenly snap and release a huge amount of stored energy.
  - They can disrupt radio signals, affect GPS, cause beautiful auroras (northern/southern lights), and sometimes even damage satellites or power grids on Earth if they're really strong.

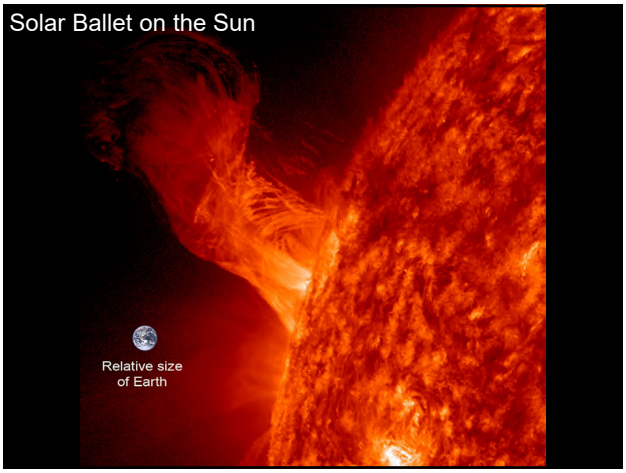
Sun Emits a Solstice Flare and CME



Solar Flare

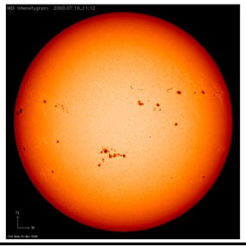


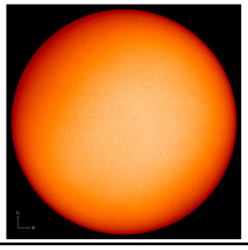
Solar Ballet on the Sun



Sunspots

- Sunspots are temporary phenomena on the Sun's photosphere that appear as spots darker than the surrounding areas.
- Sunspots indicate intense magnetic activity.





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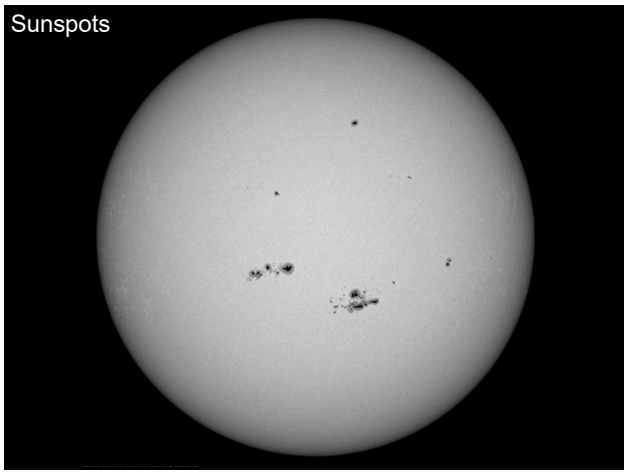
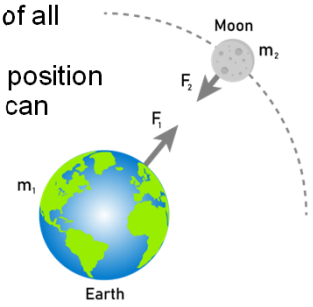
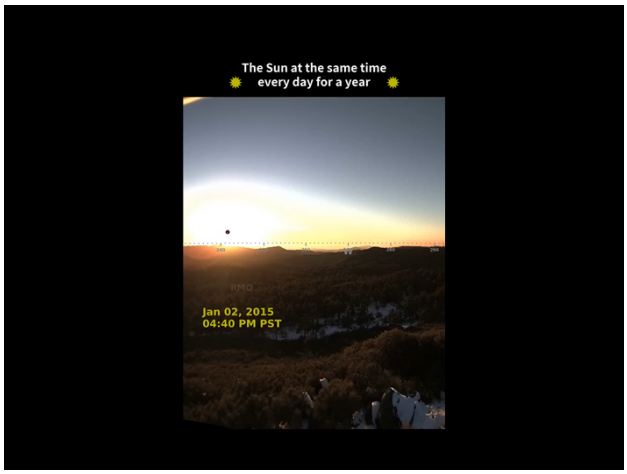


Celestial Motion

- Isaac Newton (English) published his book **Philosophiæ Naturalis Principia Mathematica** in1687.
- Newton explicitly argues that the same universal gravitation that operates on Earth governs the entire solar system and, by extension, the universe.

- The idea is that all celestial motion is caused by and only due to gravitational forces.
- Newton's theory means that the movement of all celestial objects is predictable and the position at any point in time can be calculated.




The Sun at the same time
every day for a year
Jan 02, 2015
04:40 PM PST


Is There Life Anywhere Else?

- **No life of any kind has been found anywhere else in the solar system or beyond.**
  - The building blocks of life have been found.
    - Amino acids and other organic compounds the make up living organisms.
    - Evidence of what might have been liquid water, which is required for life.

Probability of Life

- Microbial life elsewhere in the Solar System
  - 50–80% probability
- Microbial life around other stars
  - Most astrobiologists think there could be between 1 million and 1 billion inhabited worlds in the Milky Way based on chemistry and planet statistics.
- Intelligent life we can currently detect
  - No compelling evidence