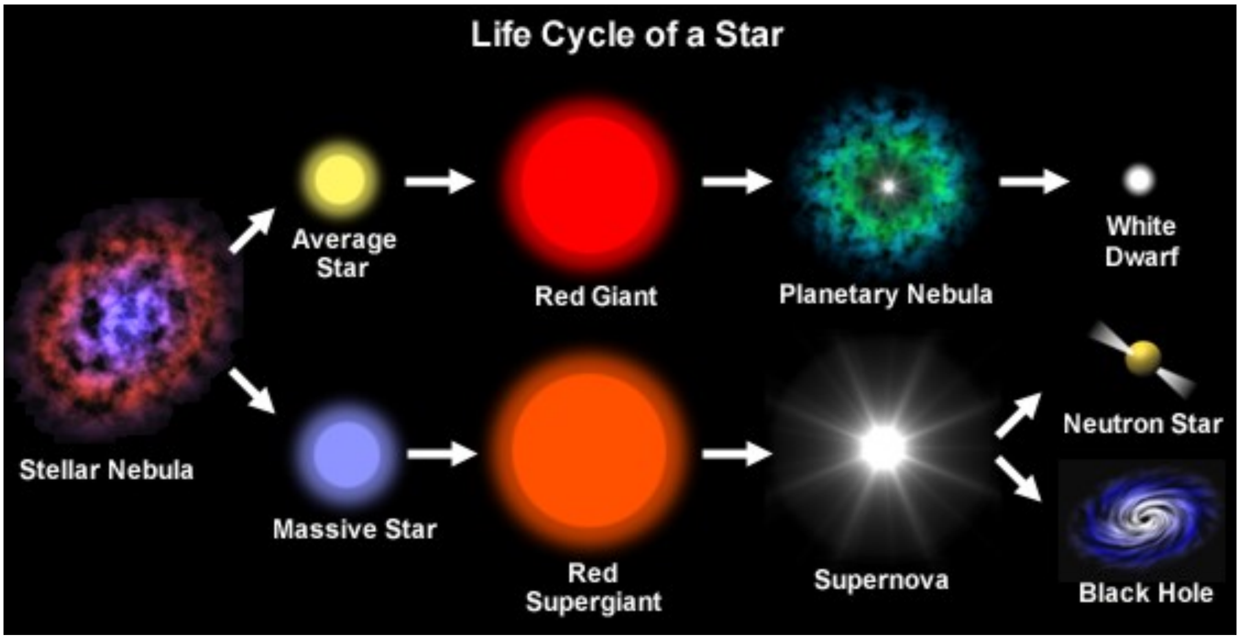
Life Cycles Of The Stars

This activity helps students conceptualize the time scales involved in astronomical processes – such as the life cycles of the stars.



Materials Needed

- Star histories (see attached sheets)
- Pens, pencils, crayons, stickers, marking pens (to decorate the timelines)
- Rulers and/or meter sticks
- Register tape, in rolls

What To Do:

1. Have students work together in groups of 3 - 5. Give each group one of the six star histories attached. Each of these is a history of a real star in the sky. All are main sequence stars – that is, stars that are currently fusing hydrogen in their cores and have not yet depleted their reserves of fusible hydrogen.

2. Each group will construct a time line showing the life cycle of their star. For each group, there are at least 5 key events that groups need to include in their time lines: (1) **Conception** (t=0) – when gases that will one day form the star start to gravitationally collapse within a giant cloud of gas (called a nebula). (2) **Birth** – when hydrogen fusion begins within the core and the new star ignites. (3) **Old Age** – when

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the hydrogen within the core is exhausted. (4) **Death** – when the star “dies, usually through the expulsion of the outer layers of gas or with a huge explosion. (5) **The Corpse** – what remains in space shortly after the star “dies”.

3. In constructing the timelines, students should let 1meter = 1 billion years….or…

100 cm (1 meter) = 1,000,000,000 years	1 billion years
10 cm = 100,000,000 years	100 million years
1 cm = 10,000,000 years	10 million years
1/10th cm (1mm) = 1,000,000 years	1million years

4. After the groups have constructed their time lines, have each group share their “histories” with the rest of the class. What do they notice about the life span of massive stars compared to the life spans of less massive stars? Since the age of the universe is about 15 billion years, what does this say about the kind of stars most likely to have remained from the beginnings of the universe?

What’s Going On?
In this activity, you can see that the very massive stars live much shorted “lives” compared to the smaller, less massive stars. Why is that?

Large stars, like all stars, form inside giant gaseous nebulae. An example of such a nebula is the Great Nebula in Orion (see photo). Inside nebulae, particles of gas and dust are attracted to each other through gravitational attraction. But at the same time, thermal motion (motion due to the temperature of the surrounding gases) competes with gravitational attraction – making it harder for the particles to “stick together.” In a “cool” nebula (with little motion due to temperature, young stars can gather up a great deal of mass before igniting. In cold nebulae, these “baby stars” can collect this mass very quickly since there is little else to compete with the gravitational forces. *This explains why massive stars spend less time in the “conception” phase compared to smaller stars.*

Large stars also exhaust their reserves of hydrogen quickly compared to smaller stars. Temperatures in the cores of large stars are much higher than the core temperatures of smaller stars. The higher the temperature inside a star, the faster hydrogen nuclei move. And the faster hydrogen nuclei move, the more likely it is that two nuclei will hit each other and fuse. So even though larger stars have more hydrogen reserves, they fuse hydrogen into helium at a much higher rate. *This explains why large stars don’t spend much time as main sequence stars (compared to smaller stars).*

Finally, large stars have quick and explosive deaths compared to smaller stars. All stars are pulled inward by tremendous gravitational forces. The outward pressure produced by nuclear fusion inside the core exactly balances the inward force of gravity. As long as these forces are in balance, the star does not expand or shrink in size. But when nuclear fusion stops, there is nothing to balance the inwardly directed force of gravity. For large stars, this inward force is tremendous – producing a spectacular contraction and spectacular explosion (e.g. a nova or super nova). What is left behind is a weird stellar fragment left when the outer layers of the star compress the core to unimaginably high densities (e.g. black holes, neutron stars, white dwarves…).

Box-O-Math

In case you are wondering whether there are any equations that describe the life span of a star – of course there is! The length of time that a star spends in the "main sequence" (adulthood) is given by the following equation:

Main sequence lifetime = fuel / fuel consumption rate ~ mass / luminosity.

But since luminosity ~ mass $^{3.5}$

Main sequence life span ~ 1 / $M^{2.5}$

If you plug in the mass of the star in terms of the solar masses (the number of times that the star is heavier than our own star), then your answer will be in terms of "solar lifetimes," where 1 "solar lifetime" = 10^{10} years = 10 billion years.

Life Histories Of Some Stars

Star: A_{crux} **Mass**: 15x mass of sun
Constellation: Crucis **Radius**: 4.77 radius of sun

Conception (time from nebula to ignition of hydrogen): 100,000 yrs
Adulthood (time from ignition of hydrogen to giant); 10,000,000 yrs
Old Age (time from giant stage to star death): 1,000,000 yrs

Type of Death: Supernova
Remains of the Star: Neutron Star

Star: Vega **Mass**: 5x mass of sun
Constellation: Lyra **Radius**: 2.61 x radius of sun

Conception (time from nebula to ignition of hydrogen); 1,000,000 yrs
Adulthood (time from ignition of hydrogen to giant): 100,000,000 yrs
Old Age (time from giant stage to star death): 10,000,000 yrs

Type of Death: Supernova
Remains of the Star: Neutron Star

Star: Sirius **Mass**: 2x mass of sun
Constellation: Canis Major **Radius**: 1.6x radius of sun

Conception (time from nebula to ignition of hydrogen): 10,000,000 yrs
Adulthood (time from ignition of hydrogen to giant): 1,000,000,000 yrs
Old Age (time from giant stage to star death): 100,000,000 yrs
Type of Death: Nova
Remains of the Star: White Dwarf

Star: Alpha Centauri A
Constellation: Centaur

Mass: 1x mass of sun
Radius: 1x radius of sun

Conception (time from nebula to ignition of hydrogen): 40,000,000 yrs
Adulthood (time from ignition of hydrogen to giant): 10,000,000,000 yrs
Old Age (time from giant stage to star death): 1,000,000,000 yrs

Type of Death: Formation of a planetary (ring) nebula
Remains of the Star: White dwarf

Star: Alpha Centauri B
Constellation:

Mass: 0.8x mass of the sun
Radius: 0.68x radius of the sun

Conception (time from nebula to ignition of hydrogen): 100,000,000 yrs
Adulthood (time from ignition of hydrogen to giant): 20,000,000,000 yrs
Old Age (time from giant stage to star death): 2,000,000,000 yrs

Type of Death: Formation of planetary (ring) nebula
Remains of the Star: White dwarf