Balloon Model of the Life Cycle of Stars

by Glenn Holliday May 2011

When I present astronomy to both adults and to youth, I hear lots of questions that have the same answer. The questions are things like “Will a black hole swallow us up?” “Will our sun blow up?” “Do all stars have planets?” And the answer is “Let's tell the life story of that star. Your question is in there.” For me personally, the life cycle of stars is a unifying concept that does more than one thing. I can use it to answer a number of specific questions. It also explains how many objects and concepts are related, and how some astronomical events cause others.

There are many forks in the road in the life of a star. This activity explains main sequence stars. This is a simplified story, and ignores many complications, exceptions, and alternate things that may happen to some stars. You can explain this for youth with a few props. My use of balloons was inspired by a balloon model of our local stellar neighborhood taught at Astronomy Camp. Some adult audiences may enjoy the balloon model if they understand what it is showing them. Teenagers may reject it as more suitable for younger children.

Supplies:

1 small red balloon 1 medium yellow balloon
1 medium orange balloon 1 large blue balloon
Optional – 1 very large blue balloon, 1 very large red balloon (these can be expensive)
1 raisin (you may want to distribute a snack size box of them to all)
1 yogurt covered raisin or similar small white colored snack
bag confetti (if in a place where you can easily clean it up. Outdoors, use dandelion fluff or maple seeds)
1 pin (suitable for popping a balloon)

Have participants blow up the balloons. The small red balloon should be the smallest – it is a red dwarf. Blow up the orange and yellow balloons to about twice the diameter of the red dwarf. Blow up the smaller of the large blue balloons to about twice the diameter of the orange and yellow dwarfs. Blow up the very large blue and red balloons as large as possible without popping them.

The story:

All stars begin life as a cloud of gas, maybe with some dust mixed in.

Throw most of the confetti into the air.

When there is enough, or if it is compressed by other nearby events, gravity pulls the gas together into a dense ball. Gravity increases the heat and pressure so much that hydrogen in the gas begins to fuse into helium. A star is born. (We ignore planetary formation from the same cloud.)

The color, temperature, and brightness of a star are all mostly determined by how much mass was in its original gas cloud.

Have participants line up with the red dwarf, orange dwarf, yellow dwarf, and blue dwarf in order.

The smallest stars fuse coolest and shine at the least energetic end of the spectrum – red. Larger stars are hotter and shine orange, even larger ones are hotter and shine yellow, and the largest and hottest ones shine blue.

Eventually the star fuses all of its hydrogen. The hot blue stars do this first, in some millions of years. Yellow and orange stars take billions of years, and the universe is not yet old enough for any red dwarf to finish fusing its hydrogen. When its hydrogen fuel is consumed, a star stops its nuclear fusion. Then something new happens. The balloon is a good model here. The balloon balances two forces: the elastic surface trying to squeeze the balloon into its original size, and the pressure of air inside it trying to expand outward. If we remove the outward pressure by cooling the balloon the balloon shrinks. If we remove the inward pressure by puncturing the balloon, the air inside it expands. Similarly, a star balances two forces: the gravity of its mass trying to squeeze its matter into a smaller sphere, and the pressure of energy given off by nuclear fusion trying to push its matter outward. When fusion stops, that force pushing outward is suddenly gone. The force of gravity contracts the star into a smaller size. But just as when gravity first contracted the original dust cloud, this makes the pressure and temperature rise in the center of the star. Fusion ignites again. Now the star is fusing helium into heavier elements. There is suddenly new energy pressing outward again. The star bounces back and becomes bigger.

Two things can happen here. The bouncing back throws some of the star's matter outward into space.

Toss some more confetti into the air.

The star is now larger diameter, and therefore cooler than it was before. Orange, yellow, and blue dwarfs all become red supergiants.

Have a participant display the red supergiant.

The star will eventually consume its helium, just as it already consumed its hydrogen. It goes through the cycle of collapse and rebound several times, The cycle stops when the star has made iron. It can not fuse iron into heavier elements. This time the star collapses into the smallest sphere it can. A smaller star becomes a white dwarf.

Give a participant the white yogurt covered raisin to display.

Its collapse made it very hot, but no nuclear fusion is happening. It will cool gradually until it becomes a dark remnant. The universe is not yet old enough for any white dwarf to have had time to cool. The gas clouds the star has thrown off into space have become a planetary nebula.

A larger star has gravity strong enough to collapse it to something smaller, denser, and stranger than a white dwarf. We call that a neutron star. An even larger star may collapse all the way into a black hole.

Give a participant the raisin to display.

Really massive stars do not get to live through the red supergiant and white dwarf phases. Some stars are born even bigger than the ones we have talked about. They are born as blue supergiants.

Have a participant display the blue supergiant.

They live only a few million years, and when they consume their hydrogen, their first collapse causes a supernova.

Pop the blue supergiant.