Acting Out the Life Cycle of Stars — Teacher Guide

This activity can be found in its original form in Reinfeld, Erika L. (CfA) and Hartman, Mark A. (MIT). "Kinesthetic Life Cycle of Stars," 2008, *Astronomy Education Review*, **7**, 158.

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- you need enough room for all students to move around freely (the activity can be done outside if necessary)
- to run the activity, the facilitator should follow the scriptinstructions found below
- if possible, actual astronomical images (e.g., the 6 .jpg files shown in Figure 2) should be projected (and discussed) as students act out each stage
- after acting out all the stages, hand out KinestheticLifeCycle_StudentSheet to each student so they have a summary of what they just did
- you can film the entire activity (all 6 stages) from above for later review
- this activity is currently written only for single stars; if you have a very large group you can do binary evolution and add in novae, SNe Ia, etc.
- you can follow-up this activity with the stellar evolution flow-charts for different mass ranges

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As a class, we're going to act out the life cycle of stars. Each of you will represent a small clump of gas, mostly made of hydrogen (since that's by far the most abundant element in the Universe).

a. We all start in random motion, wandering around aimlessly, mostly ignoring all other clumps of gas. This represents the **Interstellar Medium (ISM)**, which is what we call the gas and dust between stars. Eventually a chunk of the ISM might start getting a bit clumpy due to the force of gravity and become a **Star-Forming Nebula**. This is where a group, or **cluster**, of stars can start to form. An example of this is the **Orion Nebula** (M42), in the middle of Orion's sword.

b. After awhile, gravity becomes strong enough toward the center of our clump to attract all nearby smaller gas clumps (that's you all!). This is where a single star begins to actually form and thus we call it a **protostar**. The star now forms a dense, hot core on the inside (some students get in the core and face outward), and a slightly cooler, and less dense envelope on the outside (about twice as many students get in the envelope and face inward). Like the Orion Nebula, the **Ghost Head Nebula** (NGC 2080) is another example of a star-forming region that contains protostars.

c. Now the gas in the star's core has become hot enough and dense enough to begin **hydrogen fusion**, where hydrogen atoms are smashed together to make helium and release light and heat. Now the star begins to shine! The energy generated in the core by fusion pushes outward, so core students, put your hands out in front of you with your arms bent a bit. The envelope, on the other hand, is being pulled inward by gravity, so envelope students, put your hands out in front of you, also with your arms bent a bit. At this point the outward push of the core is perfectly balanced by the inward pull of the envelope and the star is nice and stable and said to be in **hydrostatic equilibrium**. The **Sun** is in hydrostatic equilibrium and has been for about 4.5 billion years. It will remain that way for another 6.5 billion years or so.

d. Eventually, a star's core will run out of hydrogen fuel and no longer be in hydrostatic equilibrium. At this point, various changes take place in the core and envelope of the star which causes the core to push a bit harder on the envelope. This makes the envelope expand somewhat,

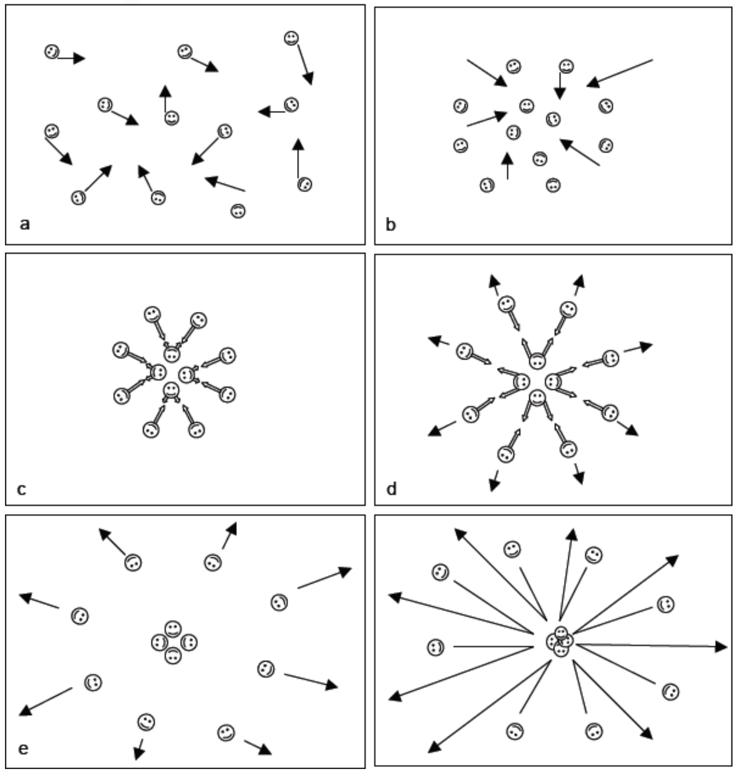

Figure 1: Acting out the stages of stellar evolution.

so everyone should unbend their arms now. When the star's envelope expands, it gets cooler and redder and much bigger and the star becomes a **red giant**. The bright red/orange star in the shoulder of Orion, **Betelgeuse**, is a red giant.

e. For stars that are *less* than about 8 times the mass of the Sun, the envelope of the red giant will gradually float away into space (float away envelope students) as the core contracts (get cozy core students). The floating away gas that used to be the star's envelope is now known as a **planetary nebula** (so named because the first astronomers to observe them thought they kinda looked like planets, even though we now know they have nothing to do with planets!). The very dense and hot core is now a **white dwarf**. The planetary nebula will continue to expand and eventually fade away, with its gas becoming part of the ISM from which it originally came. The white dwarf isn't creating any new energy and will just slowly fade away like the dying ember of a fire. The **Ring Nebula** (M57), in the constellation Lyra, is a classic planetary nebula with a relatively bright white dwarf at its center.

f. Envelope students, come on back and let's reform the red giant. Stars that are *more* than about 8 times the mass of the Sun have a much more violent end. Like the less massive stars, the core will contract (so again, get cozy core students), but the envelope of these heavier stars actually collapses toward the dense core and then bounces off of it, ultimately exploding outward into space (alright envelope students, collapse inward, bounce off the core, and explode outward!). This outward explosion is called a **(core-collapse) supernova**. The core leftover after the supernova is even more dense than a white dwarf and is called a **neutron star**. If, however, the star begins its life with more than about 20 times the mass of the Sun, the neutron star will collapse even further to an infinitely dense point known as a **black hole**, from which not even light can escape! In 1987, a massive star in a nearby galaxy called the **Large Magellanic Cloud** collapsed on itself and exploded as **Supernova 1987A**.

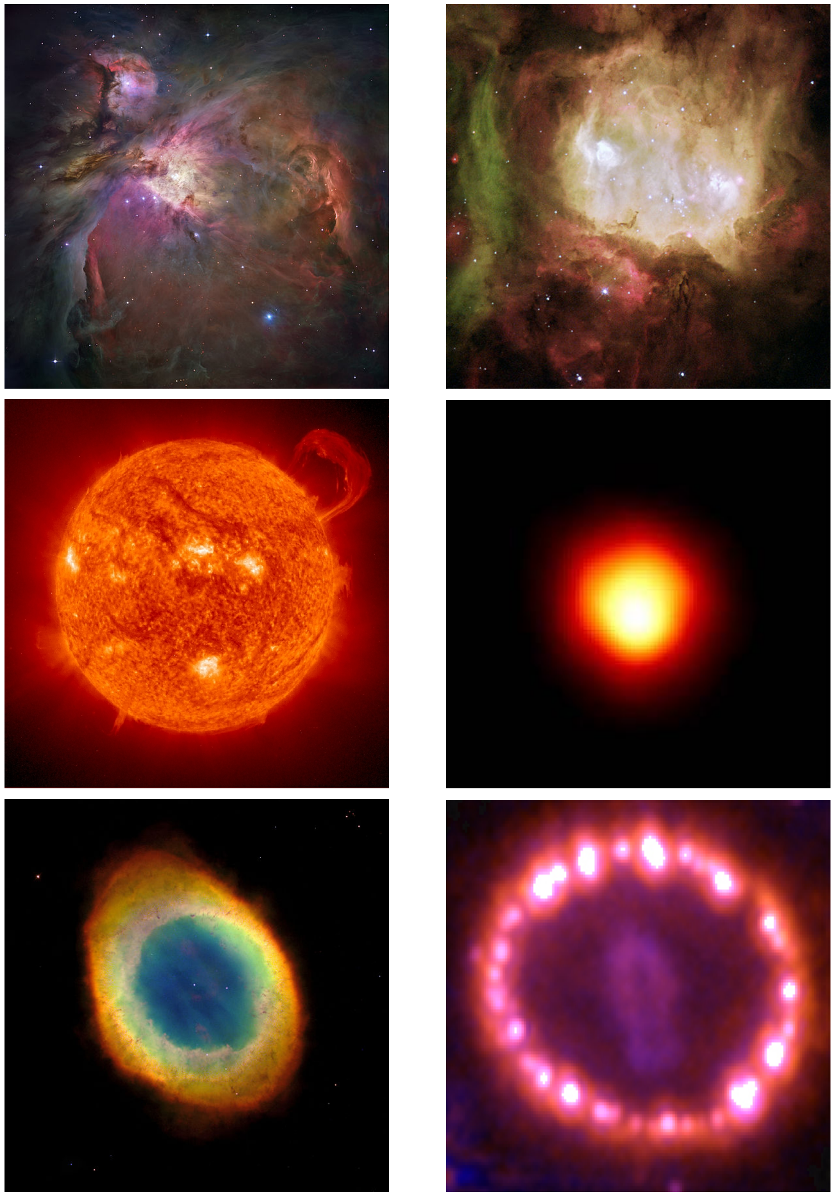

Figure 2: Actual images of various stages of stellar evolution.

a. (upper-left) The Orion Star-Forming Nebula (M42), in the middle of Orion's sword (Hubble Space Telescope [HST]; optical light; NASA/ESA)

b. (upper-right) The Ghost Head Star-Forming Nebula (NGC 2080) with protostars, in the southern constellation Dorado (HST; optical light; NASA/ESA)

c. (middle-left) The Sun (in hydrostatic equilibrium) on September 14, 1999, showing gas at about 60,000 degrees C (Solar and Heliospheric Observatory [SOHO]; ultraviolet light; NASA)

d. (middle-right) Betelgeuse, a red giant star; it can easily be seen during winter nights as the bright red/orange star in the shoulder of Orion (HST; ultraviolet+optical light; NASA/ESA)

e. (bottom-left) The Ring Planetary Nebula (M57), in the constellation Lyra, with a relatively bright white dwarf at its center (HST; optical light; NASA/ESA)

f. (bottom-right) The blob in the center is Supernova 1987A, a massive star in the nearby galaxy known as the Large Magellanic Cloud that collapsed on itself and exploded as a supernova; the ring of bright spots is some of the gas it ejected (HST; optical light; NASA/ESA)