# New Outreach Activities for Stellar Astronomy

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## Abstract

We have created two new activities to introduce children to concepts in stellar astronomy. The first introduces nucleosynthesis in a fashion accessible to most school-age children. The second classifies stars in the constellation of Orion on an HR diagram. Both activities focus on connecting astronomy concepts with the participants' own experiences.

## 1.Nucleosynthesis

The idea that everything with which we interact in our daily lives (people, furniture, cats) is made in the interior of a star is one of the most captivating ideas in astronomy, but rarely is the idea dealt with except in the most cursory fashion. In this activity participants play the role of atomic nuclei in the nuclear reactions synthesizing helium from hydrogen in the Sun's core. The interactive kinesthetic activity conveys the idea of building heavy elements in a concrete way.

### Materials

1) 2 "potential barriers" These can be anything compressible, from simple pillows or couch cushions to the padded "sumo wrestling suits" available from party rental outlets
2) 6 headbands or hats marked P for proton and 2 marked N for neutron

### Procedure

1) *Introducing the elements*. Most students will have encountered the concept of elements by late elementary school or junior high. Younger children can be introduced through the analogy of building blocks or Legos. Explore the idea that a nearly unlimited variety of structures can be built from a finite set of different kinds of building blocks. Most important to emphasize here is that the building blocks of people and planets didn't exist at the beginning of the universe. Only hydrogen and helium and traces of the next few light elements were produced in the big bang. Hydrogen and helium are gases and not useful for building anything solid or complex on their own. It is also helpful to point out that elements, the building blocks of macroscopic things, are themselves made up of building blocks called protons and neutrons. This reduces confusion during the activity.

2) *Why stars*? Equip two volunteers with P hats and "potential barriers" such that it is difficult for them to join hands when standing with the potential barriers touching. Protons in nuclei have a positive electrical charge, so nuclei repel each other, like the north poles of two magnets. It takes energy to overcome the repulsion, or potential barrier, so that nuclei can fuse. Have the students then come together at a brisk pace, compressing the foam. The important point is that faster moving, higher energy particles can over come the barrier more easily. Only in stars does material reach high enough temperatures for nuclei to join. Note that the more protons, the more repulsion to be overcome, so heavier elements require still higher temperatures to be made. We will follow the PPI chain of nuclear fusion. This is the simplest reaction for turning hydrogen into helium, and takes place in the solar interior.

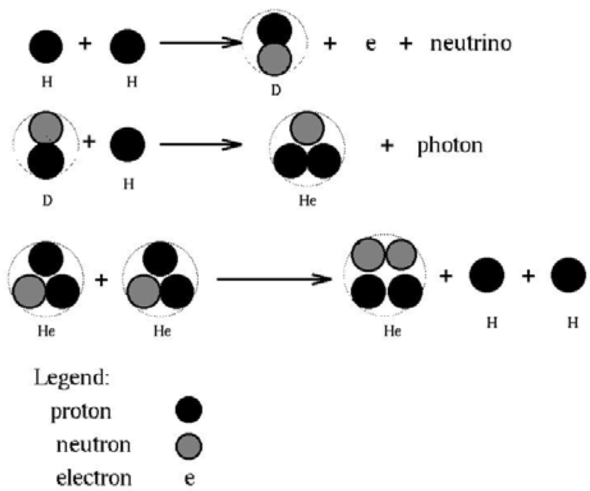



**Figure 1:** Simple diagram of the PPI chain of nuclear reactions producing helium from hydrogen. Each participant plays the role of a proton or neutron. Note that one of the protons becomes a neutron in the first reaction.

3. *Making helium*. Lead six volunteers through the PPI chain of nuclear burning (see Fig. 1). In step two of the procedure a pair of protons fused in the demonstration of the potential barrier. One of these protons becomes a neutron, which has no electric charge. This makes the deuterium nucleus stable. (For older audiences the idea of isotopes can be introduced. The number of protons (and hence the charge of the nucleus and its accompanying number of electrons) determines how the atom interacts with other atoms, so we define a given element by its proton number. Two atoms of a given element may have different numbers of neutrons. These are different isotopes. Only some isotopes are possible for an element. Deuterium is a stable isotope of hydrogen with one neutron.)

Have a third proton fuse with the deuterium, making the isotope helium 3. Bring up a second set of three volunteers to create a second $^{3}$He nucleus.

The two $^{3}$He fuse to produce the common form of helium, $^{4}$He, and two protons that are free to start the cycle over again.

While the final four volunteers are still holding hands as a helium nucleus, point out that carbon and oxygen, the most common elements in people, need 12 and 16 volunteers to simulate. Iron in a car or tool needs about 56. The heaviest elements would require packing more than 200 people into a room. Elements like silver, gold, and platinum are so difficult to make that they are produced only in the most energetic events in the universe, supernova explosions that shine brighter than 100 billion stars like our sun.

**Figure 2:** Left: Demonstrating the potential barrier (step 2). Right: Forming $^{3}$He. Green headbands denote protons, black neutrons.

## 2. Classifying Stars

Participants classify stars according to temperature and brightness on an HR diagram, just as professional astronomers do. The activity introduces graphing techniques which are valuable in science, technical, and business fields, but often underused in schools. The stars are chosen from Orion, which is the most readily recognizable constellation in the night sky, so participants can see the stars they have classified.

**Materials**

1) Large poster of Orion (A recognizable summer constellation can be substituted when Orion is not visible. This improves personal connection to the activity.)

2) Circles of paper or plastic colored and sized to represent Betelguese, Rigel, $\theta^1$c Orionis (brightest star in the Trapezium in the Orion Nebula), a solar-type star and K and M dwarfs. This gives a good range of spectral types. Data on Temperature and luminosity can be found in *Astrophysical Data* (Lang 1992) or www.enchantedlearning.com/subjects/astronomy/stars/startypes.shtml, among other sources. $\theta^1$c Orionis is an O star and can use generic values for such a star from these sources. Table 1 contains useful approximate values. Too much precision in the numbers can obscure the relative magnitudes for different stars.

| Relative to sun | Betelguese | Rigel | $\theta^1$c Orionis | Sun | K dwarf | M dwarf |
|---|---|---|---|---|---|---|
| Mass | 15 | 15 | 30 | 1 | 0.5 | 0.1 |
| Temperature | 3000 K | 10,000 K | 30,000 K | 5500 K | 4000 K | 3000 K |
| Luminosity | 100,000 | 100,000 | 500,000 | 1 | 0.01 | 0.001 |
| Lifetime (years) | 15 million | 15 million | 5 million | 10 billion | 100 billion | 1 trillion |

3) White/chalkboard or large graph paper for plotting

4) Poster Tac or other reusable adhesive.

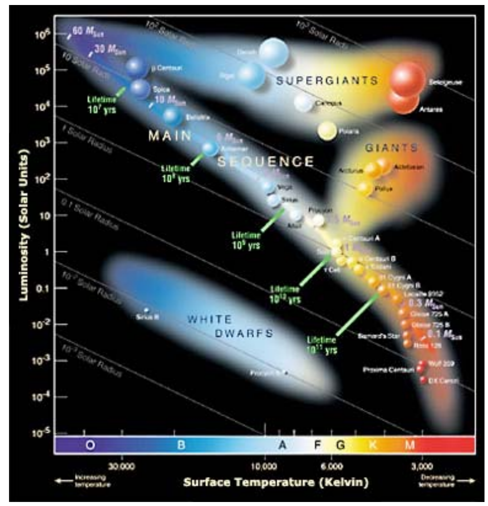
**Procedure**

1) *The sky full of stars.* Place the stars in their corresponding positions on the Orion poster. Low mass stars can be clustered around the Orion Nebula. Ask the participants to identify the constellation, and give instructions for finding it in the night sky. Emphasize that they are learning about stars they can see.

2. *Classifying stars.* Have volunteers place each star in its proper position on the HR diagram. Younger participants may need an introduction to graphing. Guide them along each axis separately until they reach the appropriate point, and then have them bring their fingers together to find the unique point on the graph that fits their data.

Emphasize comparisons between the stars. For example, Betelguese and Rigel were very similar when they formed, but Betelguese is older, with perhaps 100,000 years

or less to live, while Rigel is in the prime of its life. The radius of Betelguese is almost as large as the orbit of Jupiter, so it would swallow all the inner planets if placed in the sun's position. It is also interesting to compare the lifetimes. Small stars live much longer than massive stars despite having less fuel. This is because they have less mass to support, and so burn their fuel at a much slower rate. This is also why they are so dim.
The many types of stars around the Orion Nebula can lead into a discussion of star formation. A second constellation can be chosen for summer so that participants can immediately observe the stars they have classified.




HR diagram from *Cosmic Perspective*, Bennett, Donahue, Schneider, & Voit

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