The Emanating Brilliance of Stars

Curricular Materials Prepared by
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- *Journey of the Universe* Book: Chapter 3: The Emanating Brilliance of Stars.
- *Journey of the Universe* Film: Scene 3: The Formation of Galaxies and Stars.
- *Journey of the Universe Conversations*: Disc 1 - Program 2: Galaxies Forming; Disc 1 - Program 3: The Emanating Brilliance of Stars.

Scientific Summary:

Stars are formed when clouds of hydrogen and helium implode from the gravitational pull of their own mass. As the atoms draw closer and closer together, they collide and vibrate energetically. The dual increase in density and collisions causes conditions to become hotter and hotter. After reaching temperatures of several thousand degrees, the atoms of helium and hydrogen in these collapsing clouds of gas begin to break apart into their constituent elementary particles – protons and electrons. At this point in time, this hot dense cloud of interacting elementary particles is called a protostar.

Once temperatures reach approximately ten million degrees, the protons and neutrons begin to fuse into new stable relationships in a process called thermonuclear fusion. The nuclei of hydrogen atoms repel each other. However, when the power of the gravitational attraction is strong enough within the interior of stars, the individual nuclei of hydrogen atoms can fuse into more complex formations such as helium. A massive amount of energy is released in the center of the star through this process. The release of this energy is a force of expansion by which stars resist further collapse. As long as this expansive energy and gravitational attraction are kept in creative tension, the star can exist for billions of years. Once one of the powers becomes more powerful than the other, the star comes to an end.

Once all of the hydrogen has been converted to helium, this fusion process comes to a halt. Without the force of thermonuclear fusion pushing out from its interior, the star collapses further until the temperature escalates to a high enough level for helium to begin fusing into carbon. This process continues to repeat itself as each element is used up through fusion. For instance, once all of the helium in a star has been converted to carbon, the core of the star shrinks in upon itself and the temperature rises dramatically until carbon begins to fuse into oxygen. Next, oxygen is fused into silicon and this process continues through the heavier elements up until only iron remains in the core of the star. At this point, the star can only implode in upon itself.

When a large star collapses in upon itself, all of the atoms and nuclei in the star are dismantled as the star precipitously shrinks to a tiny speck. The energy of the implosion is so great in this collapse that the protons and electrons join together to form neutrons. However, the massive amount of energetic neutrinos released in this process causes the collapse to reverse so violently that the star is blasted apart. The resulting shockwave throws all of the star's matter out in a massive explosion called a supernova. This explosion is so powerful, in fact, that supernovas observed from Earth often outshine all of the hundreds of billions of stars in their own galaxy. During this expansion stage of supernovas, a new round of stellar nucleosynthesis takes place. All of the nuclei of all of the elements in the universe are created in these moments. Every atom of carbon, oxygen, gold, calcium, phosphorous, and the many other elements found on Earth and in our bodies are created in the death of stars.

Discussion Questions:

1. In the *Journey of the Universe* book, Brian Thomas Swimme and Mary Evelyn Tucker state that it is significant that "stars are self-organizing processes" (27). What do they mean by this and why is it a significant discovery?
2. What is fusion and what does it do? Use both the *Journey of the Universe* book and the *Conversations* featuring Todd Duncan to explore this concept.
3. As Carl Sagan has famously said, "we are all made of starstuff," or, as Brian Thomas Swimme and Mary Evelyn Tucker put it in the *Journey of the Universe* book, "the stars are our ancestors" (29). What do they mean by this? Does learning this change the way you think and feel in relationship to the larger universe?
4. In the *Journey of the Universe* book and film, the authors describe the universe as being in state of constant creative tension. How does the life of stars exemplify this observation? Does thinking about creative and destructive forces as existing in tension and as being a seedbed of creativity change your perceptions of how the universe works?
5. In the *Conversations*, Joel Primack talks about the formation of planets around stars. How do we observe these planets? What tools are necessary to observe the formation of stars and planets?

Online Resources:

- The Hubble Telescope is one of our greatest tools for observing galaxies and stars from the early moments of the universe. Visit the Hubble Telescope website for images, tutorials, and videos explaining the Hubble Deep Field and the Hubble Ultra Deep Field. This interactive tutorial features videos, animations, and images depicting the attractive force of gravity, early supernova, and more moments from the early universe as seen through the Hubble Telescope.
- The National Aeronautics and Space Administration (NASA) has a page on stars and stellar evolution.
- A variety of images, educational videos, and news on the formation and observation of stars can be found at the California Institute of Technology's website for the Spitzer Space Telescope. One useful feature is the interactive

guide to the stars found here. Students can explore similar resources from the Chandra X-ray Observatory such as videos and podcasts.

- The National Aeronautics and Space Administration (NASA) website has an educational page on stellar nucleosynthesis. Scroll down to the bottom of the page for news items as well as for activities and lesson plans aimed at 9th-12th grade learners.
- The Hayden Planetarium hosts a number of useful educational tools such as the Digital Universe Atlas, the Astrophysics Visualization Archive, and a plethora of useful links, news items, multimedia and programs such as this short video on the formation of a star cluster.
- NASA's "Astronomy Picture of the Day" website features daily pictures of stars and other astronomical bodies. Each photograph is accompanied by explanations, links, and other useful information written by professional astronomers. This photo of matter blasted out from a supernova shows the dispersion of elements through the death of a star. This remarkable photo of Tycho's supernova remnant is also worth noting.
- Go to the Yale Forum on Religion and Ecology's website for a comprehensive list of links to scientific organizations and educational resources.

Print Resources:

- *Journey of the Universe* Bibliography.
- Bibliography on Cosmogenesis from the Yale Forum on Religion and Ecology.

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