The Formation of Galaxies

Curricular Materials Prepared by
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- *Journey of the Universe* Book: Chapter 2: Galaxies Forming.
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Scientific Summary:

Approximately 13 billion years ago, less than a billion years after the beginning of our observable universe, vast clouds of atoms began to coalesce into the first galaxies. Expansive density waves, which are fluctuations in the density of matter that emerged out of the great flaring forth, helped to shape the early galaxies from the billowing clouds of matter.

Within a billion years of the formation of the first galaxies, more than 100 billion had been formed. While they come in many configurations, the vast majority of the known galaxies in the universe take the shape of either spiral or elliptical galaxies. Our own galaxy, the Milky Way, is a spiral galaxy. The spiral shape allows for a great deal of new stars to be born from the continued action of density waves on the matter present in the spiral arms. These interactions are largely absent in elliptical galaxies. Most of the stars in non-spiral galaxies will eventually die out without being replaced by newly formed stars.

When we look into the night sky or when we utilize powerful telescopes such as the Spitzer Space Telescope or the Chandra X-ray Observatory, much of what we are able to see is the light and energy created by the billions of stars contained in each of the billions of galaxies. But there is more out there than meets the eye. Held together by gravitational forces, approximately ninety percent of the mass of galaxies is composed of what scientists commonly refer to as dark matter. The remaining ten percept of the mass of each galaxy is composed of stars, gas, stellar remnants, and dust.

Many galaxies, such as our own Milky Way, bulge in the center. Within this central bulge one can frequently find a black hole. While they cannot be observed with the naked eye, black holes are a common occurrence throughout the known universe. Black holes can form in many different ways, but they are typically created when stars cannot maintain high enough levels of internal heat and pressure to resist the gravitational pull of their own mass. Literally imploded by their own weight, black holes are stars that have collapsed in upon themselves. When a black hole is formed, a boundary called an event horizon is reached in which matter and light can no longer travel outward from the singularity, or central mass, of the black hole. Since light cannot escape the gravitational

pull of the black hole, we cannot "see" them in the traditional sense. Black holes are predicted by Einstein's theory of General Relativity.

The Milky Way galaxy is one of several dozen galaxies revolving around one another and these galaxies are a part of a larger group of galaxies called the Local Group. The Local Group is comprised of more than thirty galaxies including the three galaxies nearest us: the Large Magellanic Cloud, the Small Magellanic Cloud, and the Andromeda Galaxy. The Local Group, as well as many other clusters of galaxies, is part of an even larger system called the Virgo Supercluster.

Each galaxy and larger cluster of galaxies is in a state of constant motion and change. Collisions between galaxies are not uncommon. Only recently, after the a number of remarkable 20th century discoveries such as the first observation of galaxies outside of our own Milky Way by Edwin Hubble in the 1920s, did we learn that we live in an expanding universe. Over the course of 14 billion years, the observable universe has expanded from a size smaller than a grain of sand into the vastness of a trillion galaxies spread out over many billions of light-years.

Discussion Questions:

1. What caused the clouds of gas and atoms formed during the initial flaring forth to coalesce? How do these forces and events continue to shape new galaxies and stars today?
2. Each culture has its own understanding of the origins of the universe. Choose one or two traditional, cultural explanations for the universe and compare and contrast the cultural explanation to the scientific story.
3. How does the formation and destruction of hundreds of billions of galaxies relate to your lives today? How does one orient oneself in relationship to this vast and ongoing process?
4. What different shapes and configurations do galaxies come in? Do different shapes of galaxies impact the level of creativity possible in those galaxies? Why or why not?
5. What is the shape of our own galaxy, the Milky Way?
6. Does the discovery that we live in an evolving and constantly expanding universe change they way that you think about life on Earth? How does it change your thinking? What questions does it raise for you?

Online Resources:

- The Hubble Telescope is one of our greatest tools for observing distant galaxies. Visit the Hubble Telescope website for images, tutorials, and videos explaining the Hubble Deep Field and the Hubble Ultra Deep Field.
- The National Aeronautics and Space Administration (NASA) has a page on galaxies.
- A variety of images, educational videos, and news on the formation and observation of galaxies can be found at the California Institute of Technology's

website for the Spitzer Space Telescope. Students can explore similar resources from the Chandra X-ray Observatory.

- 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, and programs relating to the formation of galaxies.
- NASA's "Astronomy Picture of the Day" website features daily pictures of galaxies and other astronomical bodies. Each photograph is accompanied by explanations, links, and other useful information written by professional astronomers. This photo of two galaxies colliding is featured in the *Journey of the Universe* film.

Print Resources:

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

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