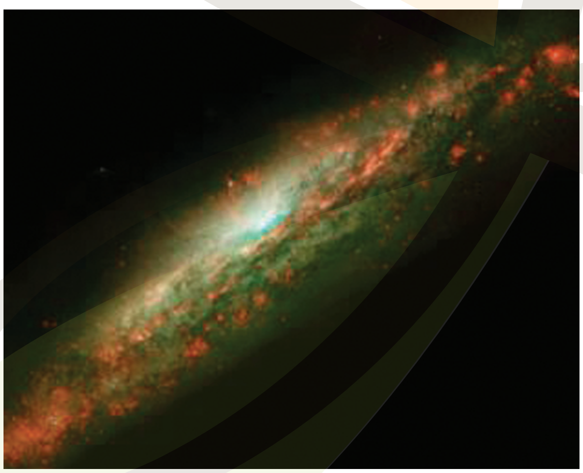
The Life Cycle of Stars

Background Information

Galaxies

Stars are massive collections of atomic particles that create light and heat at their centers. The first atoms formed from the hot gas of subatomic particles created when the universe began. Then gravity forced the atoms to join together into ever larger clusters. Those clusters grew large enough that their gravity attracted other groups of atoms, until stars eventually formed. Those stars attracted other stars until small galaxies formed. Those galaxies attracted other galaxies, finally forming large, mature galaxies such as the Milky Way.



A distant galaxy

Galaxies continue to influence each other. Although the Milky Way as a whole is stable, small changes continue — stars continue to be born, while others either die quietly or explode as supernovas. Dying stars contribute gas and dust to the already vast amount that clogs the Milky Way. Because the Milky Way forms a **plane**, a flat, two-dimensional, plate-like shape, the dust makes it difficult to see across the Milky Way.

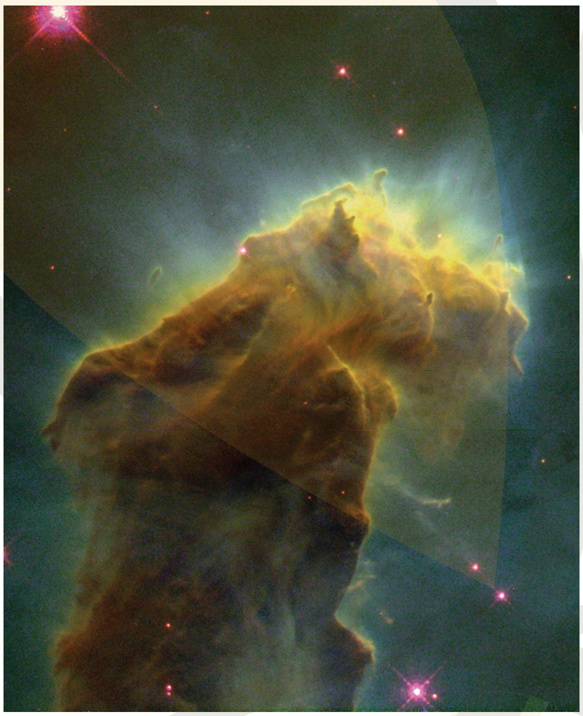
Did You Know?

- The Milky Way galaxy may contain up to 400 billion stars.
- It is estimated that there are more than one hundred billion galaxies in the universe.
- Each year, the Milky Way creates about seven new stars.
- A supernova occurs about once every 50 years in the Milky Way galaxy. Many supernovas occur that are not visible from the earth, but since the last one observed from earth occurred in 1604, the next visible supernova is overdue.

Gas and dust clog the heart of the Milky Way

A Star's Life

Supernova explosions or changes in the rotation of the Milky Way can cause a **nebula**, a massive cloud of gas and dust in outer space, to contract. As the nebula contracts under its own gravity, gas and dust accumulate into ever larger bodies. The result is often the formation of **protostars**, dense bodies of gas and dust that have not yet begun to generate light. As the mass of each protostar increases, its gravity also increases, which squeezes the core of the protostar ever harder.



Finger-like protrusions hold new stars in nebula

When the hydrogen atoms at the core of a protostar are squeezed at high enough temperatures and pressures, they fuse together to create new helium atoms. This is called **stellar nucleosynthesis**, the process in which four hydrogen atoms combine together to produce a single helium atom at the center of a star. This interesting term has three parts:

- **Stellar** means star.
- Nucleo is short for nucleus or **nuclear**, having to do with the nucleus at the center of an atom.
- Synthesis refers to the process of combining.

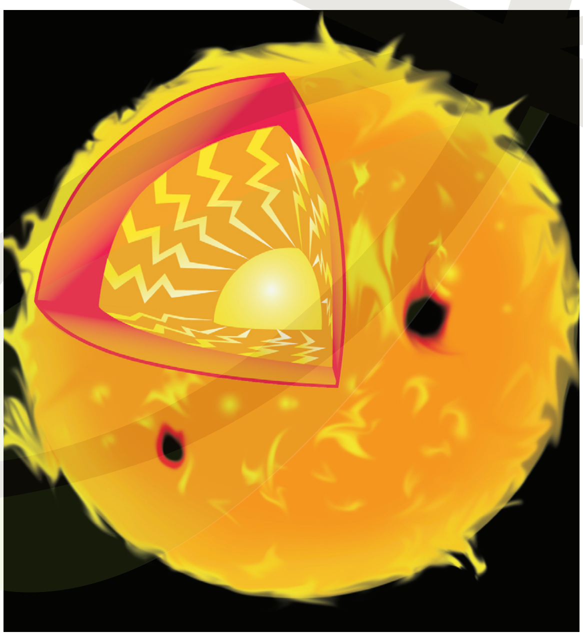
The new helium atom, however, has 0.7 percent less mass than the total mass of the four hydrogen atoms from which it was created. Most of that tiny bit of mass is converted into **nuclear energy**, the fundamental material from which mass of the universe is formed. Nuclear energy was predicted by Albert Einstein's famous equation, $E=MC^2$, which means: "energy equals mass times the speed of light squared." That little bit of mass is the fuel that the protostar burns, turning it into light and heat in the form of **photons**, particles of light energy. When nucleosynthesis begins in a protostar, it becomes a star, and photons leave the star as light and heat.

The sun was created by this process. The sun is a **yellow dwarf star**, a common type of star of average dimensions and mass. About a million years after its formation, the sun, like all yellow dwarf stars, entered the **main sequence**, the main portion of the life cycle of an average star, in which it converts hydrogen into helium steadily for billions of years. It takes an average star like the sun 10 billion years to convert the hydrogen in its core to helium. The sun is currently middle-aged, about 5 billion years old.

The light and heat radiating outward from the core of the sun and the steady gravitational pressure of the outer layers upon the core are in balance in the sun — the outward pressure equals the inward pressure. At the end of its 10 billion years as a main sequence star, however, when the hydrogen in the core has all been turned to helium, the amount of energy released decreases.

Did You Know?

- The sun turns 700 million tons (635 metric tons) of hydrogen into helium every second through stellar nucleosynthesis. Of that 700 million tons (635 metric tons), 0.7 percent, or 5 million tons (4.5 metric tons), of hydrogen is converted into pure energy and released as photons every second.
- The internal temperature of the sun is 28 million degrees F (16 million degrees C).
- The sun is 432,000 mi (696,000 km) across. If the sun were to become a black hole, the entire mass of the sun would be squeezed until it was only 2 mi (3 km) across.

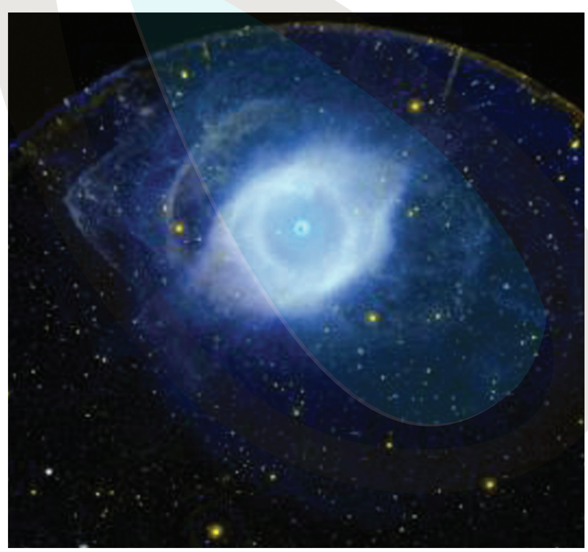


The interior the sun – an average star

In the absence of the steady outward pressure of light and heat, the outer layers will press in on the core, increasing the temperature and pressure until the layer of

A red giant star and the sun

hydrogen around the helium core begins to burn. The light and heat from that layer of hydrogen will inflate the sun hundreds of times its original size, making it shine up to 2,000 times brighter. At this point, the sun will become a **red giant**, a greatly expanded star whose outer layer is so distant from the burning hydrogen layer that the surface is relatively cool. Its red color shows that it is relatively cool in the same way that red-hot metal is cooler than white-hot metal.



A planetary nebula with a white dwarf star in its center.

ACTIVITY 2

Exploring How a Protostar Becomes a Star

Purpose

To understand how a star is formed and begins to make light and heat.

Material

Model made in Activity 1: Making a Model Showing the Formation of a Protostar.

Ball of modeling or sculpting clay of a different color than that used in Activity 1, approximately the same size as four of the smaller balls from which the model protostar is formed.

Illustration: The interior of the sun — an average star (see NAMC's CSM).

Whiteboard and marker.

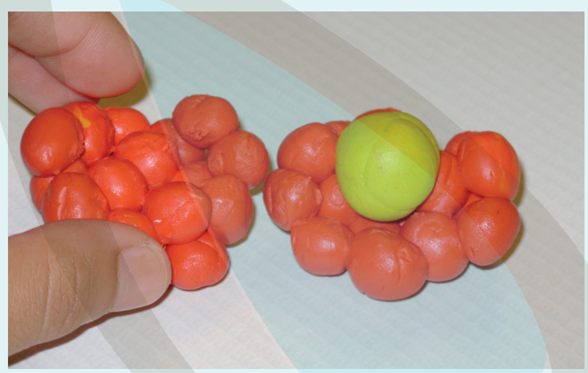
Matter and Astronomy journal and pencils.

Presentation

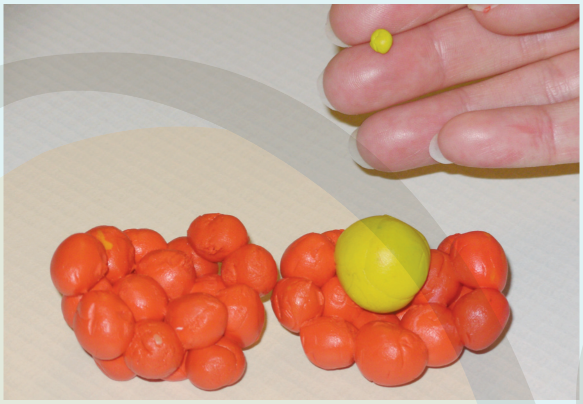
- Most Montessori teachers introduce this concept in Year 2 or 3.
- Announce to the students that they will be studying how a protostar becomes a star showing light.

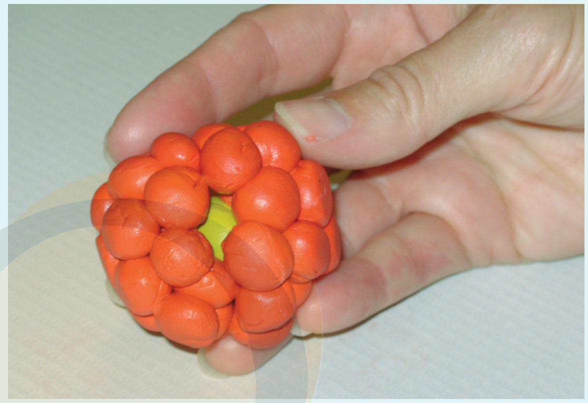
Protostar Model

- Demonstrate the protostar made in the previous activity. Briefly review with the students that the modeling dough ball represents a protostar made up of hydrogen atoms held together by gravity. Explain that the atoms in the center of the protostar get squeezed by gravity the most because they have the most atoms piled on top of them, and that this causes them to change.
- Gently pry the ball apart into two roughly equal halves, so the inner core is exposed. Explain that the atoms in the core get squeezed so much that groups of four hydrogen atoms join together to form one large, heavy helium atom.
- Take four balls from the very center of the model and squeeze them together into a single ball. Then ask a student to make a ball of the same size, but using the different color of modeling dough.
- Invite another student to place the new ball (the one of a different color) in the center of the protostar. Point out that the atoms at the center of the protostar are now helium atoms instead of hydrogen.



- Explain that when the helium atom forms, a tiny bit of hydrogen gets left over. Pinch off about 1/100 of the helium atom ball in the center of the protostar.





Stellar Nucleosynthesis

- Explain that the tiny bit of leftover hydrogen atom is the fuel that the protostar burns and turns into light and heat in the form of photons. Point out that when this process begins in a protostar, it becomes a star, and photons leave the star as light and heat. Point out that the sun is an example of a star and that light and heat eventually leave the sun and shine on the earth.

- Present the illustration, The interior of the sun — an average star. Invite the students to find the core and the other layers.

- Explain that this process of hydrogen atoms joining to form helium atoms is called stellar nucleosynthesis. On the whiteboard, write the term and the three words that make it up. Invite the students to say the words aloud.

- Gently replace the ball representing the helium atom in the center of the model, this time referring to the model as a star, no longer a protostar. Put the ball back together carefully, and retain it for Activity 3, Exploring the Life Cycle of an Average Star.

- Ask the students to use their journals to draw and label an illustration showing how a protostar becomes a star.

Extensions

- Write a short explanation about what the term "stellar nucleosynthesis" means.

- Find a book about Albert Einstein and write a paragraph about why he is well known. Include his famous formula.

- Research nuclear energy, then write a paragraph defining it and listing one advantage and one disadvantage.

