Orion Nebula

(Image Credit: HST/NASA)

The central region of the Orion Nebula is shown in an image from the Hubble Space Telescope. What do you see in this image?

In this Exploration, find out:

- *What is a nebula? Interstellar Cloud?*
- *How many stars are born each year?*
- *Which classes of stars are born most often? Which classes are born least often?*

Star Birth Teacher Guide

In this lesson, students will learn about the birth of stars in interstellar clouds of gas and dust. Students will also use an exercise in probability to learn about the relative number of stars of different classes (masses) that are born in a typical stellar nursery. This activity further explores the classes of main sequence stars introduced in the lessons Sizes of Stars and Stellar Distances.

Recommend Prerequisites: Sizes of Stars, Stellar Distances

Grade Level: 6-8

Curriculum Standards: The Star Birth lesson is matched to:

- National Science and Math Education Content Standards for grades 5-8.
- National Math Standards 5-8
- Texas Essential Knowledge and Skills (grades 6 and 8)
- Content Standards for California Public Schools (grade 8)
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Time Frame: The activity should take approximately 45 minutes to 1 hour to complete, including a short introduction and follow-up. The extension may require an additional class period.

Purpose: To aid students in understanding how stars are born, the relative numbers of stars of different masses born in interstellar clouds, and the lifetimes of stars.

Key concepts:

- Stars are different ages.
- Stars are born in giant clouds of gas and dust called interstellar clouds, which when glowing are also a type of nebula and can be called stellar nurseries.
- Many more low mass (cool) stars are born than high mass (hot) stars.

Supplies:

- A student information sheet for each student or small group of students.
- A Star Birth activity sheet for each student or small group of students.
- A color image of the Orion Nebula (Color Plate 1) or internet access for each student or group of 2-3 students
- A copy of the table of Relative Numbers of Stars Born by Class for each student and/or a copy of this table on a transparency
- 61 small colored objects identical in shape, size, and texture such as plastic pony beads (inexpensive and easily found in craft stores) for each group of two - three students. Preferred colors and quantities are 50 red, 10 yellow, one blue.
- 1 opaque container to hold the colored objects for each group of two - three students (The container must be significantly bigger than the 61 objects, and should either have a lid or be shaped such that a student's hand can fit tightly over the opening. **A disposable coffee cup with lid works well and keeps the noise of a class full of shaking cups manageable.)**
- Scratch paper for each student

Introduction:

Begin with a class discussion, first reviewing terms from the previous activities.

Light Year: Ask your students to define a light year in their own words, or introduce the concept of a light year. (From the activity Stellar Distances: "Distances to astronomical objects outside of our solar system are usually given in terms of light years. A light year is often confused with a measure of time, but is really a measure of distance. It is defined as the distance light can travel in one year, and is equal to about 9.5 trillion km or 6 trillion miles.")

Main sequence star: To refresh the student's memories, ask: What is a main sequence star? If you have not done the Sizes of Stars activity, define the term **main sequence stars** to your class. Main sequence stars are stars in the main part of their "lives" that get their energy by converting the element hydrogen into the element helium.

Next, ask the students:

- Are all stars the same age?
- Where stars come from?

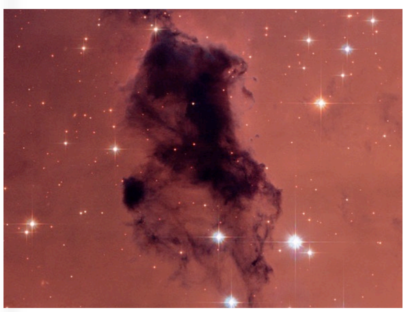
Note: The use of *italics* indicates information or instructions from the student version

Student Reading Materials

You may wish to assign the student reading provided either before or after the activity in class, or use the material as background to aid you in facilitating a class discussion.

Not all stars are the same age. In our galaxy, the ***Milky Way****, a few stars are born every year. Long before stars begin to shine as main sequence stars, the matter they will be made of is spread out in large thin clouds of gas and dust. Lying dark and cold between the stars, these vast* ***interstellar clouds*** *are usually only visible to astronomers because they can dim or block out the light of background stars. The atoms, molecules of gas, and tiny bits of dust in interstellar clouds are usually spread very thin. The space between the stars isn't really empty, but the matter in a typical interstellar cloud is spread more thinly than any matter here on the Earth. Interstellar clouds can be tens, or even hundreds, of light years across. Even though they have such a low* ***density****, these clouds can contain enough matter to make hundreds of thousands of stars like the Sun.*

A Nearby Interstellar Cloud



A dark knot of gas and dust in an interstellar cloud 9,500 light years from Earth blocks the light of the stars and stellar nursery behind it. This image shows an area of the sky about 6.5 light years wide.

(Image Credit: *NASA, ESA, and The Hubble Heritage Team (STScI/AURA))*

Every single bit of matter in the universe has gravity, including the atoms and dust grains between the stars. Events such as a ***supernova*** *sometimes trigger these low density clouds to begin to collapse under their own gravity. The collapse of an interstellar cloud begins the process of star birth.*

The collapsing cloud fragments separate into smaller pieces (clumps) that will form individual stars or systems of stars. These bits of cloud heat up as they collapse,

The Orion Nebula

(Image Credit: HST/NASA)

Introduce the Image: The image was taken by the Hubble Space Telescope, and shows a small portion of the Orion Nebula. The Orion Nebula is a stellar nursery in the constellation of Orion, and is about 1,500 light years away. The small part of the Orion Nebula shown in this image is about 2.5 light years across.

with the inner portions becoming very hot. Eventually, if the fragments have enough mass, the inner part of the collapsing gas and dust becomes hot and dense enough to start converting hydrogen into helium. And a star is born. When hot new stars begin to shine in these interstellar clouds, the gas becomes energized by the light of the stars and begins to glow. The parts of the cloud nearest to the hot young stars become a type of ***nebula.*** ***Nebulae*** *(the plural of* ***nebula****) are simply glowing clouds of interstellar gas and dust. Nebulae that contain many newborn stars are also called stellar nurseries.*

Introduce Plate 1: The Orion Nebula

Show Plate 1 as a projected image, and/or pass out this high-resolution color image of the central portion of the Orion Nebula to each student or small group of students. You can also have the students look at Plate 1 on computers. The image can be accessed on the Hubble web site at (http://hubblesite.org/newscenter/newsdesk/archive/releases/1995/45/image/a).

Ask the students to look closely at the image. What do they see?

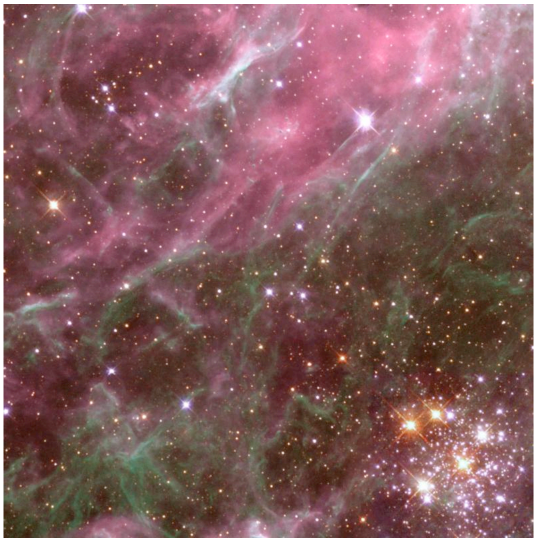
- **Colors:** The nebula is glowing. The primary colors are red and green.

The colors of the nebula tell astronomers what gases the nebula is made of. The green is from hydrogen gas. (This is false color to distinguish it from nitrogen; hydrogen really emits in red).

Hydrogen is the most abundant gas in the nebula, as well as the most abundant element in the universe. The red is from nitrogen gas. Nitrogen is much less abundant in the nebula than hydrogen, but is the primary component of the Earth's atmosphere. The little bit of blue in the image is from oxygen.

- **Stars:** The four bright stars near the center of the Nebula are called Trapezium.

Tarantula Nebula



(Image Credit: HST/NASA)

At the center of this Tarantula Nebula is a cluster of stars that make this formation appear very bright when observed from Earth. It is such a bright object in the night sky that it was at first mistaken for a star.

*The Tarantula Nebula is so large, that if it were as close to us as the Orion Nebula it would take up half the sky. The Tarantula Nebula is a known as a **starburst** region – that is, an area where an unusually high number of stars are being formed.*

These stars aren't red, as they may appear in the image, but are blue-white O and B class stars. The large amount of gas and dust between the Trapezium stars and the Earth makes them look red, much like the gas and dust in the atmosphere makes the Sun look reddish at sunset or sunrise. Fainter stars are also visible.

- **Stars with tails?** In a high quality image, shapes looking like stars with tails may be visible. If the students can see these features in the image, go ahead and discuss them. Otherwise, they can be discussed in an extension.

The "tails" are actually denser disk-shaped clouds of gas and dust about the size of our solar system (two to eight times the width of the orbit of Pluto) that are encircling individual newborn stars. Astronomers think these objects are planetary systems just starting to form. Four and a half billion years ago, before our planets formed, our own solar system probably looked very similar to these features.

Counting Stars

Ask each student or small group of students to count how many stars they can see in the picture. After a few minutes, the students should have an estimate for how many stars they can see. Query the students on how many stars they could find.

Ask the class if they think they could see all the stars in the region of the nebula seen in the image. If not, what could make stars hard to see? Some possible answers:

- Dust can obscure stars.
- Glowing gas can make stars very hard to see.
- The Orion Nebula is far away.
- The image is too small or does not have high enough resolution to see the stars.

Ask your students: Do you think that stars of some classes will be easier to see than stars of other classes? Why or why not?

High mass stars will be much easier to see than low mass stars, simply because they are much brighter. Cool, red M class stars are so dim they can be difficult to see even in the neighborhood of our solar system.

Tell the students that astronomers have counted more than 700 stars in this portion of the nebula. Compare this number with the estimates from the class.

What Stars are Born?

Ask the students " Do you expect that equal numbers of high mass stars and low mass stars will be born in a typical stellar nursery?"

When they look at stars inside and outside of stellar nurseries, astronomers have found that many more dim, red low mass stars are born than blue-white high mass stars. Whenever a star is born, it has a higher chance, or **probability,** of becoming a low mass star than a high mass star, or even medium-mass yellow star.

Explain to the class that they will do an experiment simulating the birth of stars of different masses (and therefore colors) in a stellar nursery.

Star Birth Activity

Divide the class into small groups of two to three students. Give each group of students a container with the 50 red objects, 10 yellow objects, and one blue object.

If they do not already have them, give each student or small group of students pages 3 & 4 of the student version of Star Birth.

Allow the class a few minutes to answer the pre-experiment questions, either individually or in their small groups.

The experiment itself will take roughly ten minutes, plus a few addition minutes for the making the table and answering the post-experiment questions.

Star Birth Activity

Answer these questions **before** the activity:

1) *If you have 50 red objects, 10 yellow objects, and 1 blue object all mixed up together in a box, what is the probability that an object you take out of the box (without looking) will be blue?*

   Answer: (1/61)

2) *What is the probability it will be red?*

   Answer: (50/61)

3) *What is the probability it will be yellow?*

   Answer: (10/61)

4) *If you put the first object back, mix up the objects in the box, and draw out another object, will the probabilities of drawing out an object of a particular color change or will they be the same?*

   Answer: (1/61)

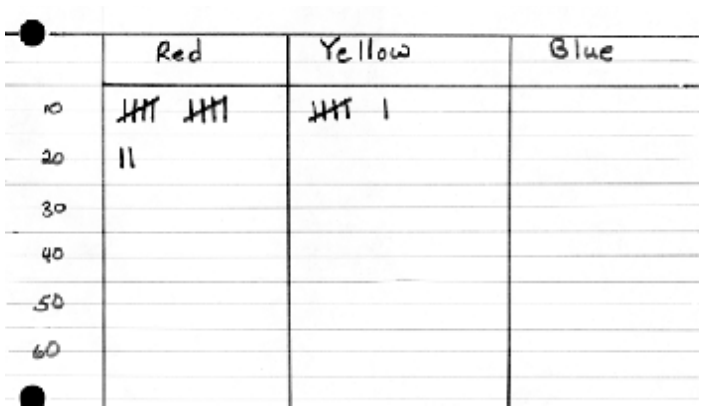
5) *If you draw out an object one at a time, record the color, and put it back before drawing another object, and do this 61 times, how many red, yellow, and blue objects will you expect to draw out? Will this number be exact or approximate? Why?*

   Answer: the numbers will be approximately 50 red, 10 yellow, and one blue, but will vary because the probability of drawing an object of a specific color will not change with each object drawn

   (Only after the experiment has been repeated many times can one expect the average distribution to be 50 red, 10 yellow, and one blue.)

Now, using the 61 colored objects in the container you have been given, you'll have a chance to see if your prediction is correct. Before you start, your group should make a table on a separate piece of paper with columns for red, yellow, and blue.

Your table might look something like this.



Keep track of the number of objects you have drawn out of each color using tick marks. Grouping tick marks 10 to a line will help you quickly count how many objects you have drawn so far. To help you count quickly, you can put numbers in the margin as shown in this example. Write the names of each of the members of your group on the top of the paper.

Next, shake up the objects in the container, and take one object out without looking.

Now, look at the object, record the color of the object, and put it back.

Repeat this until you have drawn a total of 61 times.

*Answer these questions **after** you finish the activity:*

6) *Total the tick marks in each of the 3 columns. How did you numbers compare with the numbers of objects of each color in the box? Did you get the numbers you expected?*

   Student numbers will probably vary from what they expected. Students typically expect to draw 50 red, 10 yellow, and one blue.

7) *What if you **hadn't** put the first object back? Would your probabilities for drawing out an object of a given color change, or be the same? Why?*

   Answer: Change. With each object drawn, the probability for what the next object would be would change depending on what objects remained in the container. This is called *conditional probability*.

8) *What would the total values in your columns be if you didn't put any of the objects back before drawing out the next object, and drew 61 times?*

   Answer: Exactly 50 red, 10 yellow, and one blue

Follow-up:

Once the class has completed their experiment and their worksheets, discuss the results of the experiment with the class. (You may wish to have the students turn in their worksheets prior to the discussion so that you can use them for evaluation purposes.)

- How did numbers from the different groups compare with one another?
- Were the averaged numbers for the whole class closer to the expected values than most individual group results?

Discuss the observed and predicted relative numbers of stars born in stellar nurseries.

Astronomers call the number of stars born as a function of mass the stellar **initial mass function**, or IMF for short. The IMF also states the probability of a star being born with a particular mass. Even for stellar nurseries relatively close to the Earth, the IMF for our galaxy is really an estimate. Individual stellar nurseries will have different relative numbers of low, medium, and high mass stars. Astronomers have different estimates for the IMF, but in all cases, many more dim red low mass stars are born than medium mass yellow stars like our Sun. Very massive blue-white O stars are rare. One estimate for the IMF is given in Table 1: Relative Numbers of Stars Born by Class, which is also available as a separate student handout.

Table 1: Relative Numbers of Stars Born by Class

Class	Color	Mass / Mass of Sun	Relative Number Born
O	Blue White	40	1
B	Blue White	6.5	40
A	White	2.1	200
F	Pale Yellow to White	1.3	500
G	Yellow	1	900
K	Orange	0.7	7000
M	Red	0.2	200,000

The numbers in Table 1are one estimate of the number of stars of different classes that might be born for every O class star. A few estimates are higher, many are lower, but all have many more low mass stars than high mass stars.

Table 1 is for **main sequence** stars.

Astronomers try to determine the IMF of a stellar nursery using a process similar to the counting of stars the students did near the beginning of the lesson.

Very low mass stars are so dim that many can't be counted. Astronomers must **extrapolate** the numbers of very low mass stars based on the numbers of higher mass stars. Dust and glowing gas can make it very hard to count stars. Sometimes individual stars are so cocooned in gas and dust that visible light can't even escape.

The ongoing effort to determine the IMF of stars in our galaxy and other nearby galaxies is one of many examples of how science is a dynamic field. **Not everything in science can be found in books!**

Extension:

If you have Internet access available for small groups of students, or the resources to make several good quality printouts for each small group, consider having the students examine other star forming regions.

The Hubble Space Telescope website (hubblesite.org) has fabulous images of stellar nurseries other than the Orion Nebula, along with captions containing a great deal of useful information. To further extend your investigations into the infrared part of the electromagnetic spectrum, visit the Spitzer Space Telescope website (http://www.spitzer.caltech.edu/),

Some good examples for your students are:

Eagle Nebula (http://hubblesite.org/newscenter/newsdesk/archive/releases/1995/44/)

Trifid Nebula (http://hubblesite.org/newscenter/newsdesk/archive/releases/1999/42/)

A closer look at the Orion Nebula shows disks of gas and dust around young stars believed to be forming planetary systems.

http://hubblesite.org/newscenter/newsdesk/archive/releases/1994/24/image/b

http://hubblesite.org/newscenter/newsdesk/archive/releases/1994/24/image/c

See the Orion Nebula's gas and dust gas reflecting the light of a bright young star.

http://hubblesite.org/newscenter/newsdesk/archive/releases/2000/10/image/a

And to glimpse star formation beyond our own galaxy in the nearby Large Magellanic Cloud (a satellite galaxy of the Milky Way):

30 Doradus Nebula
(http://hubblesite.org/newscenter/newsdesk/archive/releases/1999/33/)

Tarantula Nebula
(http://hubblesite.org/newscenter/newsdesk/archive/releases/1999/12/)

Questions to ask the students during, or as a follow-up, to their investigations:

- How are the stellar nurseries different from the Orion Nebula and one another? How are they the same?

- Which stellar nurseries would cause astronomers the most problems counting newborn stars and determining the IMF? Why?

- Can you find cocooned young stars that might be forming planetary systems in any of these images? If so, which ones?