Emera Astronomy Center
and M. F. Jordan Planetarium

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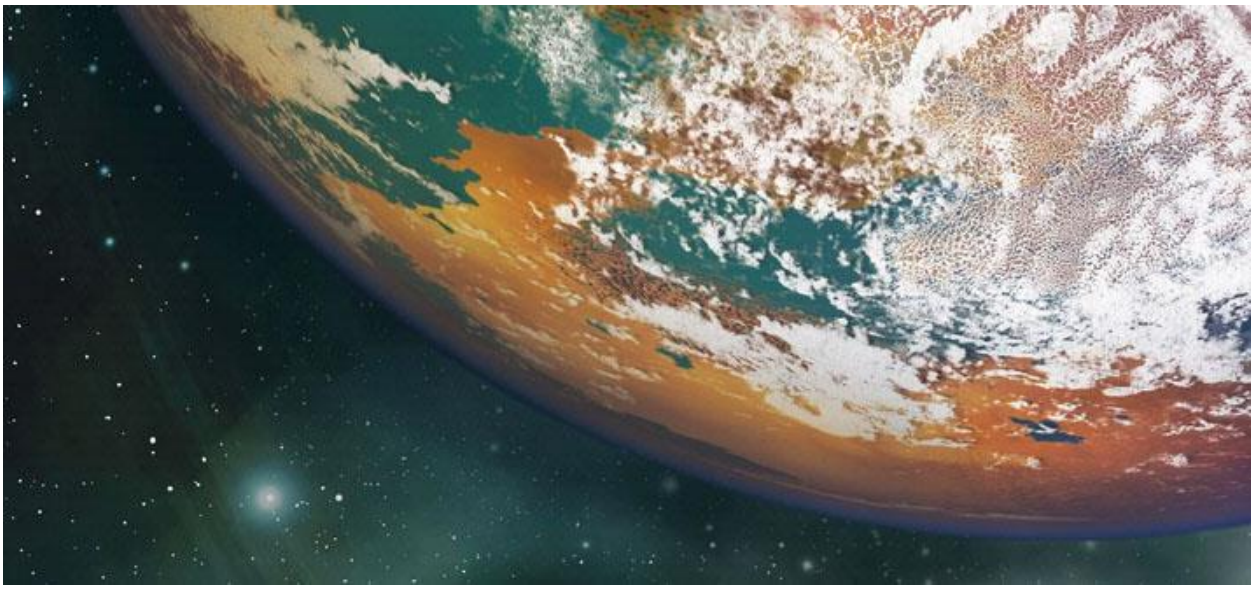

UNDISCOVERED WORLDS

COMPILED AND EDITED BY
Leisa Preble

THE UNIVERSITY OF MAINE

A Member of the University of Maine System

Emera Astronomy Center
and M. F. Jordan Planetarium

Undiscovered Worlds

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Additional Materials:

Kepler Star Wheel
Using Star Maps
Solar Motion Demo
Detecting Extrasolar Planets

Mission Statement:
The mission of the Maynard F. Jordan Planetarium of the University of Maine is to provide the University and the public with educational multi-media programs and observational activities in astronomy and related subjects.

Cosmic Classroom

Looking for fun and interesting space activities? The planetarium staff has prepared a collection of materials we call the Cosmic Classroom for you to use before and/or after your visit. These materials are entirely for use at your own discretion and are not intended to be required curricula or a prerequisite to any planetarium visit. The Cosmic Classroom is one more way that the Jordan Planetarium extends its resources to help the front line teacher and support the teaching of astronomy and space science in Maine schools.

The lessons in this Cosmic Classroom have been edited and selected for the range of ages/grades that might attend a showing of this program at the Jordan Planetarium. Those activities that are not focused at your students may be adapted up or down in level. Our staff has invested the time to key these materials to the State of Maine Learning Results in order to save you time.

The State of Maine Learning Results performance indicators have been identified and listed for the program, the Cosmic Classroom as a package, and each individual activity within the package. The guide also includes related vocabulary and a list of other available resources including links to the virtual universe. We intend to support educators, so if there are additions or changes that you think would improve, PLEASE let us know.

Thank you, and may the stars light your way.

The Maynard F. Jordan Planetarium Staff

The Program – *Undiscovered Worlds*

Undiscovered Worlds deals with some of the most profound questions of life science: the origins of life and the human search for life beyond Earth. *Undiscovered Worlds* explains extra solar planets; planets that astronomers have found living around stars other than our sun. In our planetarium adventure, we use images, models, and live demonstrations to understand why it is difficult to find an extrasolar planet, and to reveal the tricks astronomers use for finding them. The search is difficult, but in the end it could be very rewarding and it is the mission of NASA's Kepler space observatory now studying 100,000 stars.

Will we find a planet just like the Earth that is not too cold, not too hot, but just right? Can we identify life-giving water and oxygen on a distant planet? The Kepler mission and other exploration could lead to one of the most amazing discoveries ever made: extra-terrestrial life. All is discovered in this exploration called *Undiscovered Worlds*.

We are very glad that you have chosen to visit our planetarium with your group. We hope that this guide either will help you prepare your group or help you review their experience at the University of Maine's sky theater.

State of Maine Learning Results Guiding Principles

The lessons in this guide, in combination with *Undiscovered Worlds*, will help students to work towards some of the Guiding Principles set forth by the State of Maine Learning Results. By the simple act of visiting the planetarium, students of all ages open an avenue for self-directed lifelong learning. A field trip encourages students to think about learning from all environments including those beyond the schoolyard. A Jordan Planetarium visit also introduces visitors to the campus of the largest post-secondary school in Maine and encourages them to think of this as a place which holds opportunities for their future education, enjoyment and success.

Other sites on the University campus, including three museums, explore a variety of subjects, and the Visitors Center is always willing to arrange tours of the campus. A field trip can contribute to many different disciplines of the school curriculum and demonstrate that science is not separate from art, from mathematics, from history, etc. The world is not segregated into neat little boxes with labels such as social studies and science. A field trip is an opportunity for learning in an interdisciplinary setting, to bring it all together and to start the process of thinking. For a more complete discussion of field trips, please visit the Jordan Planetarium web site at http://www.astro.umaine.edu.

If used in its entirety and accompanied by the Planetarium visit this guide will help students to:

Become **a clear and effective communicator** through

A. oral expression such as class discussions, and written presentations
B. listening to classmates while doing group work, cooperation, and record keeping.

Become **a self-directed and life long learner** by

A. introducing students to career and educational opportunities at the University of Maine and the Maynard F. Jordan Planetarium.
B. encouraging students to go further into the study of the subject at hand, and explore the question of "what if?"
C. giving students a chance to use a variety of resources for gathering information

Become **a creative and practical problem solver** by

A. asking students to observe phenomena and problems, and present solutions
B. urging students to ask extending questions and find answers to those questions
C. developing and applying problem solving techniques
D. encouraging alternative outcomes and solutions to presented problems

Become **a collaborative and quality worker** through

A. an understanding of the teamwork necessary to complete tasks
B. applying that understanding and working effectively in assigned groups
C. demonstrating a concern for the quality and accuracy needed to complete an activity

Become **an integrative and informed thinker** by

A. applying concepts learned in one subject area to solve problems and answer questions in another
B. participating in class discussion

State of Maine Learning Results Performance Indicators

In conjunction with the Maynard F. Jordan Planetarium show *Undiscovered Worlds,* this guide will help you meet the following State of Maine Learning Results Performance Indicators in your classroom.

Grades 3-5

Science and Technology –

B1. Skills and Traits of Scientific Inquiry

a. Pose investigable questions and seek answers from reliable sources of scientific information and from their own investigations.

D1. Universe and Solar System.

a. Show the locations of the sun, Earth, moon, and planets and their orbits.
b. Observe and report on observations that the sun appears to move across the sky in the same way every day, but its path changes slowly over the seasons.
c. Recognize that the sun is a star and is similar to other stars in the universe.

D3. Matter and Energy

c. Describe properties of original materials, and the new materials(s) formed, to demonstrate that a change has occurred.

Grades 6-8

Science and Technology -

B1. Skills and Traits of Scientific Inquiry

a. Identify questions that can be answered through scientific investigations.
b. Design and safely conduct scientific investigations including experiments with controlled variables.
c. Use appropriate tools, metric units, and techniques to gather, analyze and interpret data.

B2. Skills and Traits of Technological Design

c. Communicate a proposed design using drawings and simple models.

C1. Understandings of Inquiry

a. Explain how the type of question informs the type of investigation.

C4. History and Nature of Science

b. Describe and provide examples that illustrate that science is a human endeavor that generates explanations based on verifiable evidence that are subject to change when new evidence does not match existing explanations.

D1. Universe and Solar System

a. Describe the different kinds of objects in the solar system, including planets, sun, moons, asteroids, and comets.

9-Diploma

Science and Technology -

D3. Matter and Energy

g. Describe nuclear reactions, including fusion and fission, and the energy they release.

Performance Indicators Snapshot

	Grades 3-5.	9-Diploma
The Show	B1.a D1.a, b, c D3.c	D3.g
	Grades 6-8. B1.a, b, c B2.c C1.a C4.c D1.a. D3.h	
The Guide	**Grades 3-5.** B1.a D1.a, b, c D3.c	**9-Diploma** D3.g
	Grades 6-8. B1.a, b, c B2.c C1.a C4.c D1.a D3.h	

A Star Is Born

DiscoverySchool.com
http://www.discoveryschool.com

CREDIT:
Lee Ann Hennig, astronomy teacher, Thomas Jefferson High School for Science and Technology, Alexandria, Virginia.

Objectives and State of Maine Learning Results Performance Indicators:

1. Learners will be able to understand that the sun is the principle energy source for phenomena on the Earth's surface. (6-8. Science & Technology. D3.h.)
2. Learners will be able to understand characteristics and movement patterns of the eight planets in our solar system. (3-5. Science & Technology. D1.a.)
3. Learners will be able to understand characteristics and movement patterns of dwarf planets, asteroids, comets, and meteors. (6-8. Science & Technology. D1.a.)
4. Learners will be able to understand common characteristics of stars in the universe (3-5. Science & Technology. D1.c.)
5. Learners will be able to understand that nuclear reactions convert a fraction of the mass of interacting particles into energy and release much greater amounts of energy than atomic interactions. (9-D. Science & Technology. D3.g.)
6. Learners will be able to access information at remote sites, using telecommunications. (6-8. Science & Technology. B2.c.)

NGSS:

1.

The General Idea:

Since we cannot watch a star evolve through its entire lifetime, astronomers use their knowledge of a star's behavior at various stages of its life to piece together a picture of the star's entire life.

The most important factor in how a star evolves and eventually dies is its initial mass. (It is assumed that the students already possess background information concerning how stars of different masses evolve—solar mass stars, such as the sun; low-mass stars 0.8 or less than the sun's mass; and higher-mass stars.)

What You Need:

Only research materials are required for this activity. You might want to have a selection of sources on hand in the classroom, but students should go to the library or the Internet for additional research. Reference materials on stellar evolution, including if possible, examples of images taken by the Hubble space telescope of stars in different stages of development. A computer with Internet access

What To Do:

1. Ask your students how they think astronomers can make inferences about the life of a particular star, from its birth to its death, taking into consideration that it is impossible to observe a star's evolution through its entire lifetime.
2. Make sure students understand that because a star's initial mass largely determines how the star will behave at various stages of its life, observing a star at any of those stages can give astronomers information about the star's initial mass and, therefore, about how the star was born, will evolve, and will die.
   Tell the class that they will be dividing into teams to do research on a star's life. Each team will focus on one aspect of the stellar evolution of a particular star.
3. Assign each of seven teams a star at a particular stage of stellar evolution: proto-star (example: the Eagle Nebula, a stellar nursery), proto-planetary disk and stellar system in formation (example: Orion Nebula), cluster of young stars (example: the Pleiades), middle-aged, normal star (example: the sun), cluster of older stars—red giant (example: Betelgeuse), dying stage—supernova, planetary nebula,

white dwarf (example: Supernova 1987A), end state of a star—black dwarf, black hole, neutron star (example: Cygnus X-1).

4. Tell students to keep track of the sources for their facts so that they or other interested classmates can go back to those sources for further information.
5. Encourage students to include visuals in their reports.
6. Have teams report their findings to the class through a poster session, sharing of photographic or printed sources, PowerPoint presentation, or some other format of the students' own choosing.
7. After each team's report, have team members lead a whole-class discussion on what could be inferred about earlier and later stages of the star's development based on information about the star at the stage of stellar evolution the team has researched. What can they infer about the star's initial mass? (For example, our sun will never become a black hole because it has too little mass, and therefore too little gravity. Rather, it will expel a ring of gas rich in heavier elements as a planetary nebula and then contract to become a white dwarf.)

ADAPTATIONS:

Instead of having team members act as discussion leaders, at the end of each report ask the class specific questions they can answer by making inferences about earlier and later stages of the star's evolution based on information they have learned from the report.

What To Discuss:

1. Explain how the Hubble space telescope's discoveries have improved our understanding of stellar evolution.

2. Debate whether manned space missions should be scheduled during times of increased solar activity. Is space exploration worth the risk of exposing humans to harmful radiation?

3. Discuss what you would expect to see if you were observing a newly forming planetary system. How would the material be distributed? What events would you expect to see on the forming protoplanets?

4. Discuss the two possible explanations of why Venus rotates retrograde and hypothesize and debate alternative explanations.

5. Analyze how astronomers came to the conclusion that Neptune's great dark spot didn't just shift from the southern hemisphere to the northern hemisphere.

6. Our sun is like a giant thermonuclear reactor, generating an incredible amount of energy each second. Fortunately, this violent maelstrom is well contained. Explain how Einstein's famous equation, $E = mc^2$, relates to the sun's energy production. Describe what you think would happen if all the sun's mass were instantly converted to energy.

EVALUATION:

You can evaluate your students on their reports using the following three-point rubric:

- **Three points:** report well researched; information clearly and logically organized; presentation interesting and lively; discussion session well organized
- **Two points:** report adequately researched; information sufficiently organized; presentation dull; discussion session disorganized
- **One point:** report insufficiently researched; information inadequately organized; presentation poorly prepared; discussion session disorganized

You can ask your students to contribute to the assessment rubric by determining a minimum number of facts to be presented in a report and setting up criteria for an interesting and lively presentation.

Continuations/Extensions:

Inner Circle

The three largest terrestrial planets, Earth, Venus, and Mars, share a common heritage in terms of their location in the solar system, composition, and age; however, the path each of these planets took on its evolutionary track is very different. Divide the class into three teams with the assignment to research and present their findings on how their individual planet evolved to its current state. The teams' combined research should make it apparent that many factors played a role in the appearance of each of the three planets and the conditions surrounding each one. Be sure students address the following factors:

1. The planet's orbital characteristics
2. Development and composition of an atmosphere
3. Rotation rate
4. Surface conditions
5. Development of life

You might also initiate a discussion about terraforming, or altering an existing planet's conditions to allow it to become more Earth-like. How could terraforming be accomplished on a planet such as Mars or Venus? Should it be done at all? Would terraforming provide an option for survival when the sun becomes a red giant?

Stellar Scripts

Have students write an article on how life on Earth would change as the sun evolves from its present state to its red giant phase, and eventually to a white dwarf. Encourage them to include the effects on Earth's environment, society, and technology and on human evolution.

Colors of Stars

Mary Kay Hemenway
The University of Texas at Austin Department of Astronomy
The University of Texas McDonald Observatory
Adapted for **UT**OPIA by Brad Armosky

Objectives and State of Maine Learning Results Performance Indicators:

1. Learners will be able to analyze the effects of heating and cooling processes in systems. (3-5. Science & Technology. D3.c.)
2. Learners will be able to use appropriate tools, metric units and techniques to gather, analyze, and interpret data. (6-8. Science & Technology. B1.c.)

The General Idea:

Students observe colors in the flame of a burning candle to explore connections between matter, light, color, and temperature — basic concepts of matter and energy. They elaborate on these basic concepts in a new context of astronomy and stars. When matter gets hot enough, it emits visible light. When heated to the same temperature, light bulb filaments, horseshoes, and stars will emit the same characteristic blend of color (or wavelengths) of light. Stars are different colors — white, blue, yellow, orange, and red. The color indicates the star's temperature in its photosphere, the layer where the star emits most of its visible light.

Getting Ready:

- Choose one of the following StarDate radio program scripts for students to read, or you may read it aloud to them: "Spring Triangle" or "Denebola."
- Optional: You may wish to check the StarDate Online web site (http://stardate.org) for interesting radio scripts that will help students find stars of different colors in the night sky. See the "Elaborate" section of this activity.
- Distribute to each group of students: white paper, crayons or colored pencils (lots of different colors), and one candle in a candle holder. Remind students of your classroom's safety rules before beginning.

What You Need:

- StarDate radio script ("Denebola" or "Spring Triangle"); included.
- Candles and candle holders (e.g., cupcakes)
- Matches
- White paper
- Crayons or colored pencils. Offer students a wide variety of colors.
- Construction paper
- Colored chalk
- String
- Spherical balloons (yellow and white)
- Ruler or meter stick

What To Do:

Light the candles. Ask the students to draw what they see in the flame, and to pay special attention to the colors they select. Ask students to record the colors they selected to draw the flame. Some students will use a wide variety of blue, yellow, orange, and red to capture the subtle hues in the flame.

Optional: If you have a digital camera, ask each group to take a picture (flash off) of their candle flame. Use the camera *after* students have completed their candle flame drawings.

What To Discuss:

When everyone is finished drawing, ask each group to describe what they saw and respond to the following questions:

1. Which part of the flame do you think is the hottest?
   The blue part is the hottest. Many think that "red" is always the hotter color, so that's what they expect.
2. As you watch the candle flame, what things or events in everyday life come to mind?
   Colors of the flame on a gas stove, camp fire, outdoor charcoal grill fire, rocket engine during liftoff, blowtorch, jet engine…

The answers will usually make the students want to look at their candle flame again, so don't extinguish the flames until all students have reported (unless it becomes a safety issue). Most will notice that the color of the flame is different close to the wick.

Optional: Load the digital images onto a computer to display on a video projector. Each group may refer to these images, as well as their drawings, to describe their flame. In stars, just as in Earth-bound fires, blue is hotter than yellow, and yellow is hotter than red. The Sun is much hotter than a candle flame. Unlike a candle, the Sun uses nuclear fusion as its energy source, not a chemical reaction like burning oil or wood. Stars are different colors because they are different temperatures. They are all "hot" compared to most things on Earth; they range in surface temperature from less then 3000 K to over 50,000 K. Explain to students that when we heat things that don't easily melt (like metal), they first look normal, then begin glowing "red-hot," and later become "white-hot."

Continuations/Extensions:

Draw scale models of stars

Because it is difficult to make three-dimensional models that preserve scale, some of the representations of stars in this activity will be flat. On a sidewalk or parking lot, try drawing colored circles in chalk for the larger stars. You can make the smaller ones out of colored construction paper. To begin, students blow up a yellow balloon to represent the Sun, then a white one that is 2.7 times larger (in diameter and circumference) to represent Vega (guide students through solving this problem):

• Measure the circumference of the yellow balloon (Cy) using string.
• Calculate the circumference of the white balloon: Cw = 2.7 ¥ Cy
• Cut a new string to the length of Cw
• Blow up the white balloon until its circumference is Cw.

Students make paper disks the same diameter and color as these two balloons. Now, they compute how large the disk would be for the larger stars. Making a disk to represent a star is like using a flat picture to represent a person. Stars are spheres of hot gas, round like balloons. Students draw the largest diameters outside (using chalk or tracing the outline with string).

To make a circle:
• Measure a piece of string equal to the calculated diameter.
• Fold the string in half and hold at the center
• Place a piece of chalk where the ends of the string meet and trace a circle.
Use the table provided to scale the star diameters. For example, if you begin with a one centimeter Sun, then Betelgeuse will be 8.3 meters! So, this activity takes a lot of space.

Star	**Diameter** (Sun's diameter = 1)	**Color**
Sun	1	Yellow
Betelgeuse in Orion	830	Red
Antares in Scorpius	775	Red
Vega in Lyra	2.7	White
Rigel in Orion	50	Blue
Proxima Centauri C (closest star to the Sun)	0.03	Red
Dubhe (brightest star in the Big Dipper)	14	Orange

Although stars range in mass from less than one-tenth the mass of the Sun to 100 solar masses, the most massive stars are not the largest. Stars like Betelgeuse and Antares have "puffed up" into red giants hundreds of times the Sun's diameter, yet Betelgeuse is about 20 times more massive than the Sun. There is a lot of empty space inside Betelgeuse. If Betelgeuse is 830 times the Sun's diameter, air at sea level is almost 25,000 times the average density of Betelgeuse.

Evaluate:

Explore (20 points)
(20 points) Candle flame drawing: Students represent the flame with a variety of colors, and accurately proportion parts of the flame. Some may include the wick and candle.

Explain (40 points)
1. Which part of the candle flame do you think is the hottest? Why?
(20 points) Students draw on prior knowledge / everyday experience and their understanding of science concepts in their explanations.
2. As you watch the candle flame, what things or events in everyday life come to mind?
(20 points) Students list a variety of things and/or events:
For instance: jet engine, blowtorch, hot oven, bread toaster coils, camp fire, Space Shuttle launch, the Sun, sunset colors…

Elaborate: Make and draw models of stars (40 points)
Parts 1 and 2: (10 points) Students inflate the yellow balloon to represent the Sun and inflate the white balloon so that its circumference is 2.4 times larger than the Sun balloon.
Parts 3 and 4: (10 points) Students accurately measure and cut out the paper disks, then correctly calculate the scale diameters for the four large stars in the table.
Part 5: (20 points)
Students accurately calculate the model star radii using the table. The radii depend on the scale size they choose for the Sun.

Students use the string and chalk to draw big circles that represent the large stars:
• Measure a piece of string equal to the calculated diameter.
• Fold the string in half and hold at the center.
• Place a piece of chalk where the ends of the string meet and trace a circle.

Name________________________________ Date_________________________________

The Color of Stars

Student Worksheet

Explore

Draw the candle flame

Explain

1. Which part of the flame do you think is the hottest? Why?

2. As you watch the candle flame, what things or events in everyday life come to mind?

Elaborate: Make and draw scale models of stars

1. Inflate a yellow balloon to represent the Sun.
2. Inflate a white balloon 2.7 times larger than the Sun balloon. The white balloon represents nearby star called Vega. How do you know if the white balloon is 2.7 times bigger?
3. Make paper disks the same diameter and color as the Sun and Vega balloons.
4. Calculate how large the paper disk would be for the larger stars

Star	**Model diameter**
Betelgeuse	
Antares	
Rigel	
Dubhe	

5. Draw the largest circles outside to represent the four large stars. How do you think you could make the circles using string and chalk?

Scale Size and Colors of Stars

Star	**Diameter** (Sun's diameter = 1)	**Color**
Sun	1	Yellow
Betelgeuse in Orion	830	Red
Antares in Scorpius	775	Red
Vega in Lyra	2.7	White
Rigel in Orion	50	Blue
Proxima Centauri C (closest star to the Sun)	0.03	Red
Dubhe (brightest star in the Big Dipper)	14	Orange

Use the table to calculate the model star diameters. For example, if you begin with a one centimeter Sun, then Betelgeuse will be 8.3 meters!

STARDATE CLASSROOM RESOURCES
StarDate: March 7, 2004

Denebola
Leo, the lion, prowls through our evening sky this month, and stands high overhead around midnight. Its two brightest stars mark opposite ends of the constellation. Regulus, the heart of the lion, is at Leo's western edge. And the second-brightest star, Denebola, marks Leo's tail at the constellation's eastern end. Look for it above and to the left of the full Moon this evening, and to the lower left of the brilliant planet Jupiter.
The name Denebola evolved from the ancient Arabic name Al Dhanab al Asad -- the lion's tail.
Like the Sun, Denebola is a main-sequence star -- a sedate, comfortable star in the prime of life. But Denebola is a blue-white star, which means that its surface temperature is several thousand degrees hotter than the Sun's. And if you placed the two stars side by side, Denebola would appear about 15 times brighter than the Sun.
This means that Denebola's consuming its nuclear fuel at a faster rate, so it'll live a shorter life.
Denebola is about 40 light-years from Earth. In other words, a beam of light -- speeding along at almost six TRILLION miles every year -- takes 40 years to travel from Denebola to Earth. The light we see from Denebola tonight left the star not long after the first humans were launched into space.
If intelligent beings live on planets in orbit around Denebola, they should just now be receiving the television broadcasts of those early missions.
We'll talk about another prominent star tomorrow.

Script by Damond Benningfield, Copyright 1998, 2001, 2004

STARDATE CLASSROOM RESOURCES
StarDate: March 15, 2004

Spring Triangle
Summer and winter offer two of the most prominent geometric shapes in the night sky -- the Summer Triangle and the Winter Circle. These patterns of bright stars dominate the evening sky during their respective seasons -- and the Winter Circle is STILL in view in the west as darkness falls.
There's no well-recognized shape for spring, but perhaps there should be. Three bright stars form a tall triangle in the east beginning around 9 p.m. The stars are spread pretty far apart, but they still stand out -- especially from cities, where bright lights overpower most of the fainter stars.
The most prominent member of this triangle is Arcturus, the third-brightest star in the night sky. It's in the constellation Bootes, the herdsman. This brilliant yellow-orange star is low in the east in mid-evening, and wheels high across the sky during the night.
It's a type of star known as a giant, which means it's old and bloated -- a preview of what our own Sun will look like in several billion years.
Well to the right of Arcturus, just a little lower in the sky, you'll see Spica, the brightest star of Virgo. And well above Spica and a little to its right is Regulus, in the constellation Leo. These stars are quite similar. Like the Sun, they're both in the prime of life. But they're hotter than the Sun, so they shine brighter and bluer.
Look for the bright but wide-spread "Spring Triangle" in the east beginning around 9 o'clock.

Script by Damond Benningfield, Copyright 2001, 2004

Strange New Planet

ASU Mars K-12 Education Program 6/99
Adapted from NASA Education Brief "EB-112: How to Explore a Planet" 5/93

Objectives and State of Maine Learning Results Performance Indicators:

1. Learners will be able to describe the different kinds of objects in the solar system (including planets, sun, moons, asteroids, and comets). (6-8. Science & Technology. D1.a.)
2. Learners will be able to make accurate observations using appropriate tools and units of measure. (6-8. Science & Technology. B1.c.)
3. Learners will be able to design and conduct scientific investigations which include controlled experiments and systematic observations. (3-5. Science & Technology. B1.b.) (6-8. Science & Technology. B1.b.)

The General Idea:
Strange New Planet brings insight into the processes involved in learning about planetary exploration. This activity demonstrates how planetary features are discovered by the use of remote sensing techniques. Students will be engaged in making multi-sensory observations, gathering data, and simulating spacecraft missions.

Getting Ready:
Photocopy enough "Strange New Planet" data sheets for each student.

What You Will Need: (Planets can be made from a combination of materials)

- Plastic bails, modeling clay, Playdoh©, styrofoam© balls, or rounded fruit (cantaloupe, c pumpkin, oranges, etc.)
- Vinegar, perfume, or other scents
- Small stickers, sequins, candy, marbles, anything small and interesting!
- Cotton balls
- Toothpicks
- Objects that can be pierced with a toothpick to make a moon
- Glue (if needed)
- Towel (to drape over planets)
- Push-pins
- Viewer material (sheet of paper, paper towel roll, or toilet paper roll)
- 5" x 5" blue cellophane squares (one for each viewer) and other selected
- Colors to provide other filters for additional information
- Rubber bands (one for each viewer)
- Masking tape to mark the observation distances
- Student data sheet

What to Do

1. Selecting a Planet
   Choose an object such as a plastic ball or fruit (cantaloupe, etc) that allows for multi-sensory observations. Decorate the object with stickers, scents, etc. to make the object interesting to observe. Some of these materials should be placed discreetly so that they are not obvious upon brief or distant inspection. Some suggestions for features are:

   - Create clouds by using cotton and glue
   - Carve channels
   - Attach a grape using a toothpick (to make moons or orbiting satellites)
   - Affix small stickers or embed other objects into the planet
   - Apply scent sparingly to a small area

   For older students, teams can create their own planets for other teams to view. This allows the students to create their own set of planetary features and write up a key to these features for the team that explores that planet to compare to their own findings.

2. Set-up
   Place the object (planet) on a desk in the back of the room. Cover the object with a towel before students arrive. Brief students on their task: To explore a strange new planet. Students can construct viewers out of loose-leaf paper by rolling the shorter side into a tube (can also use toilet paper roll or paper towel roll.) These viewers should be used whenever observing the planet. Form mission teams of 4-5 students. Make sure students have a place to record their data (student data sheets.) Encourage use of all senses (except taste unless specifically called for).

3. Pre-Launch Reconnaissance
   This step simulates earth-bound observations. Arrange students against the sides of the room by teams. These areas will be referred to as Mission Control. To simulate Earth's atmosphere, a blue cellophane sheet could be placed on the end of the viewers, taped or held in place by a rubber band. This helps to simulate the variation that occurs when viewing objects through the Earth's atmosphere. Remove the towel. Teams observe the planet(s) using their viewers for 1 minute. Replace the towel. Teams can discuss and record their observations of the planet. At this point, most of the observations will be visual and will include color, shape, texture, and position. Teams should write questions to be explored in the future missions to the planet.

4. Mission 1: The Fly-by (Mariner 4,6,7 - 1965,1969,1969)
   Each team will have a turn at walking quickly past one side of the planet (the other side remains draped under towel). A distance of five feet from the planet needs to be maintained. Teams then reconvene at the sides of the room (Mission Control) with their backs to the planet while the other teams conduct their fly-by. Replace towel over planet once all the fly-bys have taken place. Teams record their observations and discuss what they will be looking for on their orbit mission.

5. Mission 2: The Orbiter (Mariner 9,1971-72; Viking 1 and 2 Orbiters, 1976-80; Mars Global Surveyor, 1996-present)
   Each team takes two minutes to orbit (circle) the planet at a distance of two feet. They observe distinguishing features and record their data back at Mission Control. Teams develop a plan for their landing expedition onto the planet's surface. Plans should include the landing spot and features to be examined.

6. Mission 3: The Lander (Viking 1 and 2,1976-1982; Mars Pathfinder, 1997)
   Each team approaches their landing site and marks it with a push pin (or masking tape if planet will pop using a pin.) Team members take turns observing the landing site with the viewers. Field of view is kept constant by team members aligning their viewers with the push pin located inside and at the top of their viewers. Within the field of view, students enact the mission plan. After five minutes, the team returns to "Mission Control" to discuss and record their findings.

Assessment:
Each individual student should complete a Student Data Sheet. Each team shares their data with the class in a team presentation. As a class, compile a list of all information gathered by the teams to answer the question “What is the planet like?” (or each planet if multiple planets are used). Have the class vote on a name of the newly discovered planet or the geologic features discovered using the rules for naming a planet (planetary nomenclature) which is located at the USGS website: (http://wwwflag.wr.usgs.gov/USGSFlag/Space/nomen). Teams critique their depth of observations and ability to work together.

Variations:
Create a solar system of planets, hang them from the ceiling and have students make observations of all the planets.

Name:________________________________

Strange New Planet Student Data Sheet

A. Pre-Launch Reconnaissance - Earth-bound observations

1) Estimate your distance from the planet: (feet or meters).

2) Using your viewer (with blue cellophane attached to simulate Earth's atmosphere) observe the planet. What types of things do you observe? Record any observations (shape of planet, color, size, etc.)

3) Discuss all of the observations with your team members while at Mission Control. Record any team observations that differ from yours.

4) As a team, write questions to be explored in the future missions to the planet. What else do you wish to know and how will you find that information out (special features of the planet, life of any kind, etc.)

   a.

   b.

   c.

   d.

B. Mission 1: The Fly-by (Mariner 4, 6, 7 - 1965, 1969, 1969)

Using their viewers (with the cellophane removed), each team will have a turn at walking quickly past one side of the planet. A distance of five feet needs be maintained from the planet. Teams will then meet back at Mission Control with their backs to the planet until all teams have completed their fly-by of the planet.

1) Record your observations of the planet. What did you see that was the same as your Earth observations? What did you see that was different? Can you hypothesize (make a science guess) as to why there were any differences?

2) Record any similarities or differences that your team observed.

3) List the team ideas as to what you want to observe on your next orbiting mission.

a.

b.

c.

d.

C. Mission 2: The Orbiter (Mariner 9, 1971-72; Viking I and 2 Orbiters, 1976-80; Mars Global Surveyor, 1996-present)

Using a viewer, each team takes a total of two minutes to orbit (circle) the planet at a distance of two feet. Divide the two minutes by the number of team members to get the time each person gets to orbit the planet. After your observation, return to Mission Control.

1) Record your observations of the planet. What did you see that was the same as your Earth or fly-by observations? What did you see that was different? Can you hypothesize (make a science guess) as to why there were any differences?

2) Record any similarities or differences that your team observed.

3) As a team, develop a plan for your landing expedition onto the planet's surface.

a. Where will you go and why? How did your team decide where to land?

b. What are the risks or benefits of landing there?

c. What specifically do you want to explore at this site?

d. What type of special equipment or instruments would you need to accomplish your exploration goals? (Remember, anything you bring has be small and light enough to bring on a spacecraft!)

D. Mission 3: The Lander (Viking 1 and 2, 1976-1982; Mars Pathfinder 1 1997)

Each team will approach their landing site and mark it with a push pin or masking tape. Each team member will take a turn observing the landing site through their viewer. Field of view (the area that you can see through your viewer) is kept constant by aligning the viewer with the push pin located inside and at the top of their viewers. Each team has a total of five minutes to view the landing site. After each member views the landing site, return to Mission Control.

1) Now that you have landed, what do you think you can accomplish at this landing site?

2) How long (in days) will it take you to get the job accomplished?

3) Was your mission successful? Why or why not?

4) What were the greatest challenges of this mission (Personally and as a team)? What would you change for the next mission?

5) List the members of your team.

a.

b.

c.

d.

e.

f.

Is Anyone Out There?

Objectives and State of Maine Learning Results Performance Indicators:

1. Learners will be able to determine the probability of the existence of extraterrestrial life.

The General Idea:

One of the most fascinating questions which could be asked is this: "What are the chances that life exists on another planet orbiting another star somewhere out there?" The attached worksheet will help students understand these chances by taking them step by step through the mathematics used to "guesstimate an answer.

Getting Ready:

Photocopy the "Is Anyone Out There" worksheet

What You Need:

A copy of "Is Anyone Out There" worksheet for each student

What To Do:

1. Hand out the worksheet as homework, just for fun, or to complement another activity that you are doing. This worksheet is very good for a cross-curriculum activity combining the study of astronomy in science and the study of probability in mathematics.

IS ANYONE OUT THERE?

One of the most fascinating questions which could be asked is this: "What are the chances that life exists on another planet orbiting another star somewhere out there?" Perhaps it would be best to put some limits on the size of 'out there'. For purposes of this activity, "Out There" will be limited to our own island of stars, the Milky Way Galaxy. The Milky Way Galaxy probably looks a huge turning pinwheel of stars. (The word 'probably' is used since no one has been outside the galaxy and no external photographs have ever been taken.)

While the exact number of stars in the Milky Way is not known, most astronomers will agree that there are probably several hundred billion stars. For purposes of this activity, the estimate to be used is two hundred billion. (That's the number 2 with 11 zeros behind it.) Most of these stars are congregated in a central bulge with the remaining strewn out in great spiral arms.

STEP ONE:

We mentioned before that our galaxy may contain as many as 200 billion stars. However, not all of these stars are good candidates. Easily half of all the stars in the galaxy are double stars (two stars going around each other) or triple stars. If life were to develop on planets going around stars, it would have a better chance if that star were a single star like our Sun. Thus, to find out how many total single stars there are in our galaxy, do the math step below.

1. 2OO,OOO,OOO,OOO X 1/2= _100,000,000,000______________single stars

STEP TWO:

If life as we know it exists elsewhere, it probably is on a planet which goes around a sun like our own. Since not all the remaining single stars are like the Sun, some are hotter and blue in color (too hot for life) and others are cooler and red colored (too cold for life.), we will assume that only one star in ten is a star like our own. Thus, your next calculation is as follows:

2. (insert answer from step 1)__ 100,000,000,000_____________X
   1/10___________single stars

STEP THREE

Not all of the remaining stars have the more complex elements from which life could develop. Some of these stars are what we call early stars, and they contain only hydrogen. Let us suppose that only one star is five has the elements required for life to develop. Perform the calculation below.

3. (insert answer from step 2) ________________X 1/5___________single stars

STEP FOUR:

These remaining stars might not have planets going around them which would be the right size for life. If the planet were too large, like Jupiter, it would hold in all the poison gases. If it were too small, like Mercury, there would not be enough gravity to hold onto an atmosphere. The next calculation is used if we assume that that only one in ten stars have an Earth-sized planet.

4. (insert answer from step 3) _______________ X 1/10 _____________Planets

STEP FIVE:

Next, the Earth-sized planets would have to be at the exact distance from their stars. If it were too close, there would be too much heat for life; too far away - too cold. Suppose that only one planet in ten is at the right distance. Do the calculation below.

5. (insert answer from step 4) _______________ X 1/10 _____________Planets

STEP SIX:

Of these remaining planets, not all of them may have developed an atmosphere which could sustain life. Let us assume that only one in ten has the proper blanket of air. Calculate the number of remaining planets below.

6. (insert answer from step 5) _______________ X 1/10 _____________Planets

STEP SEVEN:

Even though we have narrowed things down considerably, we still are not finished. The odds are fairly thin that life might actually develop on any of these planets. To be conservative, let us reduce the chances to one in a thousand.

7. (insert answer from step 6) _____________ X 1/1000 _____________Planets

STEP EIGHT:

One last reduction is necessary. The life which mathematically might exist on these planets may only be simple life (microscopic organisms, for example.) The chances that there might be planets with <u>INTELLIGENT</u> life are slim. To be on the safe side, reduce the number of remaining planets by a factor of 1000.

8. (insert answer from step 7) _____________ X 1/1000 _____________Planets

Designing an Exoplanet

Museum of Science, Boston: Undiscovered Worlds Educator's Guide Classroom Activities

Objectives and State of Maine Learning Results Performance Indicators:

MLRs

1. Learners will acquire the abilities necessary to do scientific inquiry. (3-5. Science and Technology. B1.a)
2. Learners will be able to describe and provide examples that illustrate that science is a human endeavor. (6-8. Science and Technology. C4.c)
3. Learners will be able to understand the concepts of light, heat, electricity and magnetism. (6-8. Science and Technology. D3.h)
4. Learners will be able to describe the different kinds of objects in the sky. (6-8. Science and Technology. D1.a).

NGSS

5. Learners will be able to understand the Earth's place in the Solar System (5-ESS1.B)

The General Idea:

Our own solar system may seem incredibly large (and it is!), but it is only a very small piece of our galaxy, and our galaxy is only a tiny piece of the entire universe. Here on earth, it can be hard to visualize how tiny we really are in the grand scheme of things.

What You Need:

1. Copy of the star with planets (provided)
2. Copy of activity for each child or group (pg. 35)
3. Access to internet

What To Do:

Before the Lesson:

- Hold up the sheet with the star and planets, and ask students what they see from their desks; then take the sheet across the room and ask what they can still see.
- Ask your students why they can't see some of the objects anymore. Continue taking the paper farther and farther away until the students can only see the star. Explain that this is how our solar system might appear from another star with it's own planets.

Part I: Exoplanet Scoop!

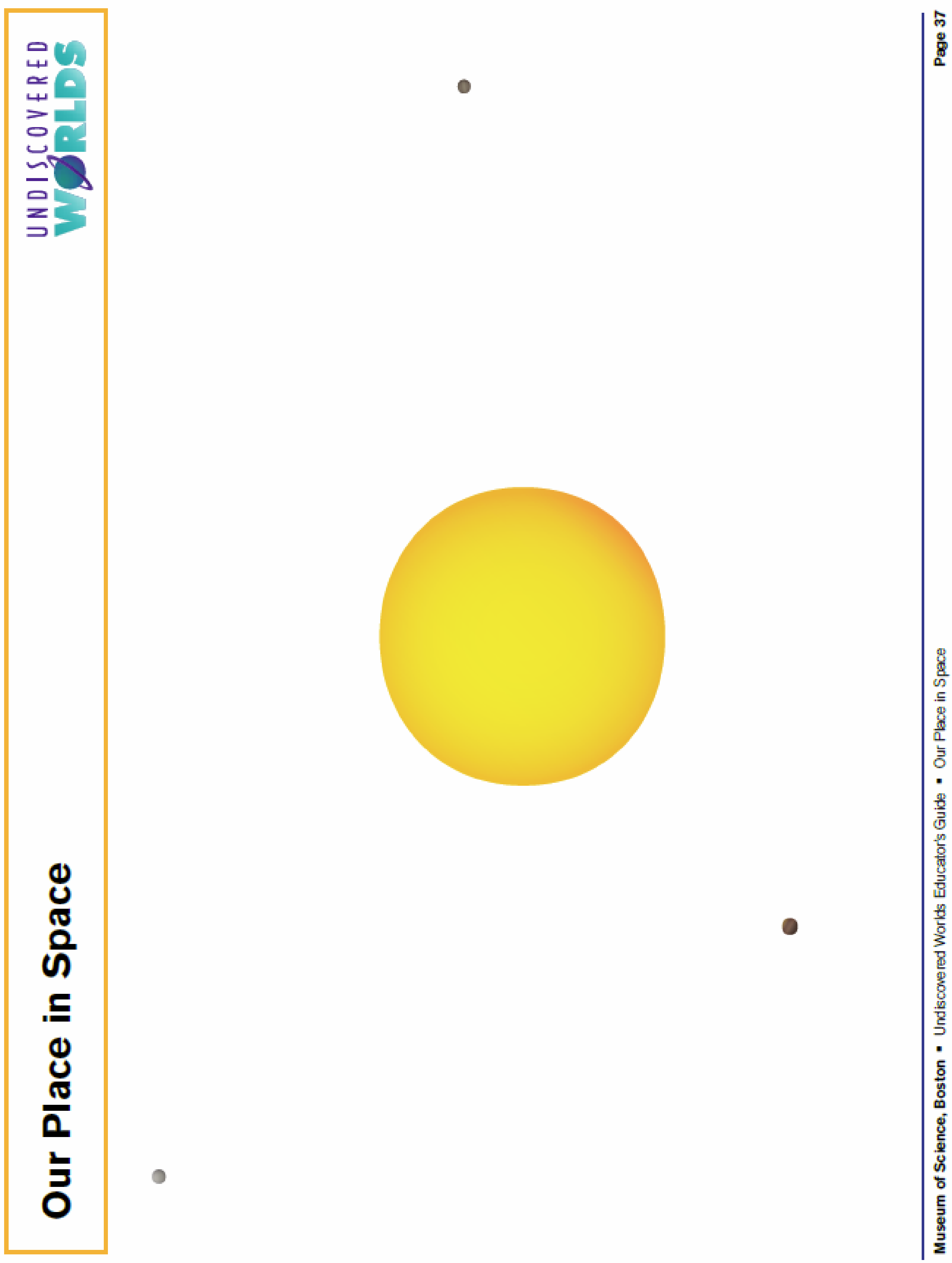
1. Ask students to research a recent exoplanet discovery and write a short news article about it. They can choose a specific planet, or a whole planetary system.
2. Compile these articles into a newsletter to distribute to the entire class. The latest news can be found in several places, including the Kepler mission website (kepler.nasa.gov), the PlanetQuest website (planetquest.jpl.nasa.gov), and the European Space Agency's CoRoT mission website (esa.int/esaMI/COROT/index.html).

Part II: Extreme Planet Makeover and Design

1. Planetquest.jpl.nasa.gov (click on "Extreme Planet Makeover" under "INTERACTIVES")
2. This interactive program allows students to create their own exoplanetary system by adjusting variables such as distance from star, planet size, star type, and planet age.
3. Photocopy the activity sheet "Design an Exoplanet" for your students.
4. Instruct them to choose the characteristics of their own alien world, then draw what they imagine it might look like.

Guided Questions:

1. How do you define a planet's year?
2. What does it mean if a planet is part of a "solar system"?
3. If a star looks like it is dimming regularly, what might this tell us? (Hint: Is something blocking the light)?
4. Why is Mercury hotter than Earth?
5. Could life survive on Mercury? Why or why not?
6. What makes Earth special compared to any other planet?


Our Place in Space
UNDISCOVERED WORLDS
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Student Activity (Grades 3 – 5)

Design an Exoplanet!

Name: ____

Imagine you are standing on the surface of a planet in another solar system. Look around: what do you see? Are there trees? Water? Is it mountainous or flat? Is the sky blue? Maybe it's red, or maybe there's no sky at all and you can see the stars during the day. How big does the Sun look? So far we have not found any planets like our Earth, and the view from any planet would look different from what we normally expect.

Fill in the blanks below to decide what characteristics your planet will have, then draw the surface of your planet in the box.

Name of planet: ______________________________

____

Size of the star (big, small, etc.): ______________________________

____

Color of the sky: ______________________________

____

Water? (yes or no): ______________________________

____

Surface type (hilly or flat?): ______________________________

____

Life? (yes or no): ______________________________

____

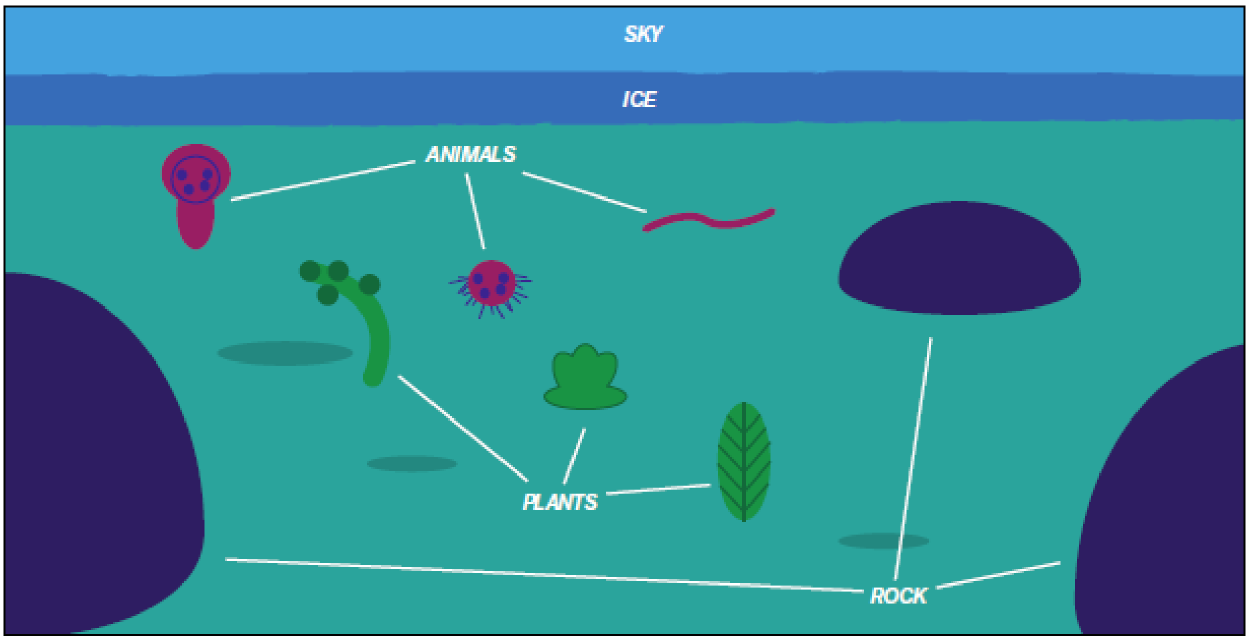
Design an Exoplanet!

UNDISCOVERED WORLDS

EXAMPLE/ANSWER KEY

Imagine you are standing on the surface of a planet in another solar system. Look around: what do you see? Are there trees? Water? Is it mountainous or flat? Is the sky blue? Maybe it's red, or maybe there's no sky at all and you can see the stars during the day. How big does the Sun look? So far we have not found any planets like our Earth, and the view from any planet would look different from what we normally expect.

Fill in the blanks below to decide what characteristics your planet will have, then draw the surface of your planet in the box.



Name of planet: CORO

Size of the star (big, small, etc.): MEDIUM

Color of the sky: GREENISH-BLUEISH

Water? (yes or no): YES, REGULAR AND ICY

Surface type (hilly or flat?): ICY AND COLD

Life? (yes or no): YES

Kepler Mission – Habitable Planets

NASA Kepler Mission Education and Public Outreach and The Lawrence Hall of Sciece
Classroom Activity Trial Version: December 2004 – Alan Gould

<u>Objectives and State of Maine Learning Results Performance Indicators</u>:

1. Learners will be able to identify what planet characteristics make a planet habitable. (6-8. Science and Technology. B1.a)
2. Learners will be able to match planet characteristics with the individual planets, and explain why this is so. (6-8. Science and Technology. C1.a)

<u>The General Idea</u>:

This activity encourages a discussion about what makes a planet habitable. By the end of the activity, everyone should realize that for a planet to support life like we find on Earth, it must have:

a) The right temperature range for there to be *liquid water*, and
b) The right size range to be able to have suitable *atmosphere*.

In this activity, students match a series of questions with corresponding correct answers and keep track of planet characteristics in a simple table. They interpret the table to answer the basic question, "What makes a planet habitable".

<u>Preparation</u>:

Make a transparency or Powerpoint slides of "Match Game (Master included at end of activity). For a powerpoint slide, make each set of match items (between the double lines) a separate slide. Make a copy of "What Makes a Planet Habitable?" (Master included at end of activity) for each student, or group of 2-5 students.

<u>What You Need:</u>

For whole group/class: 1 Transparency (or powerpoint slide) of Match Game

For each student or group (of 2-5 students): 1 copy of the chart "What Makes a Planet Habitable?"

<u>What To Do:</u>

1. **Ask the class, "What does the word *habitable* mean?"** [Suitable for life. "Habitable" derives from the same root word as "habitat."] Explain that the class will play a match game—matching up questions with correct answers—to figure out what makes a planet habitable.
2. **Hand out a "What Makes a Planet Habitable?" chart** to each student or groups of 2–5 students. Explain that during the Match Game they can keep track of planet information on these charts by putting check marks in appropriate boxes.
3. **Show the first question:**
   "I. What is Essential for Life?"
   - Read each numbered match item out loud to the class and then ask the students to write "1", "2", and "3" on a sheet of scrap paper (can be the back f the "What Makes a Planet Habitable?" chart)
   - Have the students match the items and write "A," "B," or "C" next to the matching number on their paper. Poll the students on the correct order of the letters. The correct match is:
     1 -> B   2 ->C   3 -> A
   - Emphasize that air is one of *the* most important substances for life and that water is actually even more important. You can clarify these points by asking, "Can you think of any life form

on Earth that exists without water?" and "Is there life on Earth that can exist without air?" [Allow time to discuss anaerobic bacteria if anyone brings that up. In some respects, air is not essential for life, since there are many anaerobic life forms. However, a planet without air will not have liquid water, since lack of atmosphere makes liquid water on planet surface evaporate quickly and escape the planet.]

4. **Show the next Match items:**

   "II. Planet Atmospheres."
   - Read each numbered item out loud to the class and then ask the students to write "4", "5", and "6" on the scrap paper and have them write "D," "E," or "F" by the matching number.
   - Poll the students on the correct order of the letters. The correct match is:
     4→F 5→E 6→D
   - Ask students to mark spaces relating to atmosphere in their charts of "What Makes a Planet Habitable?"—which planets have thick, thin, or no atmosphere. Ask these questions:
     "Why do some planets have no atmosphere and others have very thick atmosphere?" [Some may suggest that planet size makes a difference.]

5. **Show "III. Planet Sizes."**
   - Read each numbered item out loud to the class and then ask the students to write "7, "8," and "9" on the scrap paper. Have them to write "G," "H," or "I" next to the matching number on their scrap paper. Poll the students on the correct order of the letters. The correct match is:
     7→I 8→G 6→H
   - Ask students to mark spaces relating to planet size in their charts of "What Makes a Planet Habitable?"—which planets have thick, thin, or no atmosphere.
   - Ask, ***"Why do small planets have no atmosphere and large planets have very thick atmosphere?"*** [Gravity determines whether a planet can hold onto molecules of atmosphere. Smaller planets do not have enough gravity to hold onto the atmosphere.]
   - Ask ***"Which planets are more likely to have life: ones with thick atmosphere, thin atmosphere, or no atmosphere?"*** [It's a little like the Goldilocks fable: too much atmosphere may not be as hospitable and no atmosphere is obviously a problem for life. But thin atmosphere may be "just right."

6. **Show "IV. Temperature."**
   - Read each numbered item out loud to the class and then ask the students to write "10", "11", "12," "13," and "14" on the scrap paper. Have them to write "J," "K," "L," "M," or "N" next to the matching number. Poll the students on the correct order of the letters. The correct match is: 10→L 11→N
     12→J 13→M 14→K
   - Ask students to mark spaces relating to planet size in their charts of "What Makes a Planet Habitable?"—which planets are hot, medium, or cold temperature.
   - Ask, ***"Why is the temperature range forliquid water important in our discussion of what makes a planet habitable?"*** [All life needs liquid water, so the planet temperature must be within that range for liquid water to exist.]
   - Ask, ***"What factors seem to affect the temperature of a planet?"*** [Distance from the Sun and, especially for the inner planets, presence or absence of atmosphere. If necessary, call students' attention to the last row of their "What Makes a Planet Habitable?" chart.]

> A very interesting additional activity or demonstration that would be great to do with regard to temperature is to measure temperature of ice and of boiling water. The actual temperature of an ice water mixture depends on how much impurity (such as salt) is in the water. The actual temperature of boiling water depends on the atmospheric (barometric) pressure of the air in contact with the water.

7. **Ask, *"What are the most important things that make a planet habitable?"*** [First, make sure the students recall what *habitable* means. The most important factor is presence of liquid water. This, in turn, is determined by temperature and presence of some, but not too much atmosphere. Atmosphere, is in turn, affected by the size, and hence gravity, of the planet.]

8. **Have the students work in discussion groups to further analyze the comparative characteristics of planets** in their charts of “What Makes a Planet Habitable?” In particular, they could discuss questions such as
   - Why do some planets have a wide temperature range and others have narrow temperature range?
   - Are there other factors, not on the chart, that could affect a planet’s temperature or what kind of atmposphere it might have?
   - Could there be a moon of a planet that is suitable for life? If not, explain why not and if so, how might those conditions occur?
9. **Ask, “What does it mean to say that finding a habitable planet is sort of like the story of Goldilocks?”** [SIZE and TEMPERATURE of the planet are keys to their habitability. If a planet is too cold it can’t support life. If it’s too hot, it can’t support life. If it has *just the right temperatur*e (as Goldilocks would say) to have liquid water, then there can be life. Likewise, if a planet is to small, it doesn’t have enough gravity to hold an atmosphere. If it’s too large, it holds too much atmosphere. If it’s *just the right size* (as Goldilocks would say), it can have the perfect atmosphere for life.]
10. **NASA missions.** Conclude by explaining that a series of NASA missions are planned to search for planets around other stars (extrasolar planets). In particular, the first one is the NASA *Kepler* mission that will be able to detect planets down to Earth size or smaller. *Kepler* will be able to determine the size of a planet as well as it’s distance from its star, and hence give us an idea of possible planet temperature.

What To Discuss:

Students can visit to the Kepler website to find more about the *Kepler* mission, e.g. ***How does Kepler find planets? How small a planet can Kepler detect? When will the Kepler spacecraft be launched?*** Kepler website: http://kepler.nasa.gov
For a follow-up activity on how *Kepler* works, see the *Detecting Planet Transits* on the *Kepler* website.

Match Game

I. What's essential for life?

1. Deprived of this, you would die within a few minutes.	A. Food
2. Deprived of this, you would die within a few days	B. Air
3. Deprived of this, you would die within a few weeks.	C. Water

---

II. Planet Atmospheres

4. Planets that have a thick layer of atmosphere.	D. Earth, Venus, and Mars
5. Planets that have no atmosphere.	E. Mercury, Pluto, and the Moon
6. Planets that have a thin layer of atmosphere	F. Jupiter, Saturn, and Neptune

---

III. Planet Sizes

7. Medium-size planets (*1/2 to twice the diameter of Earth*)	G. Jupiter, Saturn, and Neptune
8. Giant planets (*over 3 times the diameter of Earth*)	H. Mercury, Pluto, and the Moon
9. Small bodies (*less than 1/3 the size of Earth*)	I. Earth, Venus, and Mars

---

IV. Temperature

10. Percent of our bodies that is water.	J. 464 to 470
11. Temperature range of liquid water. (*in degrees Celsius at sea level on Earth*)	K. -133 to 27
12. Temperature range of Venus (*in degrees Celsius*)	L. 50 to 70
13. Temperature range of Mercury (*in degrees Celsius*)	M. -163 to 427

14. Temperature range of Mars (*in degrees Celsius*) N. 0 to 100

What Makes a Planet Habitable?

	Mercury	*Venus*	*Earth*	*Moon*	*Mars*	*Jupiter*	*Saturn*	*Neptune*	*Pluto*
Size									
Big									
Medium									
Small									
Atmosphere									
Thick									
Thin									
None									
Temperature									
Hot									
Medium									
Cold									
Distance from Sun	0.39 AU	0.72 AU	1.0 AU	1.0 AU	1.5 AU	5.2 AU	9.5 AU	30 AU	39 AU

What Makes a Planet Habitable?

	Mercury	*Venus*	*Earth*	*Moon*	*Mars*	*Jupiter*	*Saturn*	*Neptune*	*Pluto*
Size									
Big									
Medium									
Small									
Atmosphere									
Thick									
Thin									
None									
Temperature									
Hot									
Medium									
Cold									
Distance from Sun	0.39 AU	0.72 AU	1.0 AU	1.0 AU	1.5 AU	5.2 AU	9.5 AU	30 AU	39 AU

Vocabulary List

Absorption lines	Indicators of an atom's change in energy state. They are visible as dark lines in a spectrograph, and each line is like the unique fingerprint of a particular element within the object being observed.
Accretion	The process of accumulating dust and gas, usually through collision, into larger objects within a protoplanetary disk.
Astronomical Unit (AU)	A unit of measurement for distances in space. This unit is based on the distance from the Earth to the Sun, which is equal to 1 AU. 1 AU = 92,955,807 miles.
Blueshift	The shortening of the wavelength of light coming from an object. Detection of this shortening, often by the shift of expected wavelengths toward the blue end of the spectrum of visible light, can indicate a star orbiting toward the observer. This is useful in the "wobble" method of exoplanet detection.
Candidate exoplanet	This type of planet has been detected to exhibit the characteristics of a transiting exoplanet but has not been confirmed by ground-based observations.
Confirmed exoplanet	This type of planet has been detected to exhibit the characteristics of a transiting exoplanet and has been confirmed by ground-based observations.
Coronograph	A disc-shaped telescope attachment designed to block out the light of a star. This attachment could be useful for directly imaging planets.
Dwarf planet	An object that (a) orbits the Sun and (b) has sufficient mass to assume a nearly round shape, but (c) may orbit in a zone that has other objects in it. There are currently five accepted dwarf planets: Ceres, Pluto, Eris, Makemake, and Haumea.
Exoplanet	A planet found orbiting a star outside our solar system. In some cases, more than one exoplanet is discovered orbiting the same star, making it part of a multiple planetary system.
Galaxy	A large system of stars held together by mutual gravitation and isolated from similar systems by vast regions of space
Habitable zone	The distances within which a planet must orbit its star to support liquid water (neither too close/hot nor too far/cold).
Hot Jupiter	Exoplanets that are roughly the same mass as Jupiter (or larger), but which orbit extremely close to their star.
Ice line	The distance from a star beyond which temperatures are low enough to allow water to freeze into ice.
Interferometry	A technique used to directly image exoplanets that involves applying destructive interference to star light in order to effectively cancel it out.
Light year	The distance that light can travel in a vacuum in one Earth year (equivalent to approximately 6 trillion miles). This unit can be used to measure both distance and time.
Nebula	An interstellar cloud of dust and gas (predominantly hydrogen and helium) from which stars and planets are often formed.

Orbital period	The time it takes an object to complete a full orbit of another object.
Planet	A celestial body that (a) orbits a star, (b) has sufficient mass to assume a nearly round shape, and (c) has cleared the neighborhood around its orbit, which means it is free of other large objects because the forming planet has accreted most of the nearby available material.
Planetesimals	Celestial bodies formed by accretion within a protoplanetary disk. These are the beginnings of larger bodies like asteroids, moons, or planets.
Protostar	A large mass in a nebula that represents the early stages of star formation. It is still accreting matter from the nebula because it has not yet initiated nuclear fusion.
Pulsar	Rotating neutron stars that emit pulses of electromagnetic radiation.
Redshift	The lengthening of the wavelength of light coming from an object. Detection of this lengthening, often by the shift of expected wavelengths toward the red end of the spectrum of visible light, can indicate a star orbiting away from the observer. This is useful in the "wobble" method of exoplanet detection.
Solar system	A collection of objects, such as planets, dwarf planets, moons, asteroids, and comets that orbit a star. "Solar system" also refers to our own planetary system, orbiting the Sun.
Spectrum	The whole range of electromagnetic radiation with respect to its wavelength or frequency
Super-Earth	An exoplanet that is 2 – 10 times the mass of Earth. This term only applies to mass and is not meant to imply any similarity to other Earth-like characteristics, such as temperature or habitability. In fact, many Super-Earths are too close to their stars and, thus, too hot to support life.
Transit	The observed passage of an exoplanet in front of its parent star, viewed as a dip in the amount of light normally emitted by a star.

Some good books to use with *Undiscovered Worlds*

Stars and Atoms: From the Big Bang to the Solar System

Stuart Clark. Oxford University Press, 1995.

The concepts and ideas of modern astronomy and cosmology are presented in this clearly worded book, which is supplemented with illustrations, charts, and tables. Read and learn about the universe and its fate, the big bang, galaxies and quasars, stars, and planets.

A Universe From Nothing: Why There Is Something Rather Than Nothing

Lawrence M. Krauss. Oxford University Press, 1995.

Bestselling author and acclaimed physicist Lawrence Krauss offers a paradigm-shifting view of how everything that exists came to be in the first place. "Where did the universe come from? What was there before it? What will the future bring? And finally, why is there something rather than nothing?"

The Story of Astronomy

Lloyd Motz and Jefferson Hane Weaver. Plenum Press, 1995.

Trace the evolution of the great astronomical ideas from their birth as pure speculations in the minds of the great ancient Greek astronomers to the reality of present-day astronomy. Read about Kepler, Tycho Brahe, Galileo, Newton, Gauss, and Einstein, and the relationship between astronomy and physics.

Life's Matrix: A Biography of Water.

Ball, Phillip. New York: Farrar, Straus and Giroux, 1999.

Tells of the possible origins of water— its history, pervasiveness and potential presence on other planets.

Asteroids, Comets, and Meteors

Marsh, Carole. New York: Twenty-First Century Books, 1996.

Compares asteroids, comets, and meteors and provides a range of general information on the solar system, the galaxy, and the universe.

Some good web sites to use with *Undiscovered Worlds*

kepler.nasa.gov/education/

Classroom Activities on Planet Finding and other resources from the NASA Ames Research Center, that will synch with the NASA Kepler Mission.

kepler.nasa.gov/education/resources/WebLinksForEducators/

Educator Web Links, including a Desktop widget, an Extrasolar Planets Encyclopedia, and a free i-phone app called "Exoplanets".

hubblesite.org/hubble_discoveries/discovering_planets_beyond/

Provides videos and information on planet formation and planet hunting strategies

planetquest.jpl.nasa.gov

Created by Students for the Exploration and Development of Space (SEDS) at University of Arizona.

Lessons From The World Wide Web

Also, a wide variety of lesson plans and activities can be found on the World Wide Web. These sites are dedicated to lesson planning in a variety of subjects.

multiverse.ssl.berkeley.edu/Learning-Resources

The Center for Science Education at U. C. Berkeley Space Science Laboratory Learning Resources page.

btc.montana.edu/ceres/html/Wobble/Wobbles.htm

A Case of the Wobbles: Finding Extra-Solar Planets

spaceplace.jpl.nasa.gov/spacepl.htm

This California Institute of Technology and NASA Jet Propulsion Laboratory site for kids offers information and activities.

www.pbslearningmedia.org/

PBS Digital Media for the Classroom and Professional Development - an online library of more than 1,000 free media resources from the best in public television.

Astronomy Web Sites Worth a Visit

Astro.UMaine.edu

The Emera Astronomy Center and the Maynard F. Jordan Planetarium and Observatory home page.

jpl.nasa.gov

NASA's Jet Propulsion Laboratory web site.

www.jpl.nasa.gov/education

Jet Propulsion Laboratory education page, with resources for educators and students.

www.dustbunny.com/afk

A web site about astronomy, designed for kids, with tons of information

www.nss.org/

The National Space Society webpage

stardate.org

Learn what's going on TODAY in astronomy on the "Star Date" web page, maintained by the University of Texas' McDonald Observatory.

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Emera Astronomy Center

The Maynard F. Jordan Planetarium does not guarantee that the information given on the above web sites to be accurate, accessible, or appropriate for students.

Additional Activities

Kepler Star Wheel

Using Star Maps

Solar Motion Demo

Detecting Extrasolar Planets