National Aeronautics and Space Administration

Afterschool Universe

A Step-by-Step Recipe Book
For Bringing the Universe Down to Earth

Educational Product	
Educators & Students	Grades 6-8

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A Step-by-Step Recipe Book
For Bringing the Universe Down to Earth

Revised: January 2012

Produced by the Afterschool Universe Team
Astrophysics Science Division, NASA Goddard Space Flight Center

http://universe.nasa.gov/afterschool/

Introduction

Afterschool Universe is an out-of-school-time astronomy program for middle school students that introduces them to the Universe beyond the Solar System.

It's a fascinating Universe out there — exploding stars! Colliding galaxies! Middle school students are intrigued by these topics — but don't have a chance to explore their interest since the middle school curriculum does not typically address these topics. *Afterschool Universe* (AU) was developed to fill this niche as the middle school years are a critical time in the development of attitudes about science and career options, especially in girls. By offering astronomy programming in out-of-school-time, where schedules are less constrained, we hope to engage students in science that already interests them and retain/sustain their engagement in science.

AU explores basic astronomy concepts through engaging hands-on activities and then takes participants on a journey through the Universe beyond the Solar System. The goal of this program is to excite students about astronomy (and science in general) and have a positive effect on the attitudes of both the program leaders and the participants towards science.

AU was piloted under the name *Beyond Einstein Explorers' Program* (BEEP) in summer programs during 2006 and 2007. The 2007 program was formally evaluated by *Magnolia Consulting, LLC* and received overwhelmingly positive feedback from students and leaders alike — the students enjoyed the informal, hands-on style of the program, and leaders found their own understanding and enjoyment of astronomy enhanced by their participation. The program was widely released in 2008.

Afterschool Universe was developed by the Astrophysics Science Division at the NASA Goddard Space Flight Center. The *Afterschool Universe* team consists of Dr. Anita Krishnamurthi, Ms. Sarah Eyermann, Ms. Sara Mitchell, Dr. James Lochner, Mr. George Gliba, and Ms. Pat Tyler. The points of contact are the project coordinator, Ms. Sarah Eyermann (Sarah.E.Eyermann@nasa.gov; 301-286-7412), and the project lead, Dr. Anita Krishnamurthi (akrishnamurthi@afterschoolalliance.org).

Our website (http://universe.nasa.gov/afterschool/) contains a variety of resources to help you implement this program. The latest version of this manual is available for download, along with separate files containing individual handouts and worksheets, and evaluation forms that you may choose to use. We also offer additional information and resources for running the program, including materials information, background presentations, and videos of several of the activities from the program (noted in their respective sessions in this manual). In addition, we've built a community of individuals who are running *Afterschool Universe*, so you can get in touch with others and share your experiences, questions, and ideas.

We hope that you and your students have fun bringing the Universe down to Earth!

Acknowledgements

Afterschool Universe gratefully acknowledges support from NASA's *Beyond Einstein* program (now recast as *The Physics of the Cosmos* program) and NASA's High Energy Astrophysics Science Archive Research Center (HEASARC). We also gratefully acknowledge funding from the Chandra EPO small grants program under grant TN78009X awarded to Dr. Christopher Reynolds at the University of Maryland in 2007-2008. The most recent phase of this program is funded by a NASA EPOESS grant NNX10AV22G.

We are deeply grateful to Mr. Peter Guttmacher, Director of Programming and Curricula Development at CYITC (DC Children & Youth Investment Trust Corporation), for his enthusiasm and support that allowed this program to be developed and pilot-tested in 2006 and 2007. We are also thankful to Dr. Irene Porro at the MIT Kavli Institute for Astrophysics and Space Research for discussions and support that led to the initial development of this program. Our thanks also go to Ms. Beth Barbier for her help during the initial development of the program.

NASA has developed a vast array of excellent astronomy education curriculum support materials over the years. Many of them have been targeted at classrooms or were developed as web-based modules. We have drawn from these and other well-tested existing resources and adapted them to be more appropriate for an out-of-school program environment. We acknowledge the use of materials and resources from the following sources:

- Universe Education Forum at the Center for Astrophysics at Harvard-Smithsonian
- HEASARC's *Imagine the Universe!* education program
- Chandra X-ray Observatory's education program
- Office of Public Outreach at the Space Telescope Science Institute
- The Astronomical Society of the Pacific's "Project Astro" program
- The education program for SOFIA (Stratospheric Observatory for Infrared Astronomy)
- "The Invisible Universe" developed by the Lawrence Hall of Science with support from NASA's Swift mission
- "Make your own Milky Way Model" from the Subaru telescope
- "High Energy Groove Cosmic Quilt" from the RXTE EPO program

Related Resources

- ***Big Explosions and Strong Gravity***
  This day-long event allows Girl Scouts in grades 5-8 to meet real scientists and join them for a day of hands-on exploration into supernovae and black holes. This site includes activity curricula and resources for facilitating the program.
  http://bigexplosions.gsfc.nasa.gov/

- ***NASA Family Science Night***
  This program encourages middle school students and their families to work together to explore the universe around them and science in everyday life. A robust curriculum and evaluation tools are available to implement these two-hour sessions in your community.
  http://sdo.gsfc.nasa.gov/epo/families/fsn.php

- ***Imagine the Universe*! Teacher's Corner**
  This site features educational content for grades 7 and up, including extensive resources for classroom educators. Learn about the universe and how we study it through downloadable lesson plans, posters, presentations, and more.
  http://imagine.gsfc.nasa.gov/docs/teachers/

- ***Starchild* Teachers' Center**
  This website features educational resources for grades K-8, which introduce the solar system, universe, and space exploration. It includes activities, movies, and puzzles for studends, as well as teacher information and activity booklets about the life cycle of stars, black holes, and gamma-ray bursts.
  http://starchild.gsfc.nasa.gov/docs/StarChild/teachers/teachers.html

Table of Contents

Running the Program

This manual is intended for leaders of out-of-school-time programs to implement *Afterschool Universe*. We have organized the sessions in a sequence such that each session builds upon the previous one. A student attending all sessions will get the maximum benefit. However, it is not absolutely necessary for students to have participated in the preceding session(s) to be able to participate in sessions that follow. Furthermore, this manual is intentionally written so that no extensive preliminary science knowledge is necessary for the program leader.

Afterschool Universe currently consists of 12 sessions. Most activities are very hands-on, and the program is very interdisciplinary. We use many techniques, including art, kinesthetic activities, and writing, in order to reach different types of learners. All the activities are based in the real world, with no need for computers or an internet connection. This is done so that the program can be run in many diverse settings. For those who have access to the internet, many sessions have suggested extension activities.

Each session is about 45–60 minutes long. Times listed for the activities are for estimation purposes and may be adjusted as needed. Outside of these basic guidelines, the program is very flexible in how you implement it. You can run the entire program over two days, once a week for 12 weeks, or in whatever way best suits your schedule.

We always appreciate receiving your feedback on how this program worked for you and suggestions for how we can improve it. We ask program leaders to use the evaluation instruments we provide you to give us your feedback and assess the impact of the program on your students. This will not only enable us to refine and revise the program in response to your needs, but also provide us the data needed to ensure continued funding and survival of the program.

There is also evaluation built into the program itself. The first session, *Modelling the Universe*, is repeated as the last session in the program to check on how participants' perception of the Universe they live in has changed as a result of this program. The eleventh session includes an activity called *Building a Cosmic Quilt*, which also provides a way for you to see what they have learned through the course of the program.

If you would like, you can also have your students maintain a notebook throughout the program, or have a large piece of paper on the wall of your classroom or meeting space (sometimes referred to as a parking lot for questions). The students can use either of these to write down one thing they enjoyed or learned about each session. This accumulates through the program in a way that both you and they can always go back to and read.

Session 1 – Modelling the Universe

General Description

Students are challenged to create a model of the Universe. This is an introductory activity that helps students think about where we fit in the Universe, and allows them to model the size, shape, and relative position of objects in the Universe. The activity has three major steps: discussion, modelling, and sharing models with the group. Students can work in groups of 3 or 4. This activity can also be done in pairs if the overall group is small.

Objectives

- To draw out the students' mental model of the structure of the Universe.
- To use the context of space science exploration of the structure of the Universe to help students reflect on the nature of models, evidence, and explanation in science.

Concepts Addressed

- Strengths and weaknesses of models
- Astronomical size and scale
- Earth's physical place in the solar system and Universe

Materials

- Copy of *Universe Model Analysis Student Worksheet* for each group of students (included in Appendix E)
- Examples of models (toy car, doll or action figure, paper airplane, map, etc.)
- A variety of crayons/colored pencils/markers
- 8.5″ × 11″ white paper — one sheet per student
- Model construction supplies — anything you have available that seems appropriate (some examples: construction paper, balloons, balls of different sizes, popsicle sticks, marbles, string, straws, toothpicks, pipe cleaners, pasta, beans)
- Large sheet of sturdy paper on which students create their models — one per group
- Scissors, glue, and tape
- (Optional) Clay or Play-Doh

Other Requirements

- Enough table or floor space for several groups of students to work together on their models

Background

A model is a simplified imitation of something that is used to better understand or work with it. Models can take different forms, including physical devices or sculpture, drawings or plans, conceptual analogies, mathematical equations, and computer simulations.

Models serve many different purposes in astronomy and other fields. A model can make something large more portable and accessible, such as representing the Earth with a tabletop globe. Models can also make something small easier to see and manipulate, such as a model of a tiny cell or DNA. And some models are the same size as the original object, used for testing or display purposes.

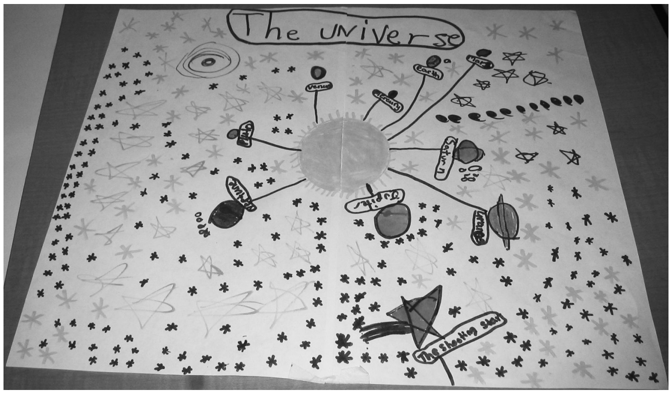
Models can be "to scale," which means that they accurately represent the proportions of an actual object. The scale model can be smaller, larger, or the same size as the original object, but the proportions must be accurate. Some models are not to scale, and do not accurately reflect the actual proportions of the original. These models can be useful when it is difficult to create a scale model, or an accurate scale model is not needed.

Session Overview

As a warm-up, students make a quick model (drawing) of something in their lives. This introduces the concept of modelling.

Students then make physical models to represent as much of the Universe as they can. They then analyze their own and others' models with regard to what they represent, what they misrepresent, what they omit, and what questions they raise.

While the idea of creating a physical model of the entire Universe can seem overwhelming, this activity quickly reveals students' ideas and preconceptions. Most students are somewhat familiar with solar system objects but may be confused about, for example, the relationship of stars to planets and the relative distances between them. The overall organization and structure of the Universe is not well known to most.



An example of a student group's model, depicting a variety of objects, and showing stars mixed in throughout the solar system.

Students should not be corrected in any way during this session, as this is intended to determine the current state of their understanding for later evaluation.

Preparation

- Make copies of the *Universe Model Analysis Student Worksheet* for each group
- Set out all listed materials equally among the groups

Activity

I. Warm-up (10 minutes)

A toy airplane, one example of a model for participants to consider.

Instruct students to individually make a quick model of something in their lives, using the white paper and crayons/colored pencils/markers available. Allow about five minutes for students to complete these drawings. Alternatively, if you think clay or Play-Doh will make this task clearer to the students, you might consider providing those materials instead of the two-dimensional paper. Students may be more comfortable with the idea of models in three-dimensions.

Ask students to identify some models in their lives, such as toy cars, dolls and action figures, models made for school assignments, model airplanes, maps, etc. It is helpful to have a couple of these examples to show during this discussion. Introduce the idea of scale – models that accurately reflect the proportions of the original object. Are the models you have discussed to scale or not to scale? Why is scale important? When does and doesn't it matter to a model? If you have sufficient example models to put one on each table, you can use these as a good starting point for this discussion.

Ask a few students to share their warm-up drawings. Are these models to scale or not to scale? Tell students to keep these ideas about models and scale in mind during the next activity.

II. Discussion (10 minutes)

Facilitate a group discussion of what models are and what they are used for. Discuss how scientists use models to help them think about how things work, and to make predictions. Ask students to name some familiar models (e.g., globe, dollhouse) and lead a discussion on whether these models are exactly like the real thing. Stress that a model is not the real thing, it is usually a simplified or modified version so it can possibly misrepresent features of the real thing. Make sure they understand that models can be two-dimensional as well as three-dimensional.

Lead an open discussion about what is **in** the Universe, and what the Universe **is**. You should leave this discussion fairly short, because their project should reflect their own introductory ideas. The models around the room may end up quite different, and this is entirely acceptable. The more of a discussion you have with the students beforehand, the more likely their models will reflect this discussion rather than their own concepts.

III. Modelling (20 minutes)

(Adapted with permission from the Cosmic Questions Educator's Guide)

1. Divide students into small groups. Groups should decide among themselves who will fill the roles of Recorder of Model Features, and Spokesperson. Students may have more than one role, but all three must be filled.

2. Ask the students to write their names on both the model they create and their worksheet.

3. With the materials in front of them, challenge students to create a model of the Universe in 20 minutes.

   Tell students they should have an explanation as to why they put objects where they do, regardless of the fact that ***they are not required or expected to have all of the scientifically correct answers!***

4. It is important to go around and help with the group dynamics in this activity. All members of the groups should be contributing ideas instead of letting one member give all of the "answers." ***Remember, students should not be corrected in any way during this session, as this is intended to determine the current state of their understanding for later evaluation.***

5. As they work, the Recorder in each group should use the Universe Model Analysis Student Worksheet to list information about the features of their model, and any questions or other thoughts that arise on this topic.

Participants hard at work on their models of the Universe.

IV. Sharing models with the group (15-20 minutes)

Now, ask the spokesperson in each group to present their model. As they do so, ask them to comment on these four questions:

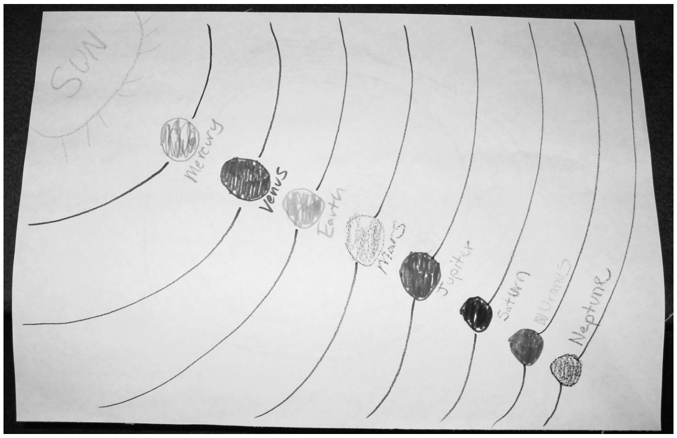
- What features of the Universe does your model represent?

- What things — that you know of — does your model misrepresent?
- What things — that you know of — does your model omit, or not represent at all?
- What questions came up as your group worked on your model?

Use the following questions with the whole group to further probe students' understanding of their models:

- Do you see any patterns?
- Which parts of the models do you think represent the "real thing" particularly well? Why?
- Which parts of the models do you think misrepresented the "real thing"?
- Are these models to scale or not to scale? Why?
- Why is making a model of the whole Universe so difficult?
- How can these models be used to predict what might happen in the Universe?
- What would an observer on Earth see if they lived in this Universe? (Where is Earth in your model?)
- What would you need to know to design a better model?

At the end of the activity, ***collect and save the models (or take a digital photo of them)***. They will be used in concert with the final session to evaluate student progress. You can even tell the students that they will be repeating this activity at the end of the program, and will be able to see how their ideas have changed over time.



A typical model of the Universe, depicting only the Solar System.

Suggestions for Running this Session

- Modelling the entire Universe may seem like a daunting task, but remember, there is no right or wrong answer. The purpose of this activity is to see what their current views are and to get them started thinking about the topic.

- Everyone needs to contribute in this activity. Depending on your group, you may need to work to facilitate this, because sometimes it can be very easy for one or two group members to take over for everybody. If this is a problem with your group, you might consider having the groups go around in a circle and have each member say one idea in turn, or directly ask other members of that group what they'd like to contribute. Balanced group dynamics can be especially difficult if this is the first time these students have worked together.

- Allow students to take over as much of the discussions as possible, trying not to lead or discourage them in any way except to ensure that all members of the groups are participating.

- The materials provided for this activity often have an impact on the models made by students. If you give the group 9 or 10 round objects, they will likely immediately think of planets and possibly not think any further. Keep this in mind as you choose your materials. For consistency, provide the same materials in Session 1 and the repeated modelling activity in Session 12.

- There are many different possible craft supplies that can be used for this activity. Some of the ones we have used in the past include:
  - construction paper
  - chenille stems
  - colorful straws
  - pom poms
  - glitter (not recommended unless you want glitter everywhere for months to come)
  - feathers (almost as bad as glitter!)
  - balloons
  - rubber bands
  - macaroni
  - dried beans

  If you choose to provide food for use in the models, consider how long you'll be keeping the model around. We like to compare the models from Session 1 with the models from Session 12, but some food materials will decay or attract pests if you keep the models around.

- Sometimes participants will want to incorporate other objects into their models (their own possessions, or other materials available in the room). It is up to you whether you permit this, and again, consider how long you'll be keeping that model. It is inconvenient if your tape measures or crayons are taped to a model when you want to use them for other activities!

- To engage students in discussion as models are presented, consider taking them on a "gallery walk" to see other groups' models. All students can gather around each model to see it as its creators explain it.

- If you feel your students need it, you may have them brainstorm a list of objects in the Universe that can be viewed with a telescope, and write these objects on a blackboard or flip chart. Ask what they know about each one as they are offered. Remember that doing this will probably ensure that each group will try to put all objects on the list into their model, regardless of whether they would have thought of this on their own or not.

Useful websites for background or activity extension

- **NASA's Universe Education Forum**
  Answers to questions about the structure and evolution of the Universe are available at this site.
  http://www.cfa.harvard.edu/seuforum/questions/
  - Extensive learning resources for investigations of the Universe
    http://www.cfa.harvard.edu/seuforum/learningresources.htm
  - *Cosmic Questions Educator's Guide*
    http://www.cfa.harvard.edu/seuforum/download/CQEdGuide.pdf
- ***Cosmic Distance Scale***
  This feature gives a feeling for how immense our Universe is, starting with an image of the Earth and then zooming out to the furthest visible reaches of our Universe — as in the "Power of 10" films.
  http://heasarc.gsfc.nasa.gov/docs/cosmic/
- ***Bad Astronomy* — Astronomy misconceptions explained**
  A great site to deal with questions about the accuracy of "science" encountered in the movies, news, books, or TV. In addition to science explanations at an easy-to-read level, topics are presented in a fun way. The site contains a blog and a bulletin board for questions.
  http://www.badastronomy.com/

Session 2 – Cosmic Survey

General Description

Questions on how big, how far, and how old objects in the Universe are might launch students into discussions about where in space the objects are located and when they formed. Students work in teams to physically manipulate paper images of objects in space, allowing them to develop and present their own mental models to address these questions. Students can work in groups of 3 or 4. This activity can also be done in pairs if the overall group is small.

Objectives

- To explore the idea of sorting and categorization in general.
- To explore multiple means of sorting and organizing objects in the Universe.
- To improve students' understanding of the size, structure, and evolution of the Universe.

Concepts Addressed

- Objects found in the Universe
- Size and distance in the Universe
- Structure and evolution of the Universe

Materials

- One set of Cosmic Survey Cards per team (included in Appendix F)
- Scissors
- Access to a laminator (if available) or sturdy paper and glue to mount the images
- One set of three *Cosmic Survey Student Worksheets* per team (included in Appendix E)

Other Requirements

- Enough table or desk space for students to work in small groups

Background

Astronomers believe our Universe began with a Big Bang that occurred over 13 billion years ago, but no one yet knows the true size of the Universe. Our view is limited not by a physical edge to space, but by how far light has travelled since the Universe began (a concept that will be addressed in the next session).

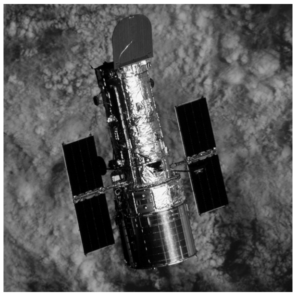
Many people are familiar with the names of objects in space, but most have an incomplete mental model of their relative sizes, distances, and ages, as well as how they fit into the structure of the

Universe as a whole. These concepts are tricky, so patience is required. In our everyday experience, the stars all *seem* the same distance away, and the Moon can *appear* closer or farther away, depending on whether you observe it near the horizon or higher in the sky. Most people's knowledge of dim and distant objects, such as nebulae and galaxies, comes from images that are all about the same size and have no indication of scale.

Here is a brief description of the objects pictured in all nine of the Cosmic Survey cards:

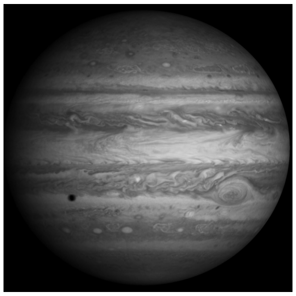
New York City is a city of over 8 million people in the Eastern United States.

The pyramids were built by the people of ancient Egypt to entomb their emperors.

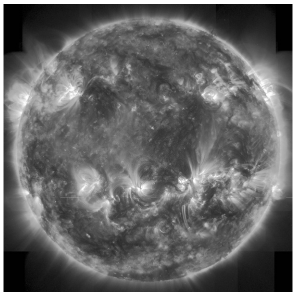


The Hubble telescope is a satellite we have put in space to take images of distant objects.

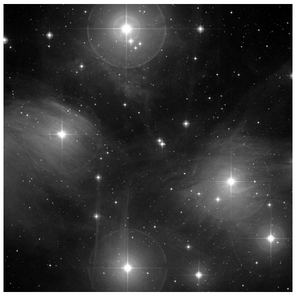
The Moon is a body that orbits the Earth. This object can be clearly seen in the night sky.



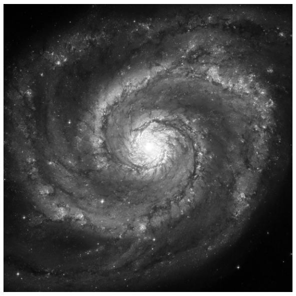
Jupiter is the largest of the planets in our solar system. Depending on the time of year, Jupiter appears as a bright object in the sky.



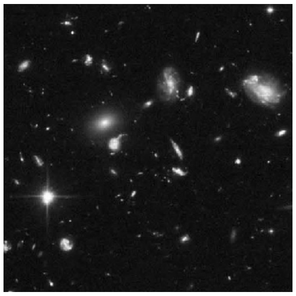
The Sun is the star in our solar system, around which the Earth, Jupiter, and all the other planets orbit.



The Pleiades stars are a star cluster, a grouping of several stars loosely bound together by gravity. It is easily visible to the naked eye in the constellation of Taurus.



Galaxies are large collections of stars held together by gravity. Most galaxies are brighter in the middle because more stars are concentrated there. The Whirlpool Galaxy is the name of a specific galaxy, not a type of galaxy.



The Hubble Galaxies are from the Hubble Ultra Deep Field, an image captured by the Hubble Space Telescope, which took a long exposure of an apparently empty patch of sky. The picture that came back, instead of being empty, contained countless galaxies. This card shows a small portion of that picture.

Session Overview

The session begins with a group discussion of students' ideas and knowledge of objects in the Universe. Working in teams, students then manipulate paper images of objects in space to arrange them in order from smallest to largest, nearest to farthest, and youngest to oldest. In the process, they must consider why they make the decisions they do. The class reassembles to share and discuss results.

Preparation

- Cut cards apart and laminate them if possible — printer paper is too thin for this activity. If you don't have access to a laminator, glue the images to heavy paper to reinforce them.
- Group the cards in sets of 9 for distribution.

- Make 1 copy of the set of student worksheets for each student.
- If you have a transparency projector, make a transparency copy of the sheet with the 9 cards so that you can put it up and discuss it with the full class. Or you can try to make a larger copy of the sheet so that you can hold it up for the whole group to see.
- Make sure that you know what the objects on all of the cards are so that you may describe them and answer questions about them with your students.

Activity

I. Discussion (10 minutes)

Students start by becoming familiar with the concept of categorizing objects according to different characteristics. You can start this discussion by asking students to categorize themselves in some way. Ask the students to line up by height or by age. Once they have done this, ask them to come up with some other criteria that they can then sort themselves by. This shows that the same group of objects (in this case, themselves) can be sorted in more than one way. Alternatively, you can use any objects you think the students will be familiar with.

Once students understand how to categorize items, ask them to name some objects in the Universe. Each time they name an object, ask if they know what it is. Ask what kind of information we could possibly learn about objects in the Universe.

Hand out the sets of cards. If you have a transparency projector, put up a transparency with the images of all the objects on their cards. Or hold up the sheet of paper so all can see it. Ask students to identify the objects on each card. If they are not familiar with the objects, explain briefly what they are using the descriptions from the background section of this session.

If you would like to avoid them sorting by size of the picture rather than size of the actual objects, you may explain this ahead of time, or you may choose to leave this open. This activity is not at all about "correct answers," but is entirely about the process, and about having reasons for the choices they make. There are ambiguities when sorting different objects, and it can be helpful for the kids to see this.

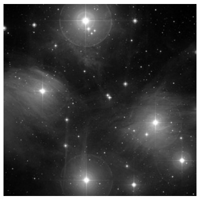
II. Team Activity (20 minutes)

(Adapted with permission from Cosmic Questions Educator's Guide)

1. Form teams of 3 to 4 students. Pairs are also acceptable if your overall group size is small. Hand out the set of *Cosmic Survey Student Worksheets* to each team. Have each team choose a Recorder and a Spokesperson.

2. Explain that each team is to discuss the three survey questions and come to an agreement — *if possible* — on the best order of images for each question. Each Recorder should record any questions that arise during each set of discussions. Have students answer the survey questions in this order, which represents increasing levels of complexity for most people.

   - How Big?
   - How Far?
   - How Old?



For the Pleiades and Hubble galaxies images, students may wonder if we are talking about the sizes of individual stars or galaxies in an image, or the size of the entire group. In each case they are to work with the relative size of the entire group.

3. Circulate through the class, encouraging them to discuss any disagreements fully and to write down arguments in support of their answers.

4. Pause to discuss each question before moving on to the next one.

III. Discussing and Sharing with the group (15-20 minutes)

Lead the entire class in a discussion about each survey question before the kids move on to the next. Play the role of moderator, requiring each group to explain **why** they chose that order. Start with "How Big?" and ask all groups to share their conclusions. Then go on to "How Far?" and "How Old?" **Do not announce the correct order**; students should be encouraged to think for themselves. Ensure that they are comfortable saying, "I don't know." Getting the "right answer" is not as important as the critical thinking skills developed as their mental models of the Universe develop. In this activity, the reasons they are put in a certain order are much more important than the order itself.

Instead of exact numbers, it may instead be useful to introduce some scale factors when considering the relative size of objects. Some examples are that 100 Earths can span the diameter of the Sun, all the planets of the solar system could fit into the Sun, and a galaxy is a "city" of many billions of stars. Provide other analogies that you feel are relevant.

To further facilitate the discussion you can ask some of the following questions:

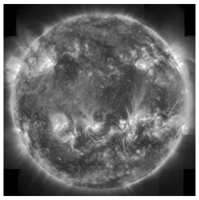
- *What is a planet? What is a star?*
- *What is a galaxy? What is in a galaxy?*
- *Which objects can you see with your naked eye?*

Elicit ideas on what big, far, and old mean on Earth versus in space. Astronomers think about these concepts much differently than we do.

This is a good place to bring in the idea of these images as models, to reinforce session 1.

Question 1: How Big?

In pictures, the objects all look roughly the same size. But the Sun is much larger than Jupiter or any planets — a million Earths would fit inside it. Size counts in nature. Objects that are a bit larger than Saturn or Jupiter will become stars, like our Sun. They collapse under their own weight and grow fiercely hot as their internal fires are kindled — and a star is born! The reason the Moon looks so big is because it is very close to us, relatively speaking.



Question 2: How Far?

Figuring out the relative distances to the Sun and Jupiter requires knowledge about the relative orbits of the planets. And depending on how much astronomy background students have, they may think the Pleiades are inside the Solar System, or that they are the farthest objects in space. Most people have a hard time understanding the relative distances of the objects outside our Solar System.

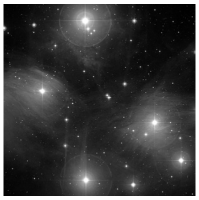
The Hubble Ultra Deep Field image is the most distant view of our Universe, completed in 2004.

Students often struggle with the distance to the Hubble Space Telescope, since it takes images of very distant objects. The telescope itself is actually in orbit around the Earth — high enough for a clear view above the Earth's atmosphere, but low enough for repairs by Space Shuttle astronauts.

Many think the Pleiades star cluster must be further away than the Hubble galaxies, because it looks smaller. But all of the stars we see in the night sky are much closer than even the nearest galaxy. The roughly 5000 stars we can see with our naked eyes (under the darkest conditions) are just the closest of the billions of stars in our own galaxy, the Milky Way Galaxy.

Question 3: How Old?

We tend to think of stars as having been around for a very long time — our Sun is billions of years old. But new stars, like those in the Pleiades, are continually being born. Young stars look blue. The Pleiades stars are "only" about 80 million years old.



In this activity, it is very valid to consider the Moon, Jupiter, and the Sun all the same age. This is because the Solar System formed at basically the same time. Multiple theories exist as to the exact order of formation, but when we are looking at times in terms of billions of years, these differences are negligible.

Which is older, the Sun or the Hubble galaxies? It depends on what you mean by "age." Although the Hubble "deep field" galaxies images were taken in recent years, they are among the most ancient and distant objects in the sky. The light from them has taken over 10 billion years to reach us, so they were born long before our Sun. (This point is raised again in Session 3.)

On the other hand, *as they appear in these images*, the Hubble galaxies are actually young galaxies! Because of light's travel time, we see them as they were when they formed 10 billion years ago, only a few billion years after the Big Bang. Many of the stars in the galaxies in this image may have been younger than our Sun when the light first left them, so we are looking at the "baby pictures" of objects that are now really quite old.

After the group discussion on all three questions, if you would like to let participants know the correct answers and observations of astronomers, you may do so. We do not consider this to be important for this activity, but the class will likely want to know, so we leave the choice up to you. If you are particularly interested in the numbers, we have done the legwork for you. You can find them in the resources section of our website.

Suggestions for Running this Session

- This activity is not about knowing the actual numbers involved for sizes, distances, and ages. We encourage you to go through the session without any such numbers, and not to give in to demands for "the answers." A lot of the numbers in this activity (especially when you're talking about distances or ages) are very large. Most people don't have a deep understanding of the difference between a million, a billion, and a trillion. They're all "big" numbers with a lot of zeroes at the end, and the differences between them aren't very meaningful. It is more important to understand the relationship between objects (e.g., "the Whirlpool Galaxy is closer to us than the Hubble Galaxies") instead of specific numbers. These relations are more likely to be retained than the numbers themselves. It may also be useful to introduce some scale factors when considering the relative size of objects. Some examples are that 100 Earths can span the diameter of the Sun, all the planets of the solar system could fit into the Sun, and a galaxy is a "city" of many billions of stars. Provide other analogies that you feel are relevant. If you feel that it is important to share the correct answers and observations of astronomers with your group, you may do so after the group discussion on all three questions. You can find this information through internet searches, or compiled together in the resources section of our website

- One of the hardest things about running this session is to answer student questions about objects, and avoid giving away information that answer the questions posed in the activity. This is particularly difficult with the Hubble Deep Field image, as most explanations mention how far away or how old the galaxies are. The descriptions of the different objects as given in the background section can be one possible way to describe each of the cards.

- There are other ways that participants may think of the questions "How big? How far? How old?" besides the literal answers, and these alternate modes of thinking may affect their ordering of the objects. For example, "How big?" could also mean the size of the image in the picture itself (how much of the frame it fills), or the apparent size from the perspective of the viewer. "How far?" will be dependent on the location of the viewer, so if a participant chooses to begin their sort from the Pleiades instead of Earth, it will affect the order of the objects. And "How old?" can also be very interesting - it could be based on the time of the object's discovery, the time the image was captured or created, or even the time of the participant's own discovery of the object! When you have participants share the order of their cards, make sure they explain the basis of their sorting, because this can lead to confusion or the idea that this is "wrong" when it is simply another way of thinking about the objects at hand.

- For the Pleiades and Hubble galaxies images, students may wonder if we are talking about the sizes of individual stars or galaxies in an image, or the size of the entire group. In each case they are to work with the relative size of the entire group.
- In this activity, it is very valid to consider the Moon, Jupiter, and the Sun all the same age. This is because the Solar System formed at basically the same time. Multiple theories exist as to the exact order of formation, but when we are looking at times in terms of billions of years, these differences are negligible.

Misconceptions

- Students have the misconception that space telescopes such as Hubble actually go to the objects and return with images. In reality, these telescopes orbit close to the Earth (like telecommunication satellites do) and only gather the light from distant objects. It is impossible to travel the immense distances to the objects in most of the pictures. See the Cosmic Distance Scale at: http://heasarc.gsfc.nasa.gov/docs/cosmic/cosmic.html

- Students often mistake apparent brightness, size or distance of an object in the sky for the actual qualities. But distance has an effect on how large or bright something looks. The same can be said of a car. It looks small when approaching from a mile away, and its headlights look faint at night; when the car gets closer, we can better observe its real size and the actual brightness of the headlights.
- In answering students' questions about objects, carefully avoid giving away information that answer the questions posed in the activity. This is particularly difficult with the Hubble Ultra Deep Field image, as most explanations mention how far away or how old the galaxies are.

Useful websites for background or activity extension

- **NASA's Universe Education Forum**
  Learn about where we are in the Universe while virtually travelling from Earth to the Hubble Deep Field galaxies, and all the stops in between.
  http://www.cfa.harvard.edu/seuforum/opis_tour_earth.htm

- **Cosmic Distance Scale**
  This feature gives a feeling for how immense our Universe is, starting with an image of the Earth and then zooming out to the furthest visible reaches of our Universe — as in the "Power of 10" films.
  http://heasarc.gsfc.nasa.gov/docs/cosmic/

- **Toilet Paper Solar System**
  This activity explores the distances between the planets, using toilet paper as a measuring tape to determine the placement of the planets.
  http://solar.physics.montana.edu/tslater/plunger/tissue.htm

- **Hubble Ultra Deep Field**
  The Hubble Space Telescope took a million-second-long exposure of an apparently blank patch of sky and saw that it wasn't blank at all — but was filled with galaxies!
  http://hubblesite.org/newscenter/archive/releases/2004/07/text/

- **Wilkinson Microwave Anisotropy Probe (WMAP)**
  NASA's WMAP satellite peered back almost to the very beginning of the Universe!
  http://www.nasa.gov/vision/universe/starsgalaxies/wmap_pol.html

- **Cosmic Questions Educator's Guide**
  http://www.cfa.harvard.edu/seuforum/download/CQEdGuide.pdf

Session 3 – The Astronomer's Toolbox: Telescopes

General Description

Working in small groups (perhaps 2 or 3 students per group), students assemble a simple version of one of the astronomer's basic tools: the telescope. They experiment with their own telescopes and investigate their properties. Students then use postcard travel time to model the time it takes for information (traveling in the form of light) to reach us from distant astronomical objects.

Objectives

- To explore the function and principles of a basic refracting telescope.
- To ensure understanding that looking farther out in the Universe means looking back in time.

Concepts Addressed

- Magnification using lenses
- Light travel time

Materials

- 1 telescope kit per student (or for every 2–3 students, depending on availability) *
- Rulers, 1 per telescope kit
- Rubber bands, 1–2 per telescope kit
- White or light-colored tissue paper (like that used in gift wrapping), ½ to 1 sheet per telescope kit, as they tear easily
- At least 1 light source (all students must look at this, so more is nice) — options are:
    - 60-watt light clear bulb (so the filament can be seen) and 1 lamp base (such as a desk lamp without the shade) [OR]
    - Maglite-type flashlights with the upright "candle" setting, clear and no colors
- (Optional) 3″ square piece of paper, 1 per telescope kit
- Postcards and stamps — 1 set per student (*remember that a postcard requires less postage than a letter*)

* *Information about where to purchase this, along with the part number can be found in Appendix C.*

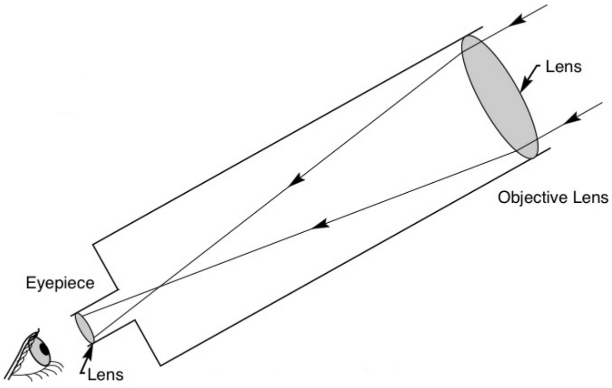
Other Requirements

- A room that can be darkened (by turning off lights and covering windows) with enough table or floor space for groups of students to spread out but work together.

Background

All telescopes are collectors of light. Some telescopes collect and focus light using a lens that light passes through. Such telescopes are called refractors. Other telescopes use a mirror from which light is reflected, and such telescopes are called reflectors. We use telescopes because they can collect much more light than our eyes can. About 400 years ago, Italian Galileo Galilei (1564-1642) was the first to design a telescope good enough to observe stars, planets and moons—and he was among the first to observe them systematically and record what he saw.

The original design Galileo came up with in 1609 is commonly called a Galilean telescope. This type of telescope uses two lenses to produce upright images. The objective, or front lens, of Galileo's telescope was only a few inches in diameter. Because of the shape of that lens, light falling on it is bent, which concentrates the light into a narrow beam. The light emerged through a second lens (eyepiece) and entered Galileo's eye. Because the diameter of the objective lens was much larger than the diameter of the pupil of Galileo's eye, the telescope collected much more light than his eye.



A simple ray tracing diagram of a very basic refracting telescope, much like Kepler's and the ones built by the students in this session.

Galileo's original telescope magnified images by three times—sufficient for those very early astronomical observations. He improved upon his original design, and his best telescope magnified objects by about 30 times. Using his telescope, Galileo observed the phases of Venus, craters on the Moon, four moons orbiting Jupiter, and sunspots on our Sun.

Johannes Kepler improved upon Galileo's design even further by changing around the types of lenses. The telescope he designed is called a Keplerian Telescope. His design allowed for a much wider field of view and greater eye relief, but the image for the viewer was inverted. However, since there is really no up or down in space, this does not pose any great disadvantage to observers.

We will build a basic refracting Keplerian telescope here, as shown in the diagram. This will not be a powerful telescope, but a simple model that students can easily build and use to explore their surroundings. Modern telescopes have bigger lenses and better optics. We can therefore see objects that are much further away.

Light from astronomical objects gives us most of the information we have about them, since we can't go to them. Although light travels very quickly, it is not instantaneous. For example, it takes light 8 minutes to reach us from the Sun, 4 years from the next nearest star, and 13 billion years from the most distant objects. As a result, we can only get information about these objects as they were when they sent out their light, not as they are right now.

Session Overview

After a short introduction from the leader, groups of students assemble a simple telescope, learn to focus light through it, and practice using it. Throughout this activity, the leader provides direction and roams among students — to provide advice for assembly and offer questions that encourage students to think analytically about their own telescope's performance. Students then mail postcards to themselves, to simulate light's travel from distant astronomical objects.

Preparation

- Leaders may want to review this website to learn about telescopes: http://www.amnh.org/education/resources/moveable_astro/telescopes.php
- This activity is much easier for the leader if they have assembled one kit and tried the activities in advance.
- Put appropriate stamps on each of the postcards.
- In order to save time during assembly, leaders may choose to do step number 4 of the telescope assembly in advance (drawing a scale on the smaller tube). This is optional.

Activity

I. Discussion (5-10 minutes)

Ask students if they know what a telescope is. What does it do? A telescope is a tool that we can use to look at the sky. It makes things that are very far away appear closer so that we can study the objects in detail.

The telescope has been around for almost 400 years now. An Italian astronomer named Galileo Galilei is associated with the telescope. Galileo did not invent the telescope, but he was the first to design one that was good enough to observe stars, planets and moons — and he was among the first to make such observations. He built a very simple telescope using a wooden tube and two lenses.

Copy the diagram that is shown in the background section onto the blackboard or whiteboard or a large sheet of paper in the room. This is actually a model of a Keplerian telescope as discussed in the background section. Briefly explain how this simple telescope works.

Tell students they will now build and use a simple refracting telescope.

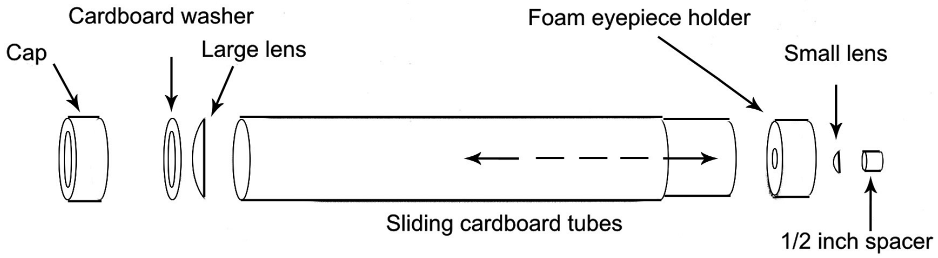
II. Building and using the telescope (~20 minutes)

(Adapted from the Learning Technologies, Inc. (now Science First) Refracting Telescope Kit)

Check our online resources for a video about building this telescope.

Throughout this process, circulate among students to advise them on assembly and give them questions for thought. They will need to take turns with their team members for the experiments after assembly.

1. Students can work alone or in teams of 2 or 3, depending on the number of kits available, and a telescope kit with a diagram of the components is distributed to each team. Students should take every item out of the kit (some pieces may be inside of others) and examine the parts they have been provided.



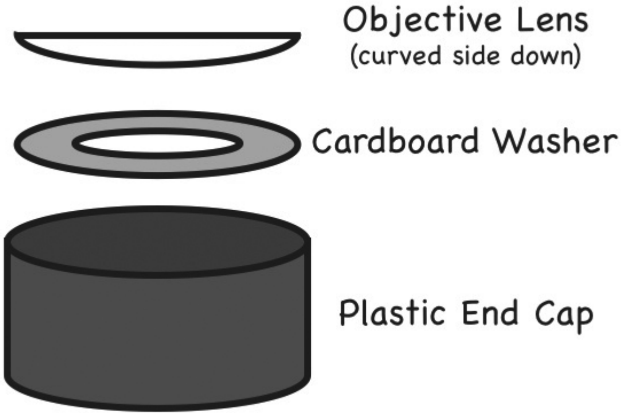
Overall view of kit's pieces and assembly.

2. They should take both lenses and look through them (from both sides) at posters on the walls, printed words, etc.

   What do they notice? Do the two lenses behave differently?

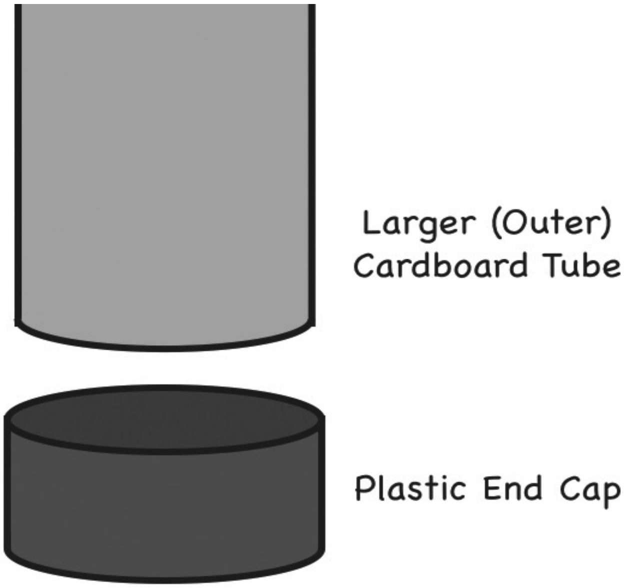
   Explain that the larger lens is the objective and the smaller is the eyepiece and refer to the general telescope diagram.

3. Lead the students step-by-step through the process of building the telescope. For the first step, lay the cap down on the table or desk with the open end up. Place the cardboard washer (disk with hole) into the cap. Holding it carefully by the edges, place the larger (objective) lens into the cap with the curved side pointing down.



Assembly of the objective end of the telescope.

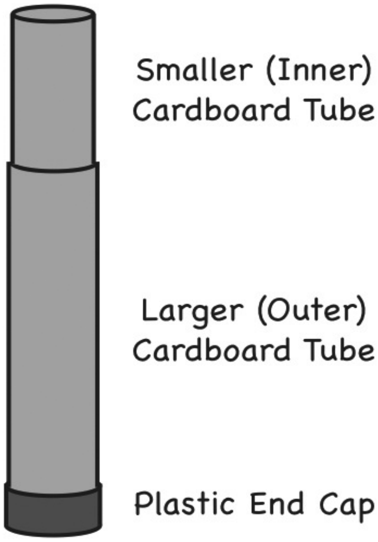
Take the two tubes apart. Insert the end of the larger of the two sliding cardboard tubes into the cap.



Attaching the objective end to the telescope.

4. To make it easier to focus the telescope, it is useful to draw a scale on the smaller tube. Using a ruler, and starting from the eyepiece end, mark each inch on the outside of the smaller tube. The first mark (label it "1") should go one inch from that end, and the second mark ("2") two inches from the end, etc. Students should be able to mark up through "11," because the tube is 12 inches long and "12" would be on the objective end.

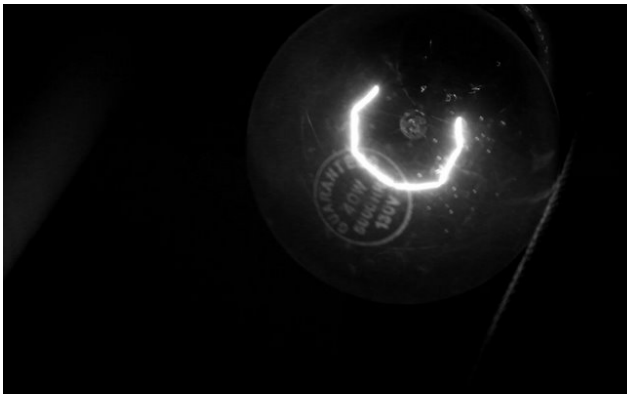
5. Fit the smaller tube back into the larger tube, but leave a little bit sticking out. Instead of inserting the second lens, place a piece of tissue paper over the eyepiece end and secure it tautly with a rubber band.



The telescope, almost fully assembled.

6. Place the light source on a table. Students stand in a circle at a distance of 3 steps from the light. Darken the rest of the lights in the room and have students aim the objective lens end of the tube at the light.

7. Students should look at (not through) the tissue paper, with the telescope roughly a foot away from their eyes. They should slide the smaller tube in and out of the large tube until they can see a clear focused image of the incandescent filament (the wires in the middle of the bulb) on the tissue paper. This will not be a dot, but rather a sharp image of squiggly lines. Once they can see this, they should record the position of the smaller tube by making a clear mark on it, such as an X.



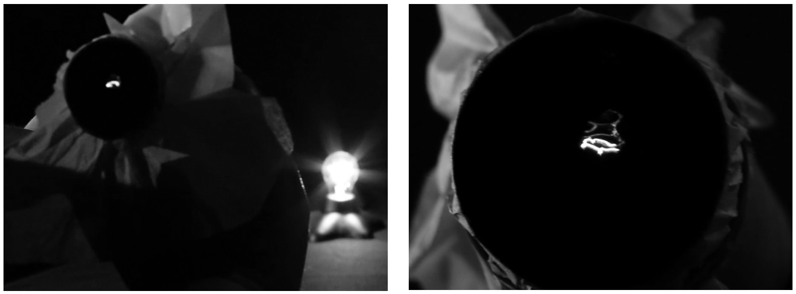
Light bulb filament. Image courtesy and copyright Alexander Lingo.

Instead of a lamp, a Maglite-type flashlight in upright "candle" mode can be used for the focusing. Here, the focus is reached when the spot of light is the smallest, and as crisp and clear as possible.

8. Students should then move as far as they can away from the light and repeat the experiment. When they get a focused image they should check the position of the smaller tube. Ask them to predict answers to the following questions:

   – *In this position, is the telescope longer or shorter than when you were closer to the light?* (Answer for leaders: it will be shorter.)

   – *If you wanted to get a clear image of a very distant object, would the telescope length have to be longer or shorter?* (Answer for leaders: it will be shorter still.)

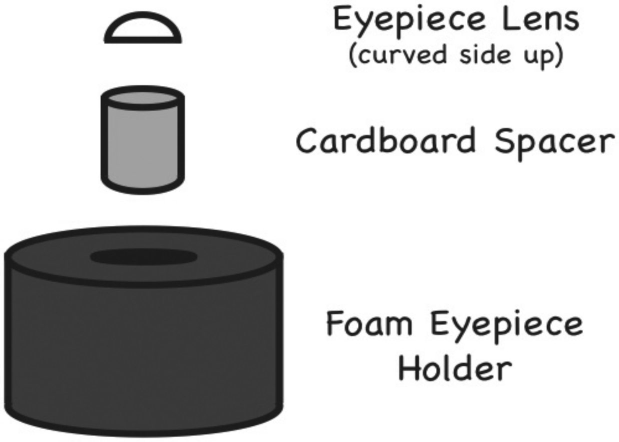


Looking at (not through) the tissue paper, you can see an image of the light bulb filament.

9. If possible, ask students to aim the telescope at a distant object through a window. Now ask them if their prediction was correct.

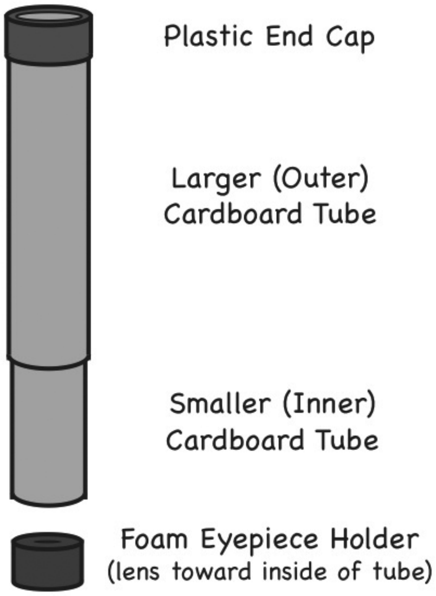
Warn students not to look at the Sun with their telescopes!
Permanent eye damage can result.

10. Turn on the lights. The room should be well-illuminated for the next part. Students should remove the tissue paper and get ready to insert the eyepiece. Lay the foam eyepiece holder on the table with one end of the hole pointing up. Push the half-inch spacer all the way down into the foam eyepiece holder so that it is flush with the table. Using a piece of cloth or tissue to protect the lens from fingerprints, push the smaller lens (eyepiece) into the foam eyepiece holder with the curved side facing up.



Assembly of the eyepiece end of the telescope.

Now pick up your two tubes and push the end of the smaller sliding cardboard tube down over the top of the foam eyepiece holder (see diagram). The telescope is now complete!



Attaching the eyepiece end to the telescope

Students can now look at "distant" objects, through the window or at the opposite end of the room. If the telescope is shaky or hard to aim, encourage students to devise a means of bracing or supporting their telescopes. It may be helpful to put up eye charts, or other images and text on the wall to give the students something particular to focus on for indoor observation.

After a few minutes, ask students what they noticed. They probably saw that the image was upside-down!

What else did they notice? Things should look closer, they should also be able to see details on objects that are already close…

Did anything surprise them?

11. **<u>Optional Extension</u>**: Cut a circle out of the 3″ square piece of paper that is a little smaller than the diameter of the objective lens, and discard the circle. Tape the paper with the hole over the objective lens and see what happens. The field of view does not get smaller, but it does get dimmer, because the light-gathering area of the lens/telescope got smaller. The larger the area, the more light you can collect, so you can see dim objects (objects that are further away). This is why astronomers want to build big telescopes!

III. Postcard activity (~10 minutes)

1. Tell students that astronomers use light to study the Universe since it is not possible to travel to the stars and galaxies. But light takes time to travel! (Students may not know this or even understand this concept.) Email and text messaging, which we tend to think of as instantaneous, are in fact slower than the speed of light — that's how fast light travels! But as fast as it is, it still takes time. Even the time between when you flip a light switch and when the light comes on is not instantaneous. Explain that we will now do an activity to understand this concept of travel time.

2. Pass out postcards, and have students work individually or in the same teams to figure out and write down the address of the program location. For example:

   Irene Smith
   Afterschool Program
   100 Main Street
   Washington, DC 20001

   Ask them to write down the date and a sentence or two that says what they are doing or did today. "I'm writing this note for the postcard activity today" works — or anything they have done that day that is unique to that date and time. They can write drafts of their sentences on separate paper first, if desired. Have them read their notes aloud.

3. Have students guess when the postcards will arrive if they are mailed today — 1 day? 2 days? Later than that?

Ask them if their postcards will tell them what they are doing at the time that they read it when it arrives. Or at the time they wrote it?

The answer is that it will tell them what they were doing when they wrote it, a day or two before they read it.

Ask for examples from students about what might change in their lives between today and when they will receive the postcard — they might get a haircut, get a new toy, go visit a friend's house, watch a TV show, etc.

4. Explain the analogy with the postcard:

   The postcard's travel is like light traveling from very far away in the Universe, from a distant star or galaxy. That light gives us most of the information we have about these distant objects, since we can't go there.

   Light does not travel instantaneously — it is very fast, but it does have a speed limit. It takes time to travel, just like your postcards: 8 minutes for light from the Sun to reach us, 4 years from the next nearest star, and 13 **billion** years from the most distant objects.

   Here are some examples of light travel time:

   - Moon to Earth: 1.3 seconds
   - Sun to Earth: 8 minutes
   - Mars to Earth: 12 minutes
   - Jupiter to Earth: 35 minutes
   - Pluto to Earth: 5.5 hours
   - Nearest star to the Sun: 4.3 years

5. You can either ask the students to mail the postcards themselves or you can collect the postcards from your students and mail them. Tell them that you will discuss what they wrote in the postcard when they receive it. Hold a follow-up discussion on this topic 2–3 days after this session when the postcards are delivered back to the program location to re-iterate the point that it takes time for objects and information to travel and get to places. That includes even light and the information it carries about the Universe.

6. Remind students to think about their postcards, and have them offer their thoughts.

   Tell them that from the Sun, we receive information "written in light" 8 minutes ago. Ask them if something were to happen on the Sun right now, when would we actually find out about it? Answer – only after 8 minutes have passed because it will take that much time for the light that carries this information to reach us on Earth. The light is a kind of "time capsule." It tells us what was happening with these objects when the light left them. We don't know what's happening there right now.

IV. Light travel time kinesthetic (15 minutes)

Check our online resources for a video about facilitating this activity.

1. You can ask the students to role play this to truly understand the concept. Ask for 7 volunteers. 4 of them will represent objects in the Universe — the Earth, our Sun, Mars, and Jupiter. The student representing the Earth will stand at one end of the room or a hallway, and those representing the Sun, Mars, and Jupiter should line up at increasing distances from Earth. Each footstep will represent the distance light travels in 1 minute. So the Sun should be 8 steps away from the Earth, Mars 12 steps away, and Jupiter should be 35 steps away.

Students in position for light travel role-playing activity.

[If you wish to carry this further, you can have another student representing Pluto standing out in the corridor to represent that it is very far away. 5.5 hours represents 330 steps, which may not be possible to do! Exact scale representation does not matter as we are focusing on the underlying concept of travel time.]

The other 3 students will represent a light ray traveling from each of the non-Earth objects – each of these students should stand beside the object they are associated with. The student representing Earth should have his/her back to those representing the other objects. Alternatively, a blindfold could be used to accomplish this goal. Either way, this emphasizes that the only information the Earth will receive will be what the light brings to it.

2. Now have the student representing the Sun touch his/her head or perform some other action. The student representing the light ray emitted by the Sun will now face away from the Sun (so that s/he cannot see what else the Sun might do) and take 8 steps to the Earth and tell the Earth that the Sun has just touched its head. The light ray carries the information to the Earth. To make this point even clearer, the student representing the light ray from the Sun can keep performing the Sun's actions all the way to the student representing the Earth.

In the meantime, the Sun might have done something else – like put on a hat – but the light will not know this and cannot tell the Earth about what happened after it left. If you would like, you can have another volunteer play the part of a second light ray to leave the Sun after the first carrying new information to the student representing the Earth.

3. Next, the student representing Mars can perform another action – say bend down and touch his/her toes. The student representing the light from Mars will now face away from Mars and take 12 steps away from Mars towards the Earth and tell the Earth that Mars just bent down and touched its toes. Again, Mars might have done something else as soon as the ray of light left it and the light would not know about this action, since the light's back was turned. Once again, you may have another student play the part of a second light ray to illustrate this point.

4. Lastly, the student representing Jupiter should carry out an action, like jumping in place. The student representing the light from Jupiter will now face away from Jupiter and take 35 steps to the Earth. S/he will now tell the Earth that Jupiter has jumped in place, but again, Jupiter might have done something else, like sit down. The light will once again not know this and can only tell the Earth what it knew when it left Jupiter.

   These are very simplistic models to show that it takes time for light to travel and it can only carry the information about the object when it left. But it should help to emphasize that we cannot receive information instantaneously and it takes time for any information to be transmitted to us via light.

Suggestions for Running this Session

- Students should slide the telescope tube slowly, as it's much easier to focus. If their hands shake, they should find a way to brace the telescope, or rest it on something for additional stability.

- You may wish to set up some indoor viewing options - an eye chart or other printed text posted on a distant wall is useful for checking out how these work (and seeing that the image is inverted). An astronomical poster on the wall can also mimic the night sky for viewing. If you want to take the telescopes outside during the day, they can be used to view trees or other natural features, but remind students to never, ever point them at the Sun.

- Think about what you want students to do with their team telescopes at the end of the activity — if they worked alone, they can take their telescope home. If they worked in groups, perhaps they can take turns taking them home? Take them outside during free periods to look at objects? If they take it home, suggest that they look at the moon with their telescope. Alternately, you can keep the kits for re-use with a later group.

- **Galileoscopes**

  The Galileoscope is a high-quality, low-cost telescope kit developed for the International Year of Astronomy, celebrated in 2009 to mark 400 years of the telescope. This 50-mm (2-inch) diameter, 25- to 50-power achromatic refractor telescope is a better telescope than the ones we use in this session, although it more expensive. It is also not as easy to assemble as the telescopes we suggest using.

  If you are interested in providing your students with an observing experience (for example a star party or a family night), we suggest you purchase 1-2 telescopes for your site. For more information and to order these "Galileoscopes", please visit https://www.galileoscope.org/

Emphasize that students should never look at the Sun with their telescope!

Misconceptions

- The two lenses used in this telescope create an inverted image. This is not a problem in astronomy (which way is up in space?), but it makes it difficult to read a street sign, for example. Don't worry, this is not a sign that you put it together incorrectly.

- We do not have the ability to travel anywhere close to light speed. Our fastest spacecraft can go a little over 48,000 kilometers per hour (30,000 miles per hour), while the speed of light is over 1 billion kilometers per hour (670 million miles per hour)!

- There may be potential confusion between telescopes and microscopes. Students may not understand the difference between the two, since both allow us to see things that we would otherwise not be able to see. The basic difference is that telescopes look at distant objects, while microscopes look at very small objects.

Useful websites for background or activity extension

- **Telescopes from the Ground Up**
  Information on the history of telescopes, different kinds of telescopes, and basic explanations of light, color, and optics
  http://amazing-space.stsci.edu/resources/explorations/groundup/

- **Science@NASA**
  Simple explanation of how telescopes work, their history, and why astronomers need more than one kind
  http://science.nasa.gov/newhome/headlines/features/ast20apr99_1.htm

- ***Scope It Out!* Game**
  A flash game explanation of how telescopes work, and the James Webb Space Telescope in

particular
http://www.jwst.nasa.gov/scope.html

- ***Sky & Telescope* magazine**
  All about tools for sky-gazing
  http://skytonight.com/letsgo/toolsforstargazing

- **Meade Instruments Corporation**
  Relatively simple explanations of how telescopes, and a range of telescope accessories, work.
  http://www.meade.com/support/telewrk.html

- **NASA's *Universe Education Forum***
  How big is our Universe? Take this journey through space and time
  http://www.cfa.harvard.edu/seuforum/howfar/index.html

- **The Galileoscope**
  The Galileoscope is a high-quality, low-cost telescope kit developed for the International Year of Astronomy. This easy-to-assemble, 50-mm (2-inch) diameter, 25- to 50-power achromatic refractor telescope is a better telescope than the ones we use in this session, though it is also a bit more expensive.
  http://www.galileoscope.org/

Session 4 – Invisible Light

General Description

Discussion and group experimentation with specialized instruments at different stations (visible, infrared, and ultraviolet) allow students to discover that "invisible" light is as real as visible. Students learn that in astronomy, it is important to make observations over a wide range of wavelengths, because the different wavelengths of light in the electromagnetic spectrum give us different pieces of information. This session ties in with Session 5.

Objectives

- To explore several different types of light, both visible and invisible.
- To reflect on the everyday and astronomical applications of light.

Concepts Addressed

- The electromagnetic spectrum
- Applications of visible and invisible types of light

Materials

- The *Electromagnetic Spectrum* handout (black and white version included in Appendix E and color version included in Appendix F)
- Flashlight (with batteries)
- One sheet of plain white paper
- Infrared light (heat lamp)
- Two Alligator jumper clip cables (the colors don't matter) *
- Photocell or solar cell **
- Amplifier/speaker *
- Audio cable *
- 9V battery
- Assortment of one or more remote controls, any kind — TV, VCR, radio, etc.
- Digital camera or camera phone
- Ultraviolet lamp *
- Invisible ink pens (or other items which are sensitive to ultraviolet light, such as ultraviolet reactive beads, glow-in the-dark stars, white powder laundry detergent, credit cards, etc.)
- Visible Light worksheet for program leader (included in Appendix E)
- Invisible Light worksheets, one per student (included in Appendix E)
- Pencils/pens
- Whatever is available in approximately 12″ × 12″ (size is not critical) sheets of material, including some that let light pass through and some that don't — such as, clear plastic,

black plastic, aluminum foil, paper, piece of cloth, wax paper, plastic bag, window screen, etc. You will need 4 sets of these materials, one set for each station.

** Information about where this can be purchased, along with part numbers can be found in Appendix C.*

*** The infrared detection circuit requires an encapsulated solar cell with two wire lead (pictured below). Information about where this can be purchased can be found in Appendix C.*

The type of solar cell used for the infrared detection circuit.

Other Requirements

- A room that can be set up with 4 tables or desks that serve as "stations" for working with different types of light.
- Access to a blackboard, whiteboard, flip chart, or large sheet of paper, and chalk or markers.

Background

The electromagnetic (EM) spectrum is made up of all the different wavelengths of light, including visible and ranging from radio waves to gamma rays. Just as our ears can only hear certain frequencies of sound, our eyes can only see visible light, which makes up a tiny portion of the entire spectrum. Remember, scientists use the word "light" for any wavelength of energy, and will use the words 'light' and 'energy' interchangeably at time.

Astronomical objects emit light at various wavelengths depending on their temperature. For example, the material around black holes is very hot and shines very brightly at X-ray wavelengths. Stars that are still forming are too cold to emit light at visible wavelengths, but do so at infrared (IR) wavelengths. Collecting data at different wavelengths is very important in astronomy, to gain a more complete picture. You can think of the fable with the blind men and the elephant:

> A group of blind men is asked to touch an elephant to understand what it looks like. Each one touches a different part, but only one part, such as the trunk, leg, or tail. They then compare notes on what an elephant is, and learn they are in complete disagreement (it is a tree, wall, snake, etc.) about what an elephant looks like. But if they combined all their experiences, they would arrive at a more complete and accurate description of the elephant.

(Long version of this story at http://www.peacecorps.gov/wws/stories/stories.cfm?psid=110)

How the receiver circuit works (for Station 2)

– No need to explain this to students, but here's the information in case of questions:

In the circuit, the photocell receives the IR signal from the flashlight and converts it to an electrical signal that is sent to the amplifier-speaker. This particular photocell is sensitive to light over a range of wavelengths, including visible and infrared light.

The photocell produces a constant electric current when exposed to light. A constant light source produces a constant current and no sound. You might hear static, if anything.

Speakers require a changing current to produce sound. When the light changes in brightness, the current produced by the photocell changes, and the speaker produces sound. You change the brightness of the light when you move your hand back and forth in front of it, so you hear "pops" each time the light is turned back on. (To the photocell, moving your hand across the beam is the same as turning the light off and on.)

Why a changing current is needed to hear sound from the speaker (for Station 2)

– No need to explain this to students, but here's the information in case of questions:

Inside the speaker, a flexible cone (usually made of paper, plastic, or metal) vibrates rapidly in response to a changing electrical current. As it moves, it pushes the air molecules around it. Those air molecules, in turn, push other air molecules near them, and the vibration is transmitted through the air as a sound wave. Our ears detect the vibration of air molecules and convert them into an electrical signal that our brain interprets as sound.

The cone vibrates because it's attached to a steel frame that receives impulses caused by the changing magnetic field from a magnet behind it. The magnet will only change if there is a change in the current it receives from the photocell. If the current is constant, there's no magnetic field change, so no impulse, no vibration, and no sound.

Session Overview

Students experiment with different types of light (different wavelengths) most of which are not visible to the human eye. Different stations allow them to experience similarities between visible, infrared, and ultraviolet light. Each station has a source of light, a detector, and sheets of material to test as potential "transmitters" or "shields" for the light. By testing various types of light with these shields and transmitters, students discover for themselves that there are types of invisible light that can be detected — but not with our eyes.

Preparation

- On the blackboard, draw the chart (template included at the end of the session) to record observations for your demonstration with visible light. Change the materials listed in your chart to whatever you are using.
- Make copies of the *Invisible Light* worksheet for each student.
- Set up the 4 stations (below) at 4 widely-separated tables with all the supplies listed under each. Label each station with its title, source, and detector(s), as well as the appropriate number. (*For large classes, you can set up two of each of these stations.*)

Demonstration station – Visible light
SOURCE: Flashlight (with batteries)
DETECTOR: Plain white paper
Set out one set of shield and transmitter materials
Set up this station near your blackboard

Station 1 – Infrared light
SOURCE: Infrared light (heat lamp)
DETECTOR: Student's hand
Set out one set of shield and transmitter materials

***** NOTE: The heat lamp can get extremely hot, and students should handle with care! Do not touch any materials directly to the heat lamp bulb, and keep hands at a reasonable distance to avoid injury. Consider putting the heat lamp inside a "cage," such as a milk crate, to prevent contact. *****

Station 2 - Infrared light
SOURCE: Remote controls
DETECTOR: Simple circuit (construction described below)
DETECTOR: Digital camera
Set out one set of shield and transmitter materials

Station 3 – Ultraviolet light
SOURCE: Ultraviolet lamp
DETECTORS: Invisible ink pen
Set out one set of shield and transmitter materials

Step 1: Building the receiver circuit (*diagram below*)

Check our online resources for a video about building this circuit.

The infrared receiver circuit.

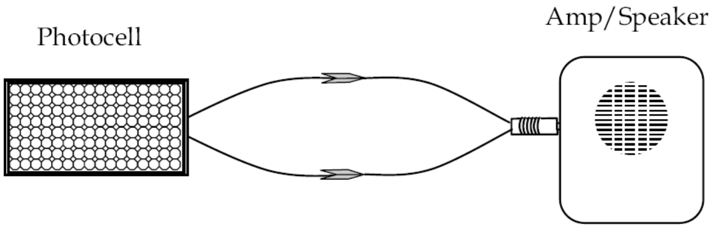
To make the photocell detector, you will use jumper cables and the audio cable to connect the photocell with the amplifier/speaker (which requires a 9V battery).

1. Clip one alligator clip from a jumper cable to one of the wire leads coming from the photocell. Always clip to the exposed (wire) end of the lead.

2. Clip the alligator clip at the other end of the jumper cable to one of the leads coming from the audio cable.

3. In the same way, use a second jumper cable to connect the other lead from the photocell to the other lead of the audio cable.

4. Put audio cable into the jack labeled “input.”



Simplified diagram of the infrared receiver circuit.

Step 2: Testing the receiver circuit

For best results, turn off any overhead fluorescent lights. They will cause the speaker to emit a constant buzz or hum, because the intensity of the light changes.

1. Turn on the amplifier. You will hear static. (The static is noise from the detector and the amplifier themselves, plus some ambient light. Daylight will produce even more noise than indoor light.)

2. Now shine a flashlight on the detector and wave it back and forth or "chop" the light in front of it with your hand. You should hear "pops" in the sound level now (see the explanation for how the receiver circuit works in the background section for why it works this way). This confirms that the photocell reacts to light falling on it. You have confirmed that your circuit works — turn off the amplifier.

Activity

(Adapted from Invisible Universe, developed by the Lawrence Hall of Science with support from NASA's Swift mission.)

I. Discussion and demonstration (15 minutes)

Pass out the electromagnetic spectrum handouts.

1. Base yourself at the demonstration station for this discussion.

   Ask the students why astronomers observe the same object in space — like a star — in more than one wavelength? Wait for answers.

   Here's a short fable that helps to explain why:

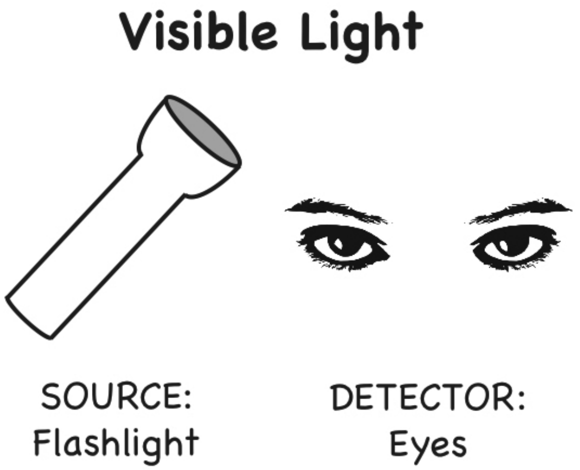
   > *A group of blind men is asked to touch an elephant to learn what it is like. Each one touches a different part, but only one part, such as the trunk, leg, or tail. They then compare notes on what an elephant is, and learn they are in complete disagreement (it is a tree, wall, snake, etc.) about what an elephant looks like. But if they combined all their experiences, they would arrive at a more complete description of the elephant and realize its true nature.*

   When we look out in the Universe, astronomers play the parts of the blind men. They observe objects like stars in different wavelengths, and then share their information with each other. This allows them to learn much more about what they are looking at than if they worked alone.

2. Tell the students you are going to talk about **sources** and **detectors** of light. Shine the flashlight at the blackboard.

   Tell them that the flashlight is a source of light because it produces its own light. Ask what other <u>sources</u> of light they can see in the room. Allow students to respond. Note that many objects <u>reflect</u> light (like the Moon, a mirror, and even the Earth itself) — they are not the <u>source</u> of light. Sources of light produce the light themselves — a star is a good example.

   Ask them how we know the light is there. Allow students to respond. Lead them to the answer of "with our eyes." Our eyes are <u>detectors</u> of light.

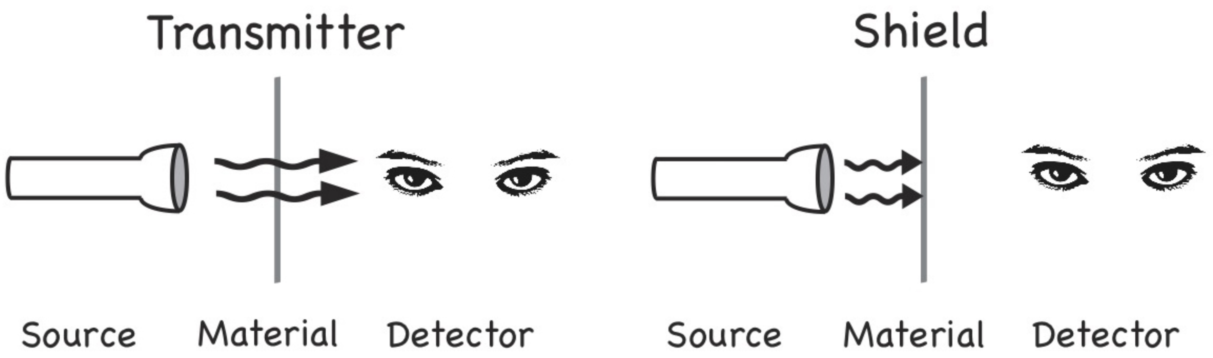


The demonstration station, visible light, and its source and detector.

   Ask what other types of detectors they can think of. Common examples are cameras and video cameras. Hold up a blank sheet of white paper. Explain that it <u>reflects</u> the visible light from the room lights or daylight, which is why we can see it. So the white paper might be considered a detector, but our eyes are the *real* detector.

3. Say that we'll next try out some **transmitters** and **shields**. Explain that some materials let light through and are called "transmitters" of light. Other materials do not let any of the light through; they block it. These are called light "shields." Ask students for examples of materials that let light through and materials that don't.

   One at a time, hold up the shield materials you have. Ask students to predict whether the flashlight's light will shine through — but don't try it yet! As students offer their predictions, have a volunteer go to the blackboard and write down the predictions for each material in that part of the table. Transmit (or partially transmit) can be recorded as "T" and shield as "S." Then hold each material in front of the flashlight (at a distance of 3–4 inches) and ask them to tell you what they see. Have the volunteer record the observed results in that part of the table.



A transmitter allows light through and a shield stops it.

4. Ask if they can think of any sources for the invisible light. They should be familiar with TV remotes. Ask if they know how TV remotes "talk" to the TV.

   Remind them to look at the handout to see the range of different types of light. Tell them they will be experimenting with some types of invisible light today, and they will see how TV remotes work.

II. Activity (20 minutes)

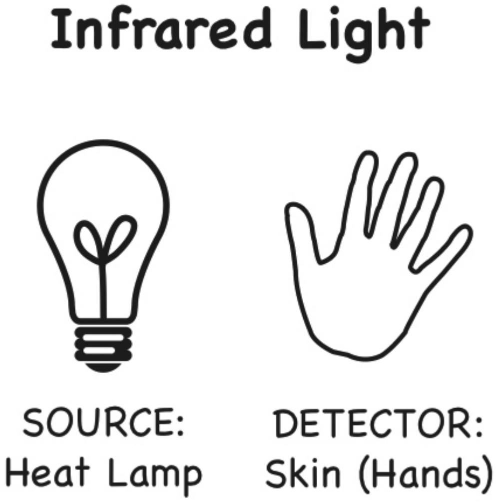
Check our online resources for a video overview of these stations and procedures.

Now we're going to "see" some <u>invisible</u> light for ourselves.

Explain that the 3 stations around the room (besides the demo station) each have a source of "invisible" light, a detector, and a set of materials that may be shields or transmitters for the light. Replace the flashlight at Station 1, and walk around to the 3 stations, pointing out the sources (IR lamp, remote control, and UV lamp) and their respective detectors, and briefly explaining what to do at each station — especially station 2.

Station 1 – Infrared Heat Lamp:

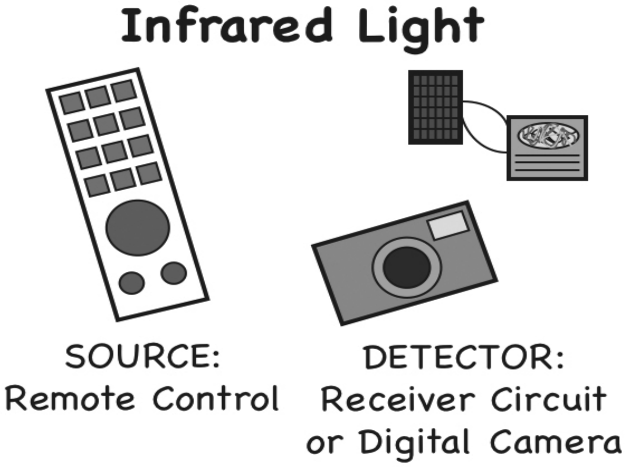
Turn on the infrared lamp and place your hand near it. Students should just feel the heat from the lamp and ignore the small amount of visible light being emitted by the bulb (the part you can see is visible light, the heat is the infrared light). <u>The skin on their hands is the detector here</u>. If it were not dangerous, we would blindfold them so they would not have the chance to be confused by visual input, but this is impractical for safety reasons.



The source and detector for station 1.

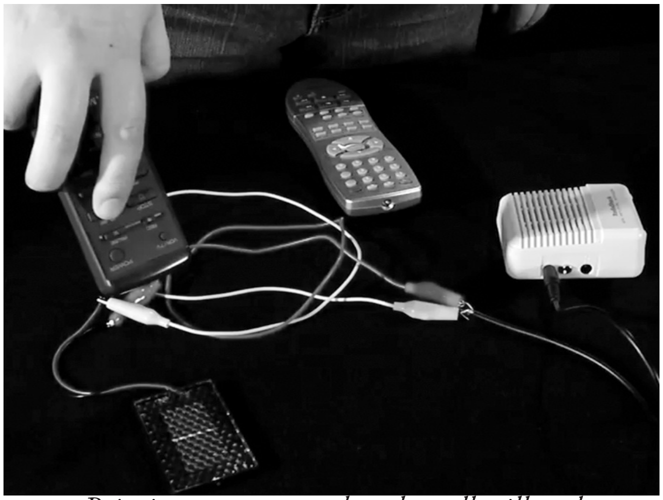
***** NOTE: The heat lamp can get extremely hot, and students should handle with care! Do not touch any materials directly to the heat lamp bulb, and keep hands at a reasonable distance to avoid injury. The plastic bags in particular melt very easily. Consider putting the heat lamp inside a "cage," such as a milk crate, to prevent contact. The best detector in the room for this is the smoke detector, but we hope to not use that one! *****

Station 2 – Infrared Remote Control:



The source and detector for station 2.

Turn on the amplifier. Students should shine one or more remote controls at the photocell in the simple circuit (it may be helpful to label the photocell at the station). The photocell will pick up the light and relay it to the amplifier, which converts it into sound. In this set-up, they can "hear" the IR light even though they can't see it.



Pointing a remote at the solar cell will make sound come out of the amplifier/speaker.

Turn on the digital camera. Have students point a remote control at the camera and push a button on the remote. Depending on the remote control, they will either see a bright beam of light or flashes of light coming out of the remote control when they push a button and watch the screen of the camera. The camera is sensitive to IR light and can see the signal from the remote control, even though we can't.

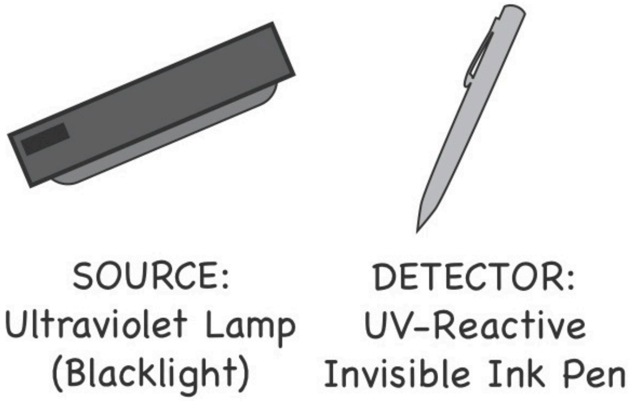
Many digital cameras can see IR light.

If there is time, students can do their tests with both the camera and the circuit and compare their results. It could be interesting to see if the results are the same.

Station 3 – Ultraviolet Light:

Write a message on a piece of plain white paper with the invisible ink pen. Turn on the ultraviolet lamp. If you hold the light over the paper, you should see the message glowing brightly. When you test various materials during the activity, you'll be looking for the message to appear. If you see a message, the ultraviolet light has been transmitted through the material. No message, and the ultraviolet light is being shielded.

Ultraviolet Light



The source and detector for station 3.

There are many other materials that react to ultraviolet light that you could use at this station, though we specifically suggest the invisible ink pen for this activity (see the Suggestions and Misconceptions for further discussion). This station is frequently the one where participants linger the longest, as there are many fun things to explore in the ultraviolet!

Students test a UV light with alternate detectors.

Explain that even though they may be able to see red light from the heat lamp and purple light from the UV lamp, this is <u>not</u> the invisible light that we are detecting. This is visible light that is too close to the UV and IR light to be filtered out, but they should ignore it for their experiment. We care about the invisible portion of the light, not the part you can see. If you can see it, it's not invisible!

If helpful, you can draw a comparison to neopolitan ice cream — even if all you want is the vanilla, it is close enough to the chocolate and strawberry that you will probably get some of them as well. Clearly demonstrate what they are actually looking for in each case. Show how the detectors react to visible light, and how that is different from their reaction to the invisible light. Demonstrate these issues clearly before they get to the stations for themselves.

Distribute the Invisible Light worksheets to each student, and split the class into 3 groups.

Have students pick one person in their group who will report their results at the 3 stations.

Have the students make their predictions for whether each material will be a transmitter or shield for each type of light before they get to the given station, and record these predictions (T or S) on their worksheet. You can have them make them all before they start to avoid the temptation to just wait and see what the answer is so that they get it "right." The goal here is not to get everything right, but rather to get used to the process of making predictions and then carrying out an experimental procedure to test those predictions.

They should also come up with a consistent experimental procedure for each of the stations. This is an important aspect of real science, too. Changes with regards to who holds what, distances between items, etc. can introduce error into their results, and should be discussed in the case of inconsistent results. When they get to the stations, let them see if their results change if they change their experimental procedure.

Participants test materials at the heat lamp station.

At each station, students try the "flashlight experiment" themselves, but using the station light source instead of the flashlight. They should shine the light source at each of the materials and experiment to answer these questions:

- *Can they see any light directly with their eyes?* (They shouldn't be able to see much, if they even see anything. **Make sure that the students do not shine the light directly into their eyes, but shine it at the materials you have laid out.**)
- *What can see it?* (The detector.)
- *Which materials block the light from reaching the detector?* For this, we specifically mean the invisible portion of the light, not the red or purple light that they can see with their eyes.

Have them record their results (T or S) on the Invisible Light worksheet. Have them try to explain the results and record their thoughts on the back of the worksheet. They will have 5 minutes (or longer if you have the time) at each station. When time is up, have the students rotate to the next station in order until everyone has been to all 3. Don't let two groups simply switch with each other, because this will leave the third group out of that rotation and they will be behind. If students complete their experimentation at a station before time is up, encourage them to explore other materials on hand to determine if they are transmitters or shields.

The leader should circulate around the room throughout this rotation to answer questions about proper set up and procedure.

III. Sharing results (15 minutes)

Bring the class back together and have each "reporter" present their summary and explanations. After each report is presented, encourage others to ask questions of the reporting group (not just the reporter). Ask students in the reporting group if they have any questions (record any that arise on the blackboard).

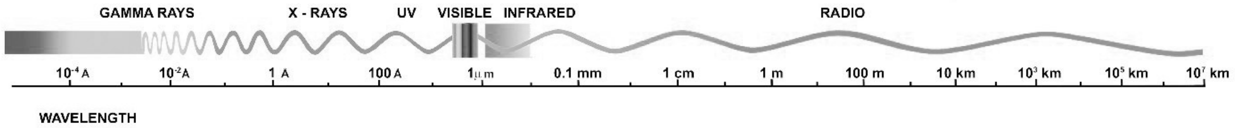
Some questions that you can pose to the reporter are:

- What did you find out?
- What was the source?
- What was the detector?
- What blocked the source?
- What let the invisible light through?
- Did anything surprise you?
- What variables could affect whether something was a transmitter or shield (thickness of material, distance from source, etc.)?

The last of these questions is especially good to discuss when groups disagree or have inconsistent results.

Summarize the class experiences on the blackboard. The leader should now explain what was going on at each station.

Go back to the spectrum handouts. Have a student point out again where visible light falls into the larger electromagnetic spectrum, then the radio waves, microwaves, infrared light, visible light, ultraviolet light, X-rays, and gamma rays.



Notice the relationship between the infrared, visible, and ultraviolet on the spectrum handout. Discuss why the ultraviolet lamp and heat lamp may have also had some visible "glow" – this is because of each source's overlap with the visible. In each lamp, there is small amount of visible light along with the invisible light that required a special detector.

Remind them that different wavelengths of light tell us different things – light with shorter wavelengths than the visible range (ultraviolet, X-rays, and gamma rays) tell us where the really hot things are.

Light with longer wavelengths (infrared, microwave, and radio) show us where the cooler ones are. Some examples:

- X-rays show us where the black holes are located in a galaxy.
- Ultraviolet light shows us where the really hot stars are.
- Infrared light shows us where the really cold stars and dust in the galaxy are.

Suggestions for Running this Session

- Test the detectors at each station to verify that sources and detectors are functional and that you understand them.

- There are many materials which react to ultraviolet light, many of which we've experimented with during the development and pilot-testing of this session. Glow in the dark stars or other items will glow in UV light. Ultraviolet-reactive beads will change color when exposed to the lamp. Laundry detergent reacts to the UV light by shining very brightly (quite differently from the simple reflection of visible light). Many financial items such as credit cards and currency have ultraviolet-based security measures that react to the presence of ultraviolet light. There are numerous other substances and materials in the world around us that can be detected with an ultraviolet light - even some scorpions glow in the ultraviolet!

  These alternate materials have never worked as well for us in this activity as the invisible ink pen. Some are messy, expensive, or difficult to use. Some only work well in complete darkness, which is impractical in many settings. And some of them get "charged up" by the ultraviolet light (like the glow in the dark items or reactive beads), which means that once you've tested them once, it'll be a while before you can use them again. The reaction of the invisible ink pens is usually the most dramatic, as it has no reaction at all to visible light. It causes the fewest logistical difficulties, as there is no way to mistake the reaction, and it does not retain its glow beyond the test.

- Test your digital camera with your remote control before providing it to the students. Some of the newer cameras have a much better IR-blocking feature, which defeats their use for this activity.

- Try to avoid a remote control with any visible light output (buttons, indicator light, or the LED itself). The existence of both visible and IR in the remote confuses participants about what they should be looking for. We also recommend using a "universal" remote that's programmed for multiple devices, or a few different remote controls, so you can show how the IR output is different for different electronics.

- When you're not using the various sources and detectors in this activity, remove the batteries in each component - especially if it's going to be a while before you use them again. We've seen these items sit around for so long that the batteries inside leak, and that's not a fun thing to clean up!

Misconceptions

- Even though students may be able to see red light from the heat lamp and purple light from the UV lamp, this is not the invisible light that we are detecting. This is visible light that is too close to the UV and IR light to be filtered out, but they should ignore it for their experiment. We care about the invisible portion of the light, not the part you can see. If helpful, you can draw a comparison to neopolitan ice cream — even if all you want is the vanilla, it is close enough to the chocolate and strawberry that you will probably get some of them as well. Clearly demonstrate what they are actually looking for in each case. Show how the detectors react to visible light, and how that is different from their reaction to the invisible light. Demonstrate these issues clearly before they get to the stations for themselves.

Useful websites for background or activity extension

- **The Electromagnetic Spectrum**
  Two sites that provide a good introduction to the electromagnetic spectrum

  – http://science.hq.nasa.gov/kids/imagers/ems/ems.html
  – http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html

- **SOFIA Infrared Observatory**

  – This site has several activities for learning about infrared light
  http://www.sofia.usra.edu/Edu/materials/activeAstronomy/activeAstronomy.html

  – Explanation of how the electronics work in the infrared activity
  http://www.sofia.usra.edu/Edu/materials/activeAstronomy/section3.pdf

- **Health in Space — UV Man**!
  This activity explores ultraviolet light coming from the Sun. Students build a detector for UV light and explore the protection/shielding offered by various household materials.
  http://www.lpi.usra.edu/education/explore/space_health/space_radiation/activity_1.shtml

- **The Spitzer Space Observatory**

  – Pictures of animals at infrared wavelengths
  http://coolcosmos.ipac.caltech.edu/image_galleries/ir_zoo/index.html

  – Gallery of objects at different wavelengths from the Spitzer Infrared telescope
  http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_astronomy/

Session 5 – The Astronomer's Toolbox: Spectroscopes

General Description

Students each build and calibrate a simple spectroscope and use it to examine light from different sources. This allows them to work the way astronomers do to learn about the composition of objects in the distant Universe.

Objectives

- To ensure that students understand that light is composed of different wavelengths of energy, including many we cannot see with our eyes.
- To show that light provides information about the composition of objects.
- To introduce the spectroscope as an instrument used to study light.

Concepts Addressed

- Electromagnetic spectrum
- The correspondence of different elements and compounds to unique patterns of spectroscopic lines at different wavelengths

Materials

- The *Electromagnetic Spectrum* handout (black and white version included in Appendix E and color version included in Appendix F)
- Paper towel tubes, 1 per student (any tube of a similar dimension, such as PVC piping, shipping tubes, etc, will work just as well for this, so the primary factor is ease of acquisition)
- Aluminum foil: two 4″ × 4″ pieces AND two 1″ × 3″ strips per student (these dimensions are estimates only)
- Masking tape
- Diffraction grating (single axis; approximately 1 inch square of material per student) *
- Light sources
  - Incandescent light bulb as a source of a continuous spectrum **
  - Additional sources of light that produce spectra with distinct lines *** (Optional, if you have access to such lights)
- Full page diagram of paper tube spectroscope, one per student (included)

** Information about where to purchase this, along with the part number can be found in Appendix C.*

** *Common household bulbs are incandescent or fluorescent light sources. If you don't know what kind of lamp you have, build a spectroscope and look at it. Descriptions of the spectra of common types of lights are at:*
http://isaac.exploratorium.edu/~pauld/summer_institute/summer_day9spectra/spectra_exploration.html

*** *Distinct lines are produced by light sources from only one element or compound. Discharge lamps are the best for this, but most institutional buildings have mercury fluorescent lamps that will work. You will want to have as many different sources of this type as possible, for increased student interest and understanding, but even one helps.*

Other Requirements

- A room that can be darkened (preferably completely darkened)

Background

Element: A material consisting of all the same atoms

Examples: pure gold, silver, copper, aluminum, and oxygen

Compound: A material consisting of atoms of two or more different elements that are chemically bound together

Examples:

- water (hydrogen + oxygen)
- table salt (sodium + chlorine)
- ammonia (nitrogen + hydrogen)
- sugar (carbon + hydrogen + oxygen)

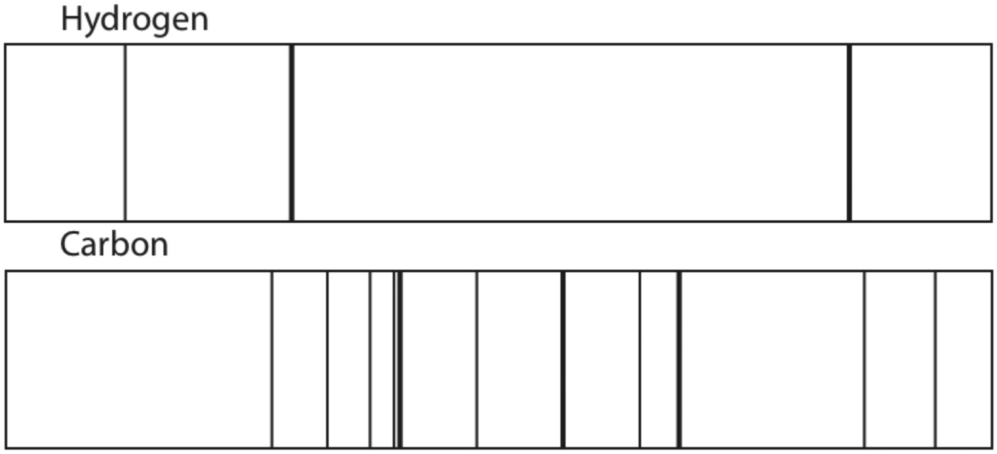
(More on the above in Session 8.)

"**Spectra**" is the plural of "**spectrum**."

A **diffraction grating** separates the light from a source into the full range of visible light, making it possible to see individual lines in the source's spectrum.

The light from each element or compound produces a unique pattern of lines (a "fingerprint" — not a technical term, by the way) that identifies its presence. The lines are always in the same place for that element or compound.

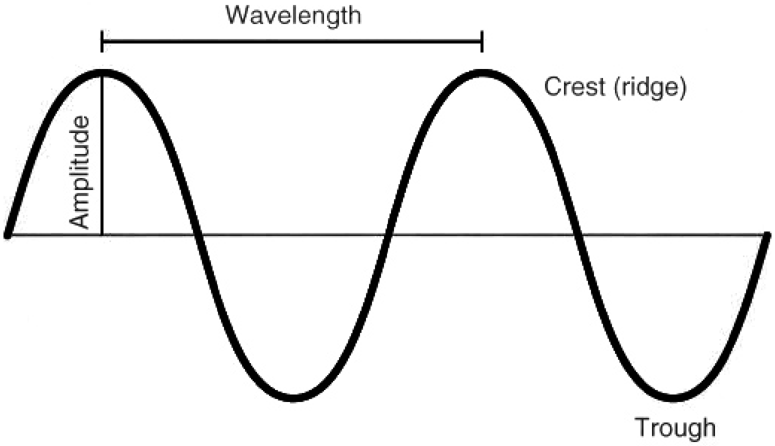
If a fingerprint of a specific element or compound is in the spectrum of a distant astronomical object, it is evidence that the element or compound is in that object.



The spectra of hydrogen and carbon, illustrating how different two different elemental spectra can be.

Using instruments such as the ones in this session, the Sun's spectrum (seen throughout the sky) appears essentially continuous, rather than having distinct lines. We call this white light, meaning it is a combination of all the colors of visible light. Rainbows are the result of sunlight being diffracted (spread out) by water droplets in the air.

When we talk about light, **wavelength** refers to the distance between the two peaks (or crests) of the light wave.



Basic terminology for talking about waves.

Longer wavelengths correspond to shorter frequencies. So, wavelength or frequency of light is a characteristic that defines what type of light it is (radio, microwave, infrared, visible, ultraviolet, X-ray, or gamma-ray). Note that scientists often use the word "light" to refer to energy in any wavelength — not just the visible range.

Element discharge lamps are the best way to show students the fingerprints for specific elements. These lamps send an electrical charge through the gas of a certain type of element. The resultant light will show the signature spectrum of that element. Viewing them is best done in a completely darkened room. Covering bulbs with colored paper or using colored bulbs **will not change** the spectral lines from that of a clear bulb, since the source of the light is the filament, not the glass of the bulb.

We use a narrow slit to select what we want to look at and adjust the size and shape of its spectrum. The diffraction grating at the other end of the device spreads the incoming light in a specific direction. During the calibration, we line the slit up so that it is perpendicular to this direction in the diffraction grating. In this way we limit the data that contributes to our spectrum. If we did not do this in some way, the spectrum for any extended object, such as a galaxy, would be hopelessly jumbled and impossible to interpret.

Session Overview

After a short discussion with the leader on what a spectroscope does, students build and calibrate a simple one. They use it to examine light from different sources — the sky and one or more artificial lights - while discussing with the leader and other students what they are seeing.

Preparation

- Put together a spectroscope of your own in advance and try it out, to make the activity <u>much</u> easier when you go through it with students.
- Become familiar with the handout to help with explanations.
- Set up all of your light sources.
- Cut the foil and diffraction gratings to the correct sizes. Exact measurements are not at all necessary. If time is an issue with the students you can also cut the necessary holes in the foil.
- Handle the diffraction grating carefully with clean hands (or gloves), touching only the edges. Avoid smudges and fingerprints, which will negatively affect the function of the spectroscope.

Activity

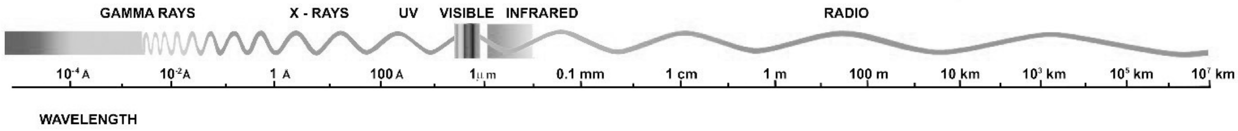
I. Discussion (5-10 minutes)

1. Ask students if they know what the word “spectroscope” means.

   spectro — from spectra or rainbow
   scope — a viewing instrument, as in telescope or microscope

   Ask them if they know what a spectrum is - the range of all the wavelengths of energy possible, from the shortest wavelengths (highest energies/frequencies) to the longest wavelengths (lowest energies/frequencies). Visible light is just a small part of the entire electromagnetic spectrum.

   Note that scientists often use the word “light” to refer to energy in any wavelength — not just the visible range.



2. Pass out the handouts of the electromagnetic spectrum. Point out the full spectrum and have a student find the small portion that is visible light. Discuss what **wavelength** means, and how wavelength corresponds to energy/frequency range.

II. Making the spectroscopes (20-25 minutes)

Check our online resources for a video about building this spectroscope.

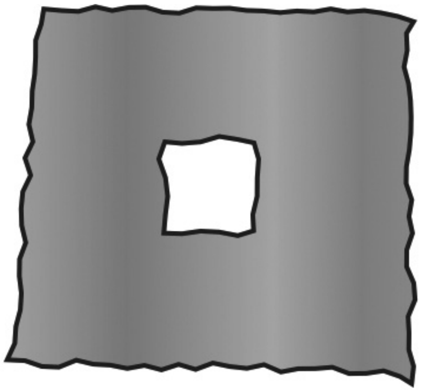
Discussion among students is encouraged for the rest of this session.

1. Distribute construction materials to the class: paper towel tubes, aluminum foil, masking tape, diffraction grating, and rubber bands. Tell the students to be very careful about touching the diffraction gratings only by the edge to avoid leaving fingerprints.

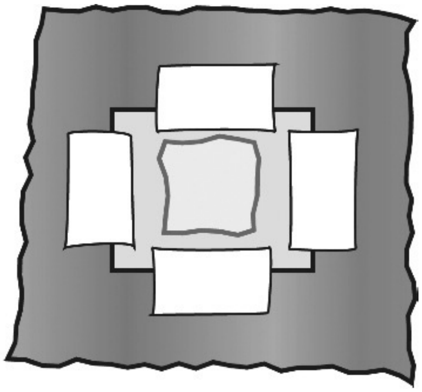
   Distribute copies of the spectroscope diagram, and go through it with the students.

   Like the telescope, the spectroscope has an eyepiece end for the diffraction grating (the end you look through) and an objective for a slit that controls the entry of light and points at the object you are observing.

2. Assemble the **grating end** first. Take one of the 4″ × 4″ pieces of foil and tear or cut a small hole in the center of it — a hole that is *smaller* than the square piece of diffraction grating. A hole in between a nickel and a dime in size is usually good. (An easy way is to fold the foil square in half, then half again the other direction. Tear off the corner that is at the center of the foil, and unfold it.)



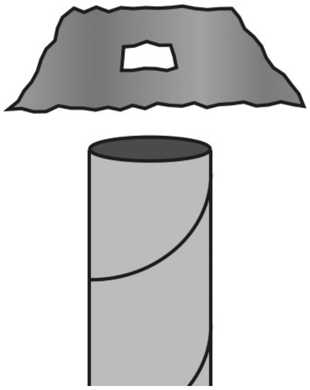
A foil square with a hole in the center.



Diffraction grating taped over the hole in the foil square.

   Again, being careful to handle the diffraction grating only by its edges, tape it over the hole. Tape only the edges of the grating, not across the middle. It doesn't matter which side of the grating or the foil is up/out.

Center this foil-mounted grating over one end of the tube, taped side in, and tape it to the outside of the tube at its edges.

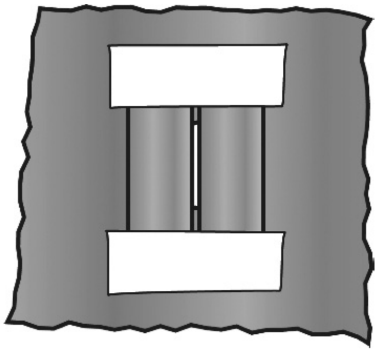


Placing the diffraction grating over the end of the tube.

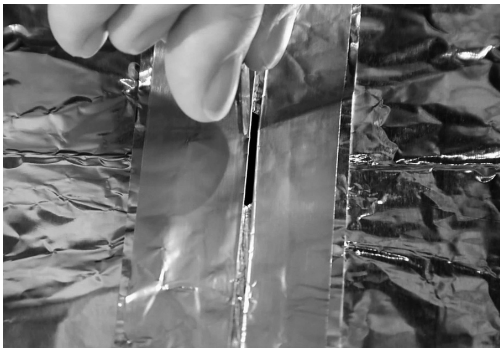
Look at the room lights with the grating installed, to see the effects of the grating before the spectroscope is finished.

3. Assemble the **slit end** on the table. Take the other 4″ × 4″ piece of foil and make a hole in the center as before. The diameter of the hole should be smaller than the diameter of the tube, to avoid gaps and tears.

   Carefully fold each of the two smaller strips of foil (the 1″ × 3″ pieces) in half along the length. Make a sharp crease at the fold of each. Lay them over the hole in the larger piece of foil so that their creased edges face each other with a very small gap between them (no more than the width of a toothpick, or the thickness of a coin). Tape the two creased pieces of foil in place over the hole, and make sure not to cover the slit with tape.

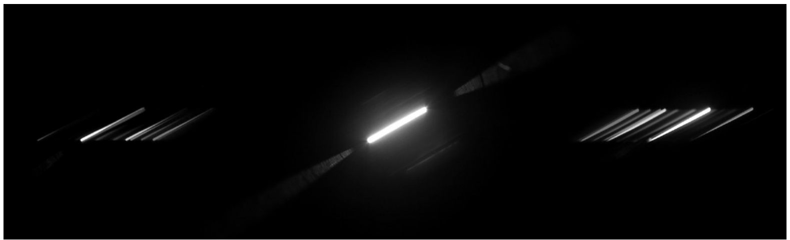


Construction of the slit end of the spectroscope.



Placement of the pieces for the slit end of the spectroscope, with the gap about as wide as the thickness of a coin.

Place the foil-mounted slit over the open end of the tube, taped side in, and wrap the foil around the end of the tube to hold it in place. <u>Don't tape the slit end to the tube</u>, but you may secure it with a rubber band if you wish. The slit allows you to select what you want to look at and adjust the size and shape of its spectrum. (The rubber band is not strictly necessary. You can also hold the slit end in place with your hand, and it is almost as easy.)



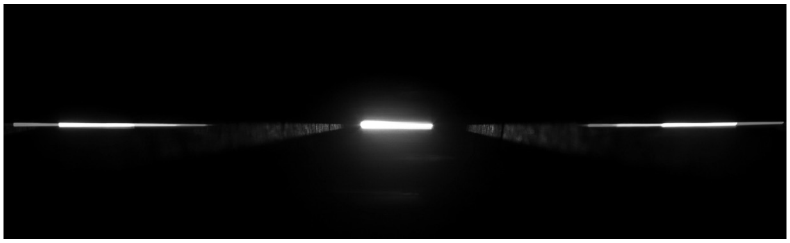
This is an example of what you might see through your spectroscope before it is aligned.

4. **Align** (precisely adjust) the spectroscope. We want to align our slit with the diffraction grating so that we get a wide spectrum, which will be easy to see. You'll need some patience for this.

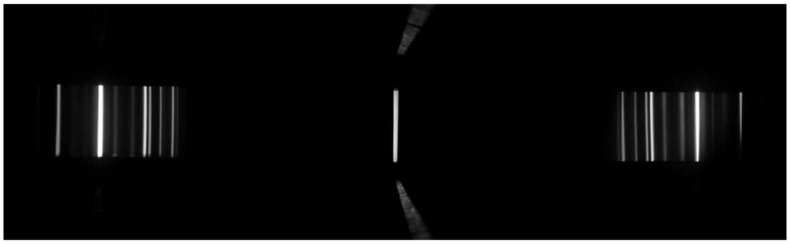
   Hold the spectroscope so that you can look through the diffraction grating end (the plastic square should be about as close to your eye as your glasses' lens or as close as you would put a microscope). Point the slit end of the spectroscope towards a light source – this can be a light in the room or if you are outside, at the SKY, but NOT the SUN! Look for a rainbow in the spectroscope, probably a little bit off to the side or up or down (you should be able to see regular light from your source coming through the slit, but the rainbow will be off-center).

<u>Never look directly at the Sun with the spectroscope or your naked eye!</u>
<u>It can result in permanent eye injury!</u>

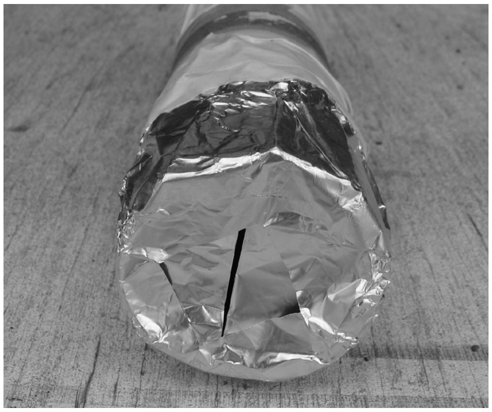
While still pointing your spectroscope at the same light source and holding the tube steady, twist the slit around until the rainbow is as "fat" or "tall" as you can make it. (Conversely, you can twist the tube while holding the slit end steady – either is equally effective.) Once you are satisfied, tape the foil of the slit end into position. That's it!



This smear of color is NOT the final state you are looking for in your spectroscope.



These nice orderly lines represent a fully aligned spectroscope. If this is what you are seeing through yours, you can tape the slit end in place.

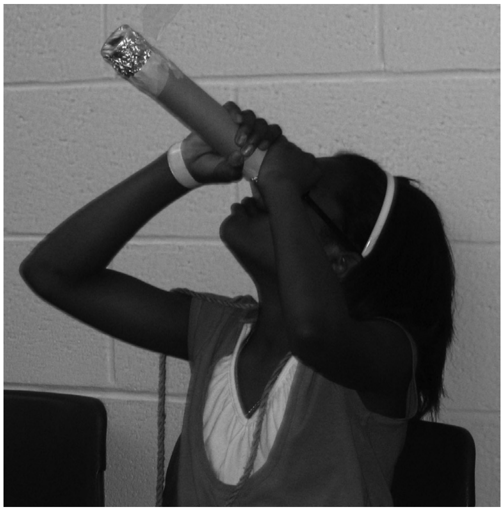


The slit end of a spectroscope. This end points at your light source.

The diffraction grating end of a spectroscope. This end goes up to your eye

Make the point that since they've built the spectroscopes themselves, they know how to fix them if they break.

III. Using the spectroscopes (15 minutes)



A girl looks at a light in the ceiling with her spectroscope.

1. Have students look through their spectroscopes at the sky, which is bright from sunlight, or, for added safety, at a piece of paper that is reflecting the sunlight.

<u>Remind students not to look directly at the Sun, only at other parts of the sky!</u>

This should work even if it's cloudy, but it may not work if it's raining. In that case, an incandescent (common household) bulb can be used.

Ask what kind of spectrum they see.

Do they have an idea of what the diffraction grating in the spectroscope is doing to the light entering it? It separates light into the different wavelengths (colors) that the light is made of. The Sun's (or the incandescent bulb's) spectrum shows all the usual colors of the rainbow. Sunlight is white light, meaning it includes all wavelengths of visible light.

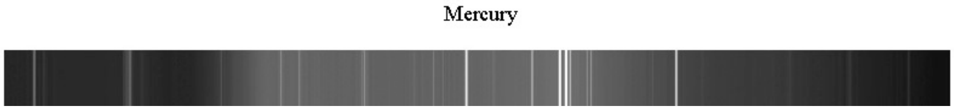
If you're interested, here's a phrase to help remember the order of the colors in the visible spectrum: **ROY G BIV** — (**r**ed, **o**range, **y**ellow, **g**reen, blue, **i**ndigo, **v**iolet)

2. The different colors seen inside the tube represent different wavelengths of light, but all are in the visible range. Going back to the handout, remind students of the last session, and the fact that the spectrum really extends beyond what they can see in their spectroscopes — to "invisible light," like infrared, ultraviolet, X-ray, radio, etc.

3. If you have light sources that produce distinct bright lines, have the students look at them but don't tell them what they are looking at. What differences do they notice between the Sun's spectrum and the spectra of these artificial lights?

Are all of the ROY G BIV colors present in this new spectrum?

Mercury fluorescent lights produce a faint continuous spectrum (like the Sun, but much dimmer) with four or five bright lines. Depending on how much your personal eyes can see, one or two lines will be red, one will be green, and two will be blue/violet. These bright lines are the spectral "fingerprint" of mercury. Whenever you see these lines at the same wavelengths, mercury is in the light source. If you don't see them, there is little or no mercury in that bulb.



Two versions of the spectrum of Mercury. The first is a simplified line drawing, and the second is a black and white version of what would actually be seen in a spectroscope.

Each element and compound has a unique fingerprint — a unique pattern of spectral lines at specific wavelengths. The word spectrum is also used to refer to the fingerprint for a particular element or compound, so mercury's fingerprint is also called mercury's spectrum. Remind students that:

Elements contain all the same kind of atom.

Examples:

- pure gold
- silver
- copper
- aluminum
- oxygen

Compounds contain atoms of two or more different elements that are chemically bound together.

Examples:

- water (hydrogen + oxygen)
- table salt (sodium + chlorine)
- ammonia (nitrogen + hydrogen)
- sugar (carbon + hydrogen + oxygen)

Astronomers use spectral fingerprints to figure out what objects, like stars and galaxies, are made of. With very powerful instruments, they can even tell how much of an element or compound is present: bright lines mean a lot; faint lines mean very little.

The spectral fingerprint of carbon.

4. It can be fun to provide colored pencils, markers, or crayons for them to draw the different spectra that they observe. In Appendix F, there is a picture of several of the different spectras that they might see, depending on what light sources are available.

5. Send students home with their spectroscopes and encourage them to look at lights near their homes. Most street lamps are either mercury or sodium lamps, but "neon" signs often contain many different elements besides neon. Sodium street lamps have a distinct dark line that is easily visible.

Remind students not to look at the Sun!

Have them talk about what they found the next time the group convenes.

Suggestions for Running this Session

- For this session, you'll need enough paper towel tubes for each student to build a spectroscope, so you should begin collecting these well in advance of the session! Ask friends, colleagues, students, etc. to save their paper towel tubes for you. You may even be able to have the cleaning staff at your location save you some (though make sure that those tubes are still a good size/shape for building a spectroscope). In a pinch, you can buy mailing tubes that have the same size/shape as a paper towel tube.

- People often ask about using toilet paper tubes or other tubes for the spectroscopes, and these generally don't work well. A paper towel tube has the right diameter and length to project the spectra from the diffraction grating onto the inner walls of the tube. There may be some other viable options out there, but we haven't found any, so we're sticking with paper towel tubes.

- When purchasing the diffraction grating for the spectroscopes, make sure you choose single axis diffraction grating and avoid double axis or holographic options. While these will create interesting effects, they will not accomplish the desired goals of this session.
- When building spectroscopes with a group of people, it is common for individuals to either get ahead or fall behind. Whoever is guiding the activity should be careful to do each step one at a time, and then pause so that everybody has a chance to catch up. Everybody following along should be encouraged to wait, and not get ahead of the group.
- If the students cut too large of a hole in the foil piece intended for the diffraction grating, they may be able to set it aside for the other end, as long as the hole they have cut is smaller than the opening in the tube.
- If you have access to them, there are special elemental spectrum light bulbs that can be purchased in a variety of different elements. These bulbs allow you to see the spectrum of specific elements, and are an excellent extension to this activity if you have access to them. However, they are expensive, so we do not include them as a default part of this session. Sometimes science departments have these lamps and are willing to lend them out for educational programs, so you might consider checking with your local high school or university.

Useful websites for background or activity extension

- ***Imagine the Universe!***
  Basics on the electromagnetic spectrum, with a link to more advanced information
  http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html
- **Steward Observatory, University of Arizona**
  Higher level information on spectroscopy and its tools, and astronomical spectroscopy
  http://loke.as.arizona.edu/~ckulesa/camp/
- **NASA's Infrared Processing and Analysis Center (IPAC)**
  Good explanations of absorption and emission spectra and spectroscopy
  http://www.ipac.caltech.edu/Outreach/Edu/Spectra/spec.html
- **University of Ottawa**
  Beautiful displays of spectra from the first 36 elements on the periodic table in the top half of the page (no need to look at the bottom half)
  http://laserstars.org/data/elements/index.html

Session 6 – Stars and Their Lives

Brief Description

Students learn that our Sun is a star. They are then led through a kinesthetic modelling activity to learn how the life cycle of a star depends on its mass. The next session (Session 7) goes into more detail about how stars fuse elements in their core, and how those elements are dispersed into the Universe at the end of their lives. Session 7 is intended to be an optional extension of this session for those leaders who wish to get into a more detailed exploration of stars.

Objectives

- To ensure that students understand that our Sun is a star.
- To show how stars go through life cycles dependant on their masses.

Concepts Addressed

- The effect of distance on how bright a source of light appears
- Energy generation in stars
- Balance of forces in the interiors of stars

Materials

- A blackboard, whiteboard, or a flipchart on an easel
- Chalk or markers
- Two 8″ × 11″ sheets of cardboard or thick construction paper
- Two identical sources of light — an uncovered table lamp with a 10W or 20W frosted bulb is best
- *The Lives of Stars* handout (black and white version included in Appendix E and color version included in Appendix F)
- Images of stars at different stages in their life cycles (included in Appendix F)
- Pair of scissors

Other Requirements

- Large room with sufficient space for students to model the life cycle of a star
- A long dim hallway or a room that can be darkened
- Electrical outlet for lamp

Background

Stars are big balls of hot gas, mostly hydrogen. Our Sun is a star, the closest one to Earth, and this is why it looks so big and bright. The Sun has a mass that is about 330,000 times more than the Earth. Its radius is about a 100 times that of the Earth, so a million Earths can fit inside the Sun! Our Sun is large relative to the planets, but it is an average size in comparison to other stars. In the extreme, stars can be up to 100 times more massive than the Sun.

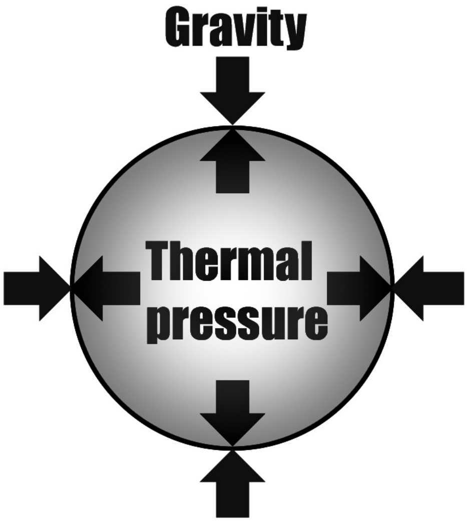
Stars generate energy by converting lighter elements to heavier elements by a process of nuclear fusion in their cores. These elements act like the "fuel" to generate a star's energy. This energy flows outward and counterbalances the inward gravitational force. Stars spend the majority of their lives with these two forces in balance, as shown in the image to the right.

Stars go through a cycle of birth and death, but the timescales involved are much longer than we associate with living things (which stars ar not). Young stars are born in clouds of gas and dust called a nebula. Particles inside these nebulae collide and clump together due to the force of gravity. When enough material has accumulated, fusion kicks in and a star is born!

The lifetime of a star depends on how massive it is. Small stars live many billions of years, but the most massive stars live only a few million years. Our Sun, a medium star, is 4.5 billion years old and about halfway through its life cycle.

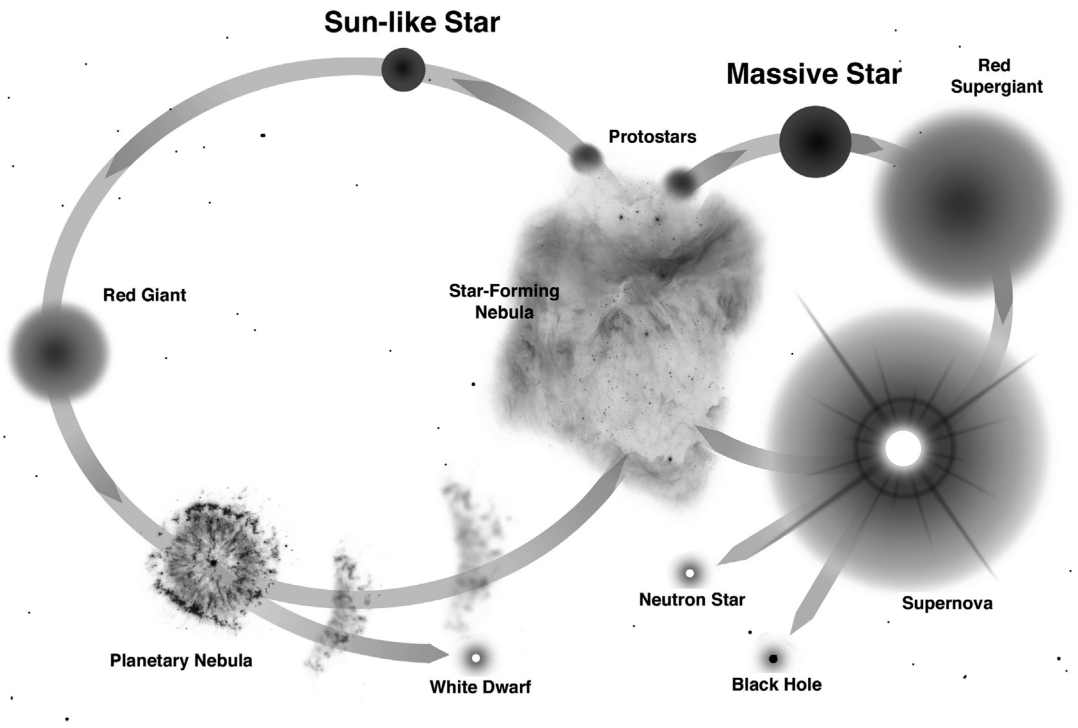
Stars that are not very massive (like our Sun) spend the majority of their lives (many billions of years) in a phase known as the "main sequence" stage in their lives. During this stage, they fuse hydrogen into helium in their cores. When this fusion ends, they expand into a "red giant" phase. Our Sun will become a red giant 5 billion years from now. At this stage in its life, the Sun will puff up and swallow the Earth. After a brief phase in which helium is fused into carbon, red giants blow off the outermost layers. These layers form a disk of material around the star – this is called a "planetary nebula" as it looked like a planet when seen through early telescopes. However, this has nothing to do with planets.

The hot core that is left behind is approximately the size of the Earth and is called a "white dwarf." White dwarfs are very dense — a teaspoonful of white dwarf material would weigh 15 tons on Earth! White dwarfs shine for many more billions of years as they slowly cool.



The balance of forces within a star.

The most massive stars run through their "fuel" at their centers in only a few million years. When the fuel is used up, the force of gravity overwhelms the outward push from the energy generated by the fusion. As a result, the core regions of the star collapse catastrophically releasing enough energy to blow apart the rest of the star. This is called a "supernova explosion." These explosions are so bright that they briefly outshine entire galaxies! Supernovae (the plural of supernova) also have so much energy that elements heavier than iron are formed during these explosions. With the exception of hydrogen



The lifecycles of both a small to medium star and a massive star.

and trace amounts of other small elements, all of the elements that make up our body (carbon, oxygen, nitrogen, iron, etc.) were formed either through nuclear fusion inside of stars or during supernova explosions. All the elements that were formed inside the stars are spewed out when they explode, and this is how elements are dispersed throughout the Universe. We are all literally made of star stuff!

From these more massive stars, the core left from the supernova may be a neutron star or a black hole. A neutron star is an extremely high density star, where gravity is so strong that protons and electrons combine to form neutrons. The density in the interior of a neutron star is much higher than in the interior of a white dwarf. A sugar-cube sized lump of neutron star material would weigh 100 million tons on Earth!

But, if the star is massive enough, the object left after the explosion is still too massive to support itself against gravity. The object continues to collapse until it forms a black hole. A black hole is a point in space with tremendous gravity — so great that not even light can escape from it, hence the term "black" hole.

Session Overview

This session begins with an activity to help students recognize that the Sun is a star and looks bright only because it is so close. It is then followed by an activity where students act out the life cycle of a star and learn the different stages a star goes through from birth to death.

Preparation

- Cut a 1″ diameter hole in the centers of the two pieces of cardboard or construction paper.
- Print copies of the images of stars at different stages in their life cycle, cut apart, and laminate them or paste them onto cardboard or construction paper.
- Print copies of the *Lives of Stars* handout.
- Familiarize yourself with the *Lives of Stars* handout.

Activity

I. Our Sun is a Star (15 minutes)

This activity is intended to demonstrate how things look brighter when they are closer and fainter when they are far away. It is best done in a long dim corridor, if possible. But a regular classroom will also work.

1. Start by discussing whether students have seen car headlights on the road at night. Ask if they notice what happens when cars are near them and when they are far away. From this discussion, students should get the idea that the same headlights looked faint when they were far away and much brighter when they were closer.

   (*You can use other examples that might better suit the experiences of your students. For example, street lights get bigger and brighter as you walk towards them and dimmer as you walk away from them.*)

2. Now, darken the room and have a volunteer stand at one end of the room with an uncovered lamp. Have them hold the cardboard or construction paper with the hole in front of the bulb so that only a circle of light is seen. This represents our Sun. Have another volunteer stand next to the first with the second lamp representing an identical star. Have the rest

Students observe two identical bulbs at the same distance.

of the students look at the two lamps. Ask them how bright the "Sun" looks from where they are standing. How bright does the other "star" look? Have them confirm that the two lamps are indeed identical, and they are the same brightness because they are both at the same distance. (Note: If the two bulbs are identical and sufficiently round, the cardboard or paper is unnecessary for this demonstration to work.)

3. Next, have the volunteer with the "star" move a little further away while the volunteer with the "Sun" stays close. Ask the other students if the two lamps look the same now. Hopefully, they will be able to see that the "star" does not seem as bright as the "Sun," even though we know that they are identical. Have the volunteer with the "star" move progressively further away from the "Sun" and repeat the conversation each time.

   Finally, have the volunteer with the "star" move as far away from everyone as possible. This simulates our nearest star compared to our sun. Ask all the other students to cluster together at the opposite end of the room and ask how bright this "star" looks. With one lamp near, and one lamp farther away, do they still look the same in brightness? Make the point that this is the same lamp, so the brightness is the same as before (as our "Sun"). Next, ask if it might ever get to a point where it looks only like a little bright dot. The students should get the point that the "Sun" looks big and bright the closer we are to it.

When the two bulbs are at different distances, they will appear to be different sizes and brightnesses, even though they are identical.

   (This comparison works best in spaces that are large enough for the distances to make a difference. If you are in a small space, you can try this activity with smaller/dimmer bulbs.)

4. Now ask what would happen if we took one of these lamps outside into the sunshine. Would we be able to see the light from this bulb? It would be lost in the Sun's glare! Similarly, the stars are always there in the sky, but <u>we can only see them when it gets dark</u> because the sunlight is too bright during the daytime. Ask if anyone has ever witnessed a total solar eclipse — the sky gets very dark during the daytime and we can see the stars!

5. The students should now be led to the conclusion that the other stars in the sky are just like our Sun. They look so small because we are very far away from them. Remind them of the postcard activity in Session 3. If someone was to mail a postcard from the nearest star to us, it would take over 4 years to reach us if it traveled at the speed of light! Space is very big!

6. Write the following on the blackboard/whiteboard/flipchart:

   Our Sun is a star, just like the tiny points of light we see in the sky at night. It looks bigger and brighter only because we are very close to it.

II. Stellar Life Cycles Kinesthetic Activity (~25 minutes)

(*Adapted from the "Kinesthetic Life Cycle of Stars" activity developed by Erika Reinfeld at the Harvard-Smithsonian Center for Astrophysics and Mark Hartman at the MIT Kavli Institute for Astrophysics and Space Research.*)

During this activity, students will model the life cycles of stars. Hand out the Lives of Stars handout and explain that during this exercise the students will take on the different roles shown in the cycle. They will act out the birth, life, and death of a star!

Clearly explain any and all safety considerations to students. Impress on the students that they must not hurt each other as they move about and act out the life of a star. You may want to conduct this activity outside, if space is limited.

Guide each section of the life cycle with specific steps – instead of having student rush inward and outward, instruct them to "take three steps backward" or another cue to proceed calmly to a new position.

The majority of physical contact between students should take place with only hands, but if this is an issue for you or your students, even this is unnecessary.

If you are comfortable with it, students can be encouraged to make sound effects where appropriate – explosions and collapses can be dramatic! The overall noise of the activity should be kept quiet enough to hear leader instructions throughout.

Before beginning the activity, write on the blackboard and verbally ask the following questions:

- *What holds a star together?* (Answer is gravity.)
- *Do stars change over their lifetime?* (Yes.)

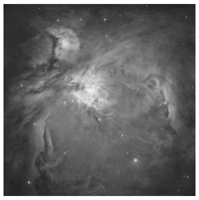
Explain that this next activity will show how stars change and what might make them change. Tell them that they will play the roles of a star in the different stages of its lifetime. You will start with the life cycle of a small or medium-sized star, and then repeat the activity for a large star. It is recommended that you do a trial run of each activity, and then repeat it for maximum impact and understanding.

SMALL & MEDIUM STARS

This kinesthetic activity models the life of a small to medium sized star, such as our Sun. Check our online resources for a video about the small star kinesthetic.

Each person involved in this activity represents a bit of the material that goes into making such a star.

- **Stage 1: Star Formation**

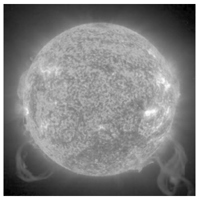


Students should move around or dance freely and be as spread out as possible to simulate that bits of space matter are hanging out more or less randomly as a cloud in space. If space allows, students should have their arms partially or totally stretched out at their sides.

The activity facilitator should give the students a cue (such as a reminder that gravity will pull things together). After this cue, when students come close to each other, they should remain close, adding more and more students to the group until everybody is included in the big circle. There should remain plenty of space between the people at the center, so they have enough room to group further together as the activity progresses.

Students dance freely in the star formation stage of the life cycle activity.

- **Stage 2: Main Sequence Star**



Once all of the students are clumped together, we say that a star has been born. The students at the edges form a ring facing inward, as the outer shell of the star. They should raise their hands in front of them, palm outward, to represent the inwardly directed force of gravity. Those at the center – the core of the star – should face outward and put up their hands in front of them in the same way. This represents the energy generated by the fusion of hydrogen at the center of the star, which causes an outward pressure. The two groups are now effectively pushing at

Students act out the main sequence star stage of the life cycle activity.

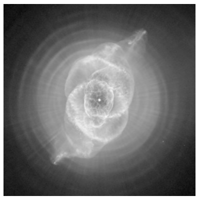
each other, palm to palm, without moving. The students that form the shell may push gently inward, and the students that form the core may push gently outward with the same force. This represents the balance of forces that characterizes a star on the Main Sequence, where stars spend most of their life.

- **Stage 3: Red Giant**

After billions of years, our star runs out of hydrogen (its fuel) to fuse at the center. When this happens, the students in the center stop pushing outward and drop their hands, symbolizing the loss of that outward pressure that comes from the fusion process. The students representing the core take a tiny step backwards, bringing them closer together, a result of the gravitational force without the balancing outward pressure. Because everything in the core is now closer together, it heats up, which gives our star enough energy to start fusing all that helium that has built up, and it has a new fuel! Not only do the students that represent the core put their hands back up, but because of all the extra heat, the outward force is even greater than before! To show this, the shell students take a step away from the core students. Point out that the star has now increased in size! This is what we call a Red Giant.

Students act out the red giant star stage of the life cycle activity.

- **Stage 4: White Dwarf**



Eventually the star runs out of helium to fuse at its center as well. Once again, the students in the center stop pushing outward and drop their hands, the gravitational force briefly overwhelms the star, and the students representing the core take another tiny step backwards. As before, this causes the core to heat up some more, but in a small star, it can't heat up enough to fuse any other elements. All the heat can do is give one last dying push of energy, pushing the shell away. The core students take another tiny step backwards, forming what we call a "white dwarf." The shell students drift off, representing material dissipating into space. While this shell material is dissipating, we call this a planetary nebula. Point out the spot in the handout/poster they are now at.

Students act out the white dwarf star stage of the life cycle activity.

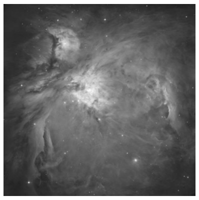
The students should understand this is the end of one star's life, but the material that drifts off into space can go on to participate in other dances and create new stars.

LARGE STARS

Check our online resources for a video about the large star kinesthetic.

This kinesthetic activity models the life of a large star that is many times the mass of our Sun. Each person involved in this activity represents a bit of the material that goes into making such a star.

- **Stage 1: Star Formation**

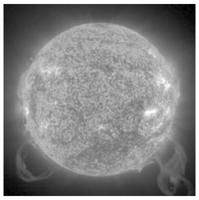


Students should move around or dance freely and be as spread out as possible to simulate that bits of space matter are hanging out more or less randomly as a cloud in space. If space allows, students should have their arms partially or totally stretched out at their sides.

The activity facilitator should give the students a cue (such as a reminder that gravity will pull things together). After this cue, when students come close to each other, they should remain close, adding more and more students to the group until everybody is included in the big circle. There should remain plenty of space between the people at the center, so they have enough room to group further together as the activity progresses.

Students dance freely in the star formation stage of the life cycle activity.
This stage is the same for large stars as it is for small and medium stars.

- **Stage 2: Main Sequence Star**



Once all of the students are clumped together, we say that a star has been born. The students at the edges form a ring facing inward, as the outer shell of the star. They should raise their hands in front of them, palm outward, to represent the inwardly directed force of gravity. Those at the center – the core of the star – should face outward and put up their hands in front of them in the same way. This represents the energy generated by the fusion of hydrogen at the center of the star, which causes an outward pressure. The two groups are now effectively pushing at each other, palm to palm, without moving. The students that form the shell may push gently inward, and the students that form the core may push gently outward with the same force. This represents the balance of forces that characterizes a star on the Main Sequence, where stars spend most of their life.

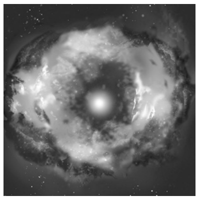
The main sequence stage is also the same for large stars as it is for small and medium stars.

- **Stage 3: Red Giant**

After billions of years, our star runs out of hydrogen (its fuel) to fuse at the center. When this happens, the students in the center stop pushing outward and drop their hands, symbolizing the loss of that outward pressure that comes from the fusion process. The students representing the core take a tiny step backwards, bringing them closer together, a result of the gravitational force without the balancing outward pressure. Because everything in the core is now closer together, it heats up, which gives our star enough energy to start fusing all that helium that has built up, and it has a new fuel! Not only do the students that represent the core put their hands back up, but because of all the extra heat, the outward force is even greater than before! To show this, the shell students take a step away from the core students. Point out that the star has now increased in size! This is what we call a Red Giant. Point out that we were at the same stage for the smaller stars – both small and large stars go through this stage (though the time-frames involved are different). However, what happens next is different for the two types of stars.

Students once again act out the red giant stage of a star's life cycle.

- **Stage 4: Supernova**



As with a smaller star, eventually the core runs out of helium to fuse. Once again, the students in the center stop pushing outward and drop their hand, the gravitational force briefly overwhelms the star, and the students representing the core take a tiny step backwards. As before, this causes the core to heat up some more, because everything is closer together. In a large star, this is sufficient to start the next level of fusion. The students that represent the core put their hands back up, and again the shell students take a step away from the core students to represent the greater outward force.

The largest stars are able to go through these steps multiple times, contracting the core and expanding the shell of the star outward with each repetition. The students can act this out multiple times, continuing to face each other and "push" with a balance of forces in between each collapse and expansion phase.

Eventually, the core of the star is made of iron, and at this point it has really run out of fuel! No matter how big the star is, it can't get enough energy to fuse iron. The outward force again goes away, and the core students stop pushing outward and drop their hands. Since the inward force of gravity is still in effect, but the core has no more energy to hold it up, the core collapses – the core students take another step backwards.

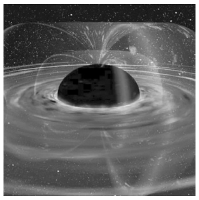
Students acting out the part of the star's shell rebound off of the core and fly off into space to form other stars.

When the core collapses, two things happen simultaneously:

1. The core heats up dramatically, causing one last outward wave of energy and pressure. In our activity, the students who make up the core of our star should make a stronger push outward than any they have made so far.
2. With nothing to balance the gravitational force, the shell rushes inward towards the core. The students who make up the shell should rush inward towards the core, with their hands still raised.

When the shell material reaches the outward pressure wave, it rebounds off and explodes outward. Our students represent this meeting when the hands of the students in the shell meet the hands of the students in the core, which are pushing outwards. The shell students should bounce (gently) off the core students' hands and explode outward in all directions, simulating the supernova! (This is labeled as "Supernova" on the handout.)

The core students then take a final step backwards, ending up closer together than they have been up to this point, because the core collapses even more and creates an even denser object than a white dwarf: either a neutron star or a black hole, depending on the original mass of the star.



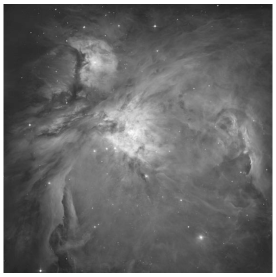
At this point, ask the students to tell you what this looks like. Ask them if they have ever been in this position before.

It is important to point out that from these points, the endpoints of each dance, the cycle starts again with Stage 1. Collect the group back together, and conduct a discussion about what they just did. Look at the handouts and/or poster and walk through the activity that was done. Ask students to describe what was going on at each stage.

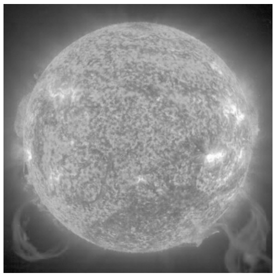
Now, revisit the questions that you asked originally. There should be a consensus as to the answers, and an understanding that stars go through stages that are part of a cycle.

III. Matching images of stars to the handout (10-15 minutes)

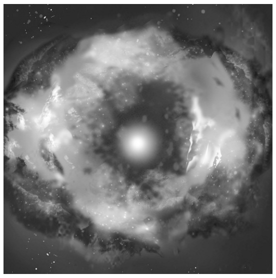
1. Split the students into groups of 2 or 4. Distribute the images of the stars at different stages in their life cycles to them. The images given are:



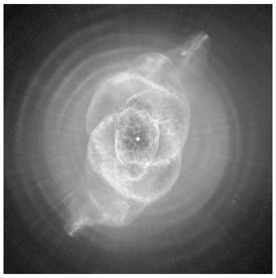
The Orion nebula as an example of a gas cloud in which stars are born



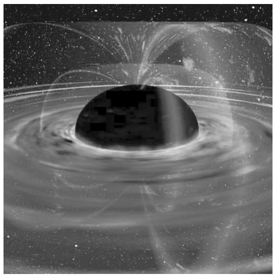
An image of our Sun (taken by the SOHO spacecraft), as an example of a main sequence star



An artist's impression of a supernova explosion



A picture of a white dwarf (that, in this case, is surrounded by a "planetary nebula" which is the gaseous remains of the original star but has nothing to do with a planet)



An artist's impression of a black hole

2. Talk about how these five objects are connected to each other and what is going on in each image. Now ask the student teams to cut apart the images. Ask the students to place the images on the handout at the proper stage in the cycle. Ask for students' thoughts.

   Please note, some of these objects are from the life cycle of a low-mass star, and some are from the life cycle of a high-mass star, so don't let that confuse you.

Suggestions for Running this Session

- Because this is an activity where everybody gets up and moves around, you may need to be conscious of crowd control issues. If this is an issue, have the students do all actions slowly and gently, and remind them that we are all peaceful, non-violent stars. In the end, you know your group best, so treat them accordingly.

- If you feel that physical contact is an issue for your group, it is entirely possible to do this session without any touching at all. Set up those ground rules at the start of the activity if that's the route you want to take.

Misconceptions

- Before this session, many participants may have heard something about supernovae and carry the misconception that the Sun will end its life in a violent explosion or a black hole. This is untrue, as the Sun will follow the life cycle of a small/medium star, ending up as a white dwarf with a planetary nebula. Remind them of this during the activity, to emphasize which life cycle will apply to the Sun.

Useful websites for background or activity extension

- ***Imagine the Universe!***
  Check out this site for more information and activity books on the life cycles of stars.
  Designed for educators at the high school level.
  http://imagine.gsfc.nasa.gov/docs/teachers/lifecycles/stars.html

- ***Chandra Science Center***
  This site offers a clear but higher level explanation of the story of stellar evolution with interactive graphics and animations. There are also suggestions for other activities and web-based games.
  http://chandra.harvard.edu/edu/formal/stellar_ev/

Session 7 – Stars and Their Lives (Part II)

Brief Description

This session is an optional extension of the previous session (Session 6) on stars. It will go into more details of how stars generate energy by a process of fusion in their cores. All the elements in the Universe are made in stars. The session ends with a demonstration and an activity that show how the most massive stars collapse at the end of their lives and disperse the elements out into the Universe.

Objectives

- To expose students to the idea that stars generate energy by "cooking" elements in their cores.
- To show that supernova explosions spew out the elements stars have cooked in their interiors into the Universe.

Concepts Addressed

- Nuclear fusion
- We are all "star stuff" — we are all made of the elements stars create in their cores

Materials

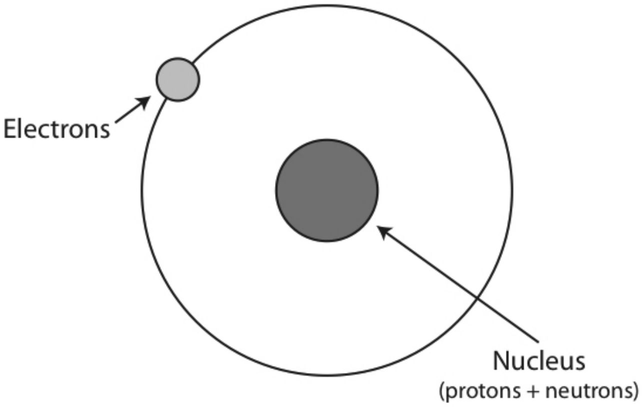
- Periodic table (1 per student; black and white version included in Appendix E and color version included in Appendix F)
- Clay (or Sculpey, for a more permanent model) of 5 or more different colors to represent different elements — enough to create the stellar core and several small balls for each element. See the "Preparation" section for procedure.
- Hotplate
- Heavy oven mitts or set of rubber-tipped tongs
- Clear bowl (at least 6″ in diameter and 2″ deep) filled with cold water
- Ice (to be added to the bowl of water to keep it cold during the session)
- Empty soda cans (without dents or creases)
- Tennis balls (1 per student)
- Ping pong balls (1 per student)

Other Requirements

- Electrical outlet for hotplate
- Large room with free space or a corridor for activity using the tennis balls and ping pong balls

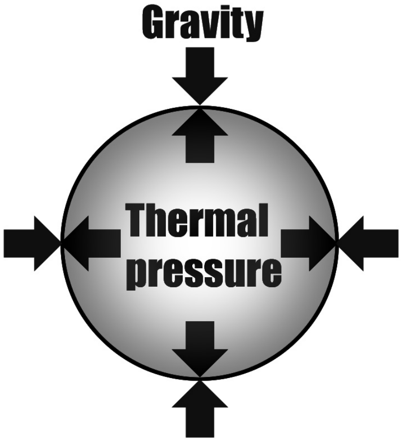
Background

Stars are big balls of hot gas, mostly hydrogen. Stars generate energy by converting lighter elements to heavier elements by a process called "nuclear fusion" in their cores. Elements are made of atoms. Atoms are composed of a central "nugget" called the nucleus that is composed of protons and neutrons. The nucleus is surrounded by a cloud of one or more electrons. An element is characterized by the number of protons in its nucleus. Different elements have different numbers of protons in their nuclei. For example, hydrogen has one proton, helium has two protons, oxygen has eight protons, and so on.



Basic elements of an atom.

Nuclear fusion is the process by which the nuclei of two atoms come together and merge, forming a new nucleus. Since an element is defined by the number of protons in the nucleus of each of its atoms, nuclear fusion invariably converts one element into another. During most of a star's life, energy is generated by the fusion of hydrogen nuclei (consisting of just one proton and no neutrons) into helium nuclei (consisting of two protons and two neutrons). It takes four hydrogen nuclei to produce one helium nucleus (and, in the process, two of the protons undergo a conversion into neutrons). The energy generated by the fusion flows outward and counterbalances the inward pull of gravity on the star. Stars spend the majority of their lives with these two forces in balance.



The balance of forces within a star.

Stars go through a cycle of birth and death, but the timescales involved are much longer than we normally associate with living things. Young stars are born in clouds of gas and dust called a nebula. Particles inside these nebulae collide and clump together to form stars. When enough material has accumulated, the pressure and temperature in the core exceeds a critical threshold and fusion kicks in. A star is born!

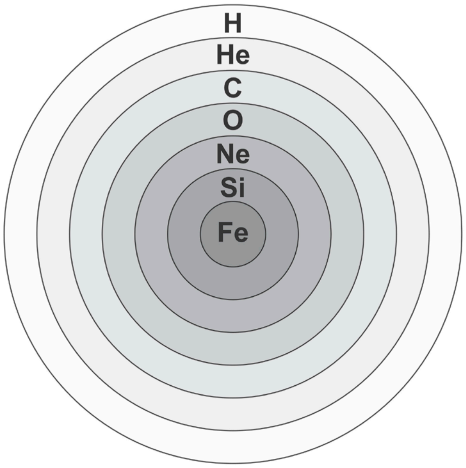
The lifecycle of a star depends on how massive it is. Small stars live many billions of years, but the most massive stars live only a few million years. Our Sun, a medium-sized star, is 4.5 billion years old and about halfway through its life cycle.

Stars that are not very massive (like our Sun) spend the majority of their lives (many billions of years) in a phase known as the "main sequence" stage in their lives. During this stage, they fuse hydrogen into helium in their cores. When this fusion ends, they expand into a "red giant" phase. Our Sun will become a red giant 5 billion years from now. At this stage in its life, the Sun will puff up and swallow the Earth. After a brief phase in which helium is fused into carbon, red giants blow off the outermost layers. These layers form a disk of material around the star — this is called a "planetary nebula," as it looked like a planet when seen through older telescopes. However, this has nothing to do with planets.

The hot core that is left behind is approximately the size of the Earth and is called a "white dwarf." White dwarfs are very dense — a teaspoonful of white dwarf material would weigh 15 tons on Earth! White dwarfs shine for many more billions of years as they slowly cool.

Due to the higher temperatures and pressure in their cores, the nuclear fusion in massive stars does not stop with carbon. The star goes through successive periods in which carbon is fused into oxygen, oxygen is fused into neon, neon into silicon, and silicon is fused into iron. The sequence of nuclear fusion stops with iron. This is because fusing iron into the next element requires an <u>input</u> of energy rather than resulting in a release of energy. At this point, the star has an "onion" structure in which an iron (Fe) core is surrounded by rings of the different elements that the star has produced, as illustrated below. The specific elements, the thickness of layers, and their order may vary from star to star.

Once nuclear fusion stops, the force of gravity finally overwhelms the core. The core collapses catastrophically, releasing enough energy to blow apart the rest of the star. These explosions, known as supernovae, are so bright that they briefly outshine entire galaxies! Supernovae also have so much energy that elements heavier than iron are formed during these explosions. With the exception of hydrogen, all of the elements that make up our body (carbon, oxygen, nitrogen, iron etc.) were formed either through nuclear fusion inside of stars or during the supernova explosions of massive stars. All the elements that were formed inside stars are spewed out when they explode, and this is how elements are dispersed throughout the Universe.



An example of the "onion shell" structure of a star.

Session Overview

This session consists of a series of interactive demonstrations. The first demonstration shows how stars fuse elements in their cores to make new elements. The second demonstration shows how a star collapses at the end of its life, while the final activity is intended to show how elements get dispersed into the Universe when the star explodes.

Preparation

- Make the stellar clay core before the session. Start by making a ball about 1 inch in diameter using the color of clay that will represent neon. Completely cover that ball with a ¼″–½″ layer of "oxygen-colored" clay. Then add a layer of "carbon," then "helium," then "hydrogen." You can choose any colors you like to represent these elements, but it will be easier to see the layers if adjacent colors contrast with each other. You may make this model out of Sculpey instead of clay if you would like a more permanent version. If you use Sculpey, you should cut this model in half before baking it. This step can wait until the demonstration if you are using soft clay.

  Onion shell model split open.

  Record the colors you used for each element and keep that handy throughout Part II.

  In addition, make several small clay balls of each of the colors/elements. In order to demonstrate all the different fusion reactions you will need at least twenty balls for hydrogen, five balls for helium, one for carbon, one for oxygen, and one for neon, in order of increasing size. As they go up, they should be roughly equivalent in size to their squished counterparts.

- Plug in the hotplate so it starts heating. Set up the bowl of cold water and put aside. Allow time for the hot plate to heat thoroughly before starting. **<u>PRACTICE</u>** the demonstration for Activity 2 before attempting in front of students. It helps to use an underhand motion, starting with the palm of your hand pointed towards the ceiling, so you can easily flip your wrist over and dunk the can.

  The underhand motion that helps
  with this demondstration

- Make ice beforehand so that you can have a bowl of ice water for this session.
- Familiarize yourself with the periodic table.

Activity

I. Demonstration of Where Elements Come From (15 minutes)

Check our online resources for a video about this clay fusion demonstration.

1. This part of the session is an interactive discussion and demonstration of how stars fuse elements inside their cores. A suggested path for this discussion is below. Allow students to reply after each of the questions before proceeding. You can have students handle the small clay balls as they come up in discussion. If you have sufficient clay, you can have the students work in pairs or small teams to make their own stellar clay models as they follow your lead.

2. Ask who in the class has heard the term "atoms." Ask what they know about atoms. If they don't mention protons and electrons, just leave them out. But if they do mention them, then you can say that an element is defined by the number of protons it has in its nucleus. Hand out the periodic tables.

3. Ask where the elements come from. In the Big Bang, hydrogen (H) — the lightest element, and helium (He) — the second lightest, were created. This is partly why there is so much of these elements in the Universe. The Universe today is about 90% hydrogen and almost 10% helium. All the rest of the elements make up much less than 1% of the Universe. (A very small amount of lithium — the third lightest element — was also created in the Big Bang, but mention this only if it comes up in discussion.) But where does everything else come from? See if anybody has any ideas.

Hydrogen and helium atoms.

4. All of the other elements come from stars, but how? The center of a star is very hot (millions of degrees) and very dense. This means that there's a lot of stuff in a space that's too small. Draw an analogy to cooking. Ask them what happens when you cook. They probably know that you mix and heat ingredients, and get something new. This is a good analogy to what happens in a star. The process of fusion releases energy. And it is this energy that makes the Sun and all other stars shine. This keeps the balance in the star — the energy generated by the fusion flows outward and balances the pressure inwards from the force of gravity so the star doesn't collapse.

5. In the early life of a star, there is a lot of hydrogen in the center, and all those hydrogen atoms bump into each other. Often, some of them will stick together. This is called fusion. Show four small clay balls representing hydrogen, and smash them together. You can have

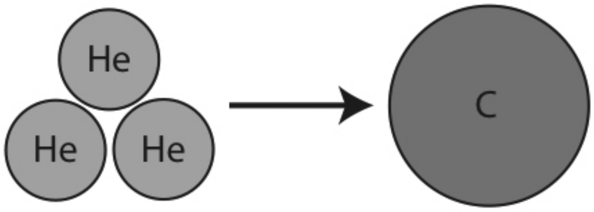
student volunteers come up and fuse the clay balls together at each step, if desired. Or the student groups can do this if they are also making clay stellar models along with you.

6. When these four hydrogen atoms stick together, they form a new element called helium. Bring out a different color clay ball, and explain that it will represent helium. Explain that this is what our Sun is doing now — fusing hydrogen to helium. It has been doing this for 4.5 billion years and will continue for about another 5 billion years.

Four hydrogen atoms becoming a helium atom.

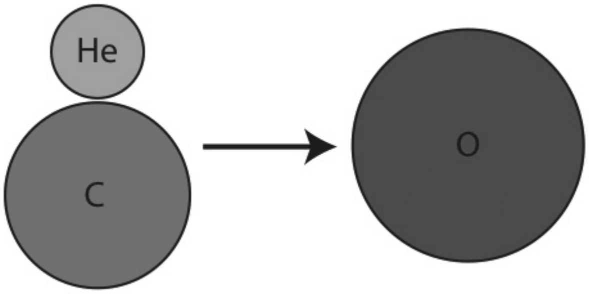
7. Although there is a lot of hydrogen in the star, at some point the hydrogen in the center runs out. Ask what do you think happens at this stage. Remind them of the dance in Session 6 and ask what they did at this point. The correct answer is that the core of the star shrinks.

8. This increases the temperature. Since it is now hotter, helium will start fusing. Helium is heavier than hydrogen so it takes more energy — a higher temperature — to fuse. Explain that when helium fuses, carbon (C) is formed. Smash three balls representing helium, and bring up the clay ball for carbon.



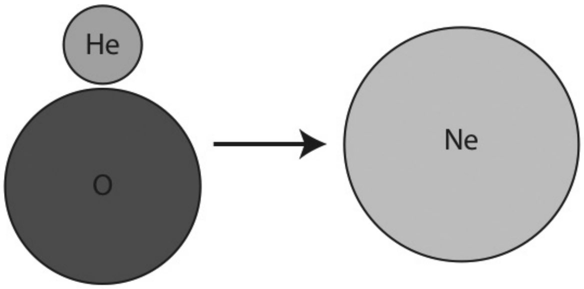
Three helium atoms becoming a carbon atom.

9. Point out that helium fusion continues until the the core is predominantly carbon, and the helium is not bumping into much other helium. In the Sun, things actually stop there! Again, remind them of what happened in Session 6 during the dance. But if the star is much bigger than the Sun, the core shrinks again and it gets even hotter at the center. A carbon and a helium atom can then fuse together to make an oxygen (O) atom.



Helium and carbon atoms becoming an oxygen atom.

10. Then a helium atom and an oxygen atom can also fuse to form a neon (Ne). Use clay balls of other colors to demonstrate these steps.



Helium and oxygen atoms becoming a neon atom.

11. Explain to them that in the largest stars, this process can continue up to the point where iron (Fe) is formed. In order to fuse iron, energy is required. That is, the process requires an input of energy rather than producing energy. Now the balance in the star is broken — the gravity pressing inward isn't balanced by the outward energy created by fusion.

12. Hold up the clay stellar core and then slice into it. Explain that at the end of its life, the center of a massive star looks like this, with all the elements that a star has created in its lifetime in layers inside. It should similar to a color version of the image in the background, with concentric rings of the different elements.

13. Have them look at their copies of the periodic table. Mention that nearly all elements in the periodic table are made in stars.

II. Demonstration of stellar core implosion (20 minutes)

(*Adapted from the Chandra X-ray Observatory's activity on supernova*e)

🎞 Check our online resources for a video about the can crunch procedure and explanation.

Warning: Make sure students don't get too close to this one!
The hot plate remains hot for most of this session!

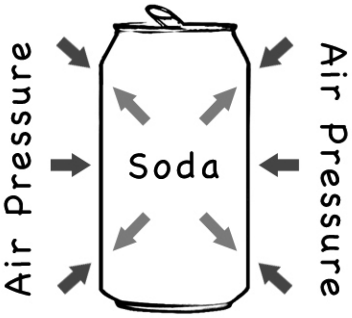
1. Start by telling the students that we will now explore what happens inside the star when the fusion stops. We will do a demonstration that models this process. But as we learned in Session 1, models do not necessarily depict the situation exactly. This demonstration only shows the principle of how the collapse of a stellar core occurs.

2. Place a small amount of water in an empty aluminum soda can (one or two tablespoons). Too much or too little water will affect how well this demonstration works. Set the can on the hot plate. Heat the can until the water starts to boil. When you can hear the rapid boil of the water, and plenty of steam starts to come out of the opening in the top of the can, quickly pick up the can with an oven mitt or tongs and flip it over (open side down) into a bowl of cold water. The can will instantly implode with a crunching sound.

An example of a can that has been imploded.

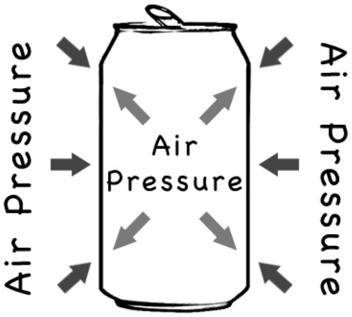
3. Explanation:

When you buy the aluminum can from the store and it still has liquid in it, the can holds its shape due to the equilibrium between the pressure from the soda inside directed outward and the pressure of the air outside of the can directed inward.



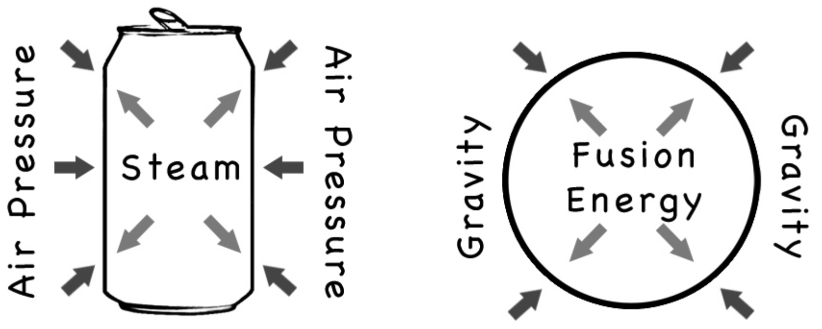
The balance of forces in a can full of soda.

After the can has been emptied of liquid, the shape is held in equilibrium by the pressure of the air inside the can directed outward and the pressure of the air outside of the can directed inward.



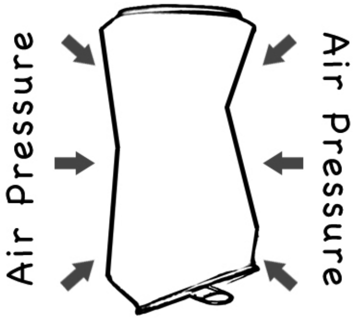
The balance of forces in a can after the soda has been emptied.

Heating the water in the can causes it to turn into steam, which drives the air out of the can because the steam has higher pressure. Now the can is held in equilibrium by the <u>pressure</u> of the steam pushing outwards (like fusion energy in a star) and the <u>pressure</u> of the outside air directed inwards (like the gravity of the star, but not quite the same).



During our demonstration we heat water in our soda can, which means the can fills with steam, which balances the air pressure from outside. We compare this to the balance of forces in a star during the majority of its life.

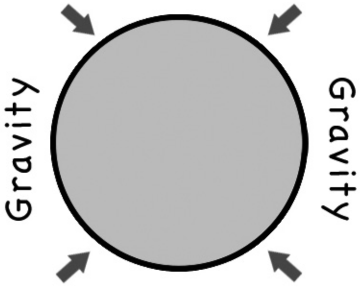
When the can is inverted over the cold water, the steam instantly condenses into water. The water occupies a much smaller volume than the steam did, resulting in much less pressure inside the can. With nothing on the inside to balance the outside pressure the can will implode (like the core of a star collapsing).



The can collapses because there is no longer a balance of forces.

This is sort of like what happens in a supernova, the end of the line for large stars. The star explodes when the two forces that were balancing each other — pressure outwards from the energy generated at the center countering the force of gravity inwards — are no longer in equilibrium.

The central core of the star collapses (similar to the implosion of the can) and the material in the rest of the star starts to fall onto this core. It rebounds and sends the material in the star flying out. This is what is called a supernova explosion and the power of this rebound effect can be seen in the next demonstration. Supernovae do a very important job in the Universe — the explosion sends all those elements out into space and makes new elements with its energy.



The lack of fusion energy inside the star to balance the gravity causes the final collapse of the star.

Tie this activity into the kinesthetic activity that students did in Session 6. How does this experiment parallel the motions that they made at the end of the life cycle of a large star?

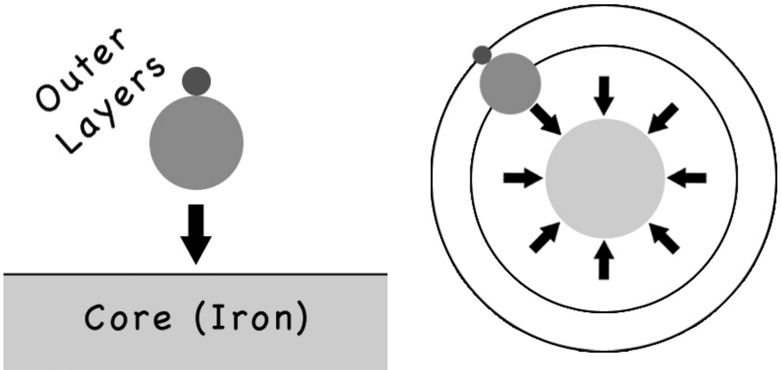
III. Ejection of Outer Layers of a Star (20 minutes)

(*Adapted from the Chandra X-ray Observatory's activity on supernovae.*)

Check our online resources for a video about the ball bounce procedure and explanation.

This activity is intended to show how elements created inside a star get flung out into space during a supernova explosion. Again, this activity only shows the principle behind how this happens and does not reflect the exact process. This activity is best done in a large room with some open space or in a corridor (or it can be done outdoors).

1. Have participants stand in a group, each holding a ping pong ball and a tennis ball. Bring the focus back to the end of the large star kinesthetic life cycle in Session 6. Explain that the ground (Earth) represents the dense inner core of a star. The tennis ball represents the outer part of the core that is falling inward as the star collapses. The ping pong ball represents the outer layers of the star. This idea is illustrated in the following images. Tell them that



The tennis and ping pong balls represent the outer layers of a star falling towards the iron core as it goes supernova.

they are now going to model a supernova explosion and see what happens to the stuff in a star when it explodes.

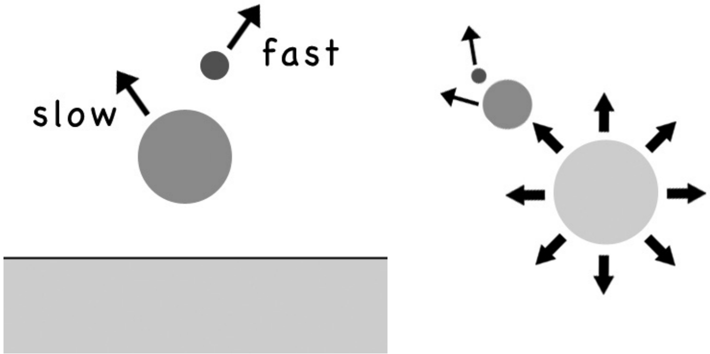
2. Have everyone drop the tennis ball alone, then the ping pong ball alone. Ask them to notice how high the ping pong ball bounces when dropped in this fashion. Have them hold the balls in a stack (ping pong ball on top of tennis ball, as shown in the photo below), and think about what's happening — these layers are falling inward toward the Earth. Have them predict what might happen when the balls fall.

Participants waiting to drop their balls on cue.

3. Have everyone drop their stacked balls and yell, "3-2-1-SUPERNOVA!" What happened? Let everyone do it again once or twice.

Participants observe what happens to the balls once they are dropped.

4. Discuss what happened with the students. What did each ball represent? Did the experiment match their predictions? (When the two balls hit the floor, the ping pong ball will suddenly rebound with a lot of energy. It will bounce higher than it did when it was dropped by itself.) What will happen in space when a spherical star explodes? (The material will go shooting out in all directions.) This idea is again illustrated in the following images.



The tennis and ping pong balls as the outer layers of a star shooting off into space after they have rebounded off of the iron core during a supernova explosion.

5. Have the students imagine what it would be like if everyone on Earth did this at the same time. With the idea of 6 billion ping pong balls shooting off in all directions from the Earth at the exact same time, we get a more accurate mental image of a supernova.

6. Explanation:

   Once the core of a star has been turned to iron, no more energy can be generated through nuclear fusion. The balance between gravity and the outward flow of energy is broken, and gravity causes the core of the star to catastrophically collapse. This collapse takes just a few seconds. At the end of this collapse, the material in the core comes together with such a large force that some part of it "rebounds." This rebounding material slams into the outer layers of the star, blowing them into space at great speed. This is the supernova. This activity illustrates how a gravitational bounce can eject material at great speed. The tennis ball represents rebounding core material. As it bounces, it slams into the ping-pong ball representing matter in the outer parts of the star, causing the ping-pong ball to be ejected upwards at great speed.

   So the supernova explosion sends all of the elements the star created out into space. They become a part of other stars, planets, galaxies, and even you and me. We are all made of "star stuff!"

   Discuss the difference between an *implosion* (falling inward) and *explosion* (going outward). Tie this activity into the kinesthetic activity that students did in Session 6.

Suggestions for Running this Session

- If you are having trouble with the can crunch demonstration, consider whether you have too much water, whether you are too slow in turning the can over, or whether you haven't let it heat long enough and there isn't enough steam. Practice is very important for getting this right.

- We recommend that you always handle the aluminum cans with some sort of protection, even if the can seems cool enough to touch. While you could use oven mitts for this, we've found that tongs work better for two reasons - it's easier to see the can as you handle it, and it reduces the potential for being accused, "Hey, I think you crunched that with your hand!" All in all, it makes the demonstration much clearer when you use tongs. Silicon-tipped cooking tongs work especially well for grabbing the can gently and securely.

- As mentioned earlier, you'll want to flip the can over into the ice water as quickly as possible. To facilitate this, use an underhanded motion with your tongs. Start by holding the tongs with your palm and wrist facing upward, grab the can, and then flip your hand (and the can) over so that your palm and wrist are now facing downward. It's a little unnatural at first, but it makes flipping the can much quicker and easier! Practice really does make perfect, too.

- If you are considering running this program more than once, consider buying non-pressurized tennis balls. Pressurized ones will lose pressure with time, and will no longer bounce. Non-pressurized ones do not have this problem, and you will save money in the long run.

Misconceptions

- Whether it's squishing clay, crunching a can, or bouncing a tennis ball and ping pong ball, none of these examples are literal parallels to the behavior of a star. We certainly don't want to give the idea that atoms squish together, or that a star collapses when water condenses inside! Be sure to give equal explanation to what's going on in the activity... and the similar behavior in the life cycle of a star.

Useful websites for background or activity extension

- ***Imagine the Universe!***
  Check out this site for more information and activity books on the life cycles of stars.
  Designed for educators at the high school level.
  http://imagine.gsfc.nasa.gov/docs/teachers/lifecycles/stars.html

- **Chandra X-Ray Observatory**
  This page from the Chandra X-Ray Observatory discusses the supernova demonstrations
  http://chandra.harvard.edu/edu/formal/demos/snr.html
  http://chandra.harvard.edu/edu/formal/stellar_ev/

Session 8 – Our Cosmic Connection to the Elements

General Description

An interactive discussion of elements and compounds begins with the leader and class breaking down a substance into smaller and smaller pieces that still retain its identity. The discussion continues with the periodic table, common elements and compounds, and the astronomical origin of the elements that make up our bodies. Students determine the composition of a sample of "space particles" and discuss the difficulties of finding a truly representative sample. They view printed elemental spectra and discuss how astronomers determine the composition of distant objects (reinforces Session 4 on spectroscopy).

Objectives

- To introduce students to the idea of elements.
- To explore composition in the context of the Universe and astronomical objects.
- To draw the connection between elements in space and elements in the human body.

Concepts Addressed

- Elements and compounds
- Composition of the Universe
- Spectroscopy

Materials

- One poundcake. Choose one with the fewest artificial ingredients so that the students will recognize the ingredients. This activity will work best if you choose something that is as uniform looking as possible. If you substitute with a different type of cake, or another type of food, keep in mind that it must be dense enough to not fall apart when cut.
- Knife to cut the cake
- Gloves or wet wipes for safe food handling
- Enough paper plates to hold pieces of cake as it is cut (enough to serve the class, if allowed)
- Sample of a pure element (a piece of copper pipe works well)
- Periodic table, one copy per student (black and white version included in Appendix E and color version included in Appendix F) *
- *Universe Trail Mix* ingredients (see *Universe Trail Mix* Procedure for amounts): rice, split peas, macaroni, black beans, pink beans, and colored sprinkles
- Large bowl to mix the trail mix
- Plain white paper towels or printer paper, one sheet per student
- Plastic spoons (only one is required, but have extras on hand)
- *Universe Trail Mix* worksheet (included in Appendix E)

- Universe Trail Mix key (included in Appendix F) *
- Elemental Spectra handout (included in Appendix F) *
- Paper to write on, 1 sheet per student

** You can laminate these handouts if you want to use them with other groups. You only need to hand out one of these sheets per group of students.*

Other Requirements

- A room with sufficient space for students to spread out and count their "elements"
- Access to a blackboard or flip chart is advised

Background

Atom: The smallest particle of an element that still has the characteristics of that element

Element: A *material* consisting of all the same atoms

Molecule: Two or more atoms of the same or different elements that are chemically bound together

Compound: A *material* consisting of atoms of two or more different elements that are chemically bound together

The copper/other pure element used here is an element, while the pound cake is a compound since it is made of many different substances (or elements).

The lightest elements (hydrogen, helium, and some lithium) were created in the Big Bang.

Then, as the Universe cooled, matter clumped together to form stars. In the stars, those first elements were fused into heavier ones by the energy from the stars' gravity — up to a certain point. Remember that we covered this is Sessions 6 and 7.

The formation of elements heavier than iron and lead requires more energy than a star has. But the explosion of a star at the end of its life (a supernova) provides enough energy to make the much heavier elements. A supernova throws all of its elements out into space, where new stars can use them as they form.

We know the Sun is a later-generation star because it has those heavier elements (we know that from spectroscopy, among other ways). So the elements in our bodies — like carbon, hydrogen, nitrogen, oxygen, and trace amounts of many others — came from the explosion of earlier stars!

We are made of star stuff!

Session Overview

An interactive discussion of elements and compounds begins with the leader and class breaking down a substance (poundcake) into smaller and smaller pieces that still retain its identity (its "atoms").

The discussion continues with the periodic table, common elements and compounds, and the astronomical origin of the elements we are made of. Students take a sample of "space particles in the Universe" (a prepared mixture of rice, beans, etc.), determine its composition, and discuss the difficulties of finding a truly representative sample.

Students view a chart of spectra matched with the elements that produce them, and they discuss how astronomers determine the composition of distant objects (reinforces Session 4 on spectroscopy).

Preparation

- ***Universe Trail Mix***

  This takes a bit of time, so <u>prepare this mixture at least a few hours before you implement this session</u>:

  Using the recipe below, measure the ingredients into a large bowl and mix well. Use the same size "measuring cup" (a plastic spoon) for all of the ingredients.

  – 40 spoonfuls of rice (to represent 89% abundance of hydrogen in Universe)
  – 4 spoonfuls of split peas (to represent 9% abundance of helium)
  – 2 spoonfuls of macaroni (to represent 0.75% abundance of carbon)
  – 2 spoonfuls of black beans (to represent 0.75% abundance of oxygen)
  – 1 spoonful of pink beans (to represent 0.25% abundance of nitrogen)
  – fraction of a spoonful of sprinkles (to represent the tiny abundance of all other elements)

  The amounts of macaroni, black beans, pink beans, and sprinkles are highly exaggerated, because they would not be visible in the mixture in smaller amounts.

- Laminate handouts if desired.
- Have the poundcake and knife ready. Wash your hands or wear gloves while handling the poundcake, if it is to be consumed after use. Save the ingredient label.

Activity

I. Poundcakium activity (15-20 minutes)

1. Remind the group about the previous session and the fact that the calcium and iron — and many other elements — in our bodies were created in a star that exploded. In fact, all of the elements originated well outside our Solar System. Elicit student thoughts about this.

2. Hold up the poundcake. And ask the students what it is.

   Tell the students that you are going to pretend to have just discovered this new element, called “poundcakium.” Ask about its characteristics, and let them answer. Answers should include that it’s all one flavor, texture, and color (at least on the inside).

3. Cut the cake in half.

   Ask the students what you have now. Will it taste the same? The answer is yes, so it is the same thing we had before. Still poundcakium, but in two pieces.

4. Cut it in half again.

   Ask what it is now. The answer is that it is still poundcakium.

Sliced poundcake.

   If you were to continue to cut it in half, you would eventually get to single crumbs. Ask the students if you would have destroyed or created any poundcakium as you did this? Does it become something else other than poundcakium by cutting it? The answer is no.

5. If allowed, serve the poundcake! You can continue while students munch.

6. Discuss with the students how many things are made of more than one ingredient. Ask them what they think the ingredients are in poundcake (which you used to represent poundcakium). Let them answer, then read through the pronounceable ingredients on the poundcake label.

7. Tell the students that flour, sugar, milk, and eggs (or whatever the recognizable ingredients are) are made of elements such as carbon and hydrogen.

   Pass out the individual copies of the periodic table. Point out carbon and hydrogen.

8. Ask the students if they know anything about elements. Tell them that an element is a material made of atoms of a single type, like carbon or hydrogen. Elements are the building blocks for matter — everything that we can see and touch.

9. Hold up your pure element. (For our example, we will say you are using a piece of copper tubing. You can also use other examples of pure elements if you have them readily available.)

   If the kids handle the copper (or other elements), make sure to have them wash their hands afterwards. Wet wipes might make this process easier.

   Tell them that copper is an element that occurs naturally on Earth.

   Say that copper is very hard to cut, but in theory we could do the same thing we did with poundcakium. If we could cut the copper in half, would it be a different substance? No, it's still the same substance, with the same properties, and the total weight (of the two pieces together) is still the same. Since copper is an element, no matter how many times it's cut it in half, we will always have copper. It is a fundamental property of elements that they retain their characteristics, even down to a single atom.

   Make sure you remember to wash your hands after handing a substance such as copper.

An example of a copper pipe.

10. Refer back to their handouts. Tell them that all of the known elements have been organized into this Periodic Table of the Elements. It is arranged so that the elements in the same rows and columns have common characteristics, though each remains unique. Some are solids, some are gases, and some are liquids at room temperature, for example.

    Ask if they recognize any of the elements. See if they can give examples of everyday objects, and the elements they're made of. (Examples: aluminum in soda cans, silver/gold in jewelry, diamonds (carbon), iron in steel, hydrogen and oxygen in water — "lead in pencils" should be corrected to "carbon (in the form of graphite) in pencils".)

Some common substances like table salt (NaCl — sodium chloride) or water (H_2O) are compounds, which are made of two or more elements chemically bound together.

Ask if poundcakium is an element or a compound. Wait for responses with explanations. They should answer that we were pretending that it was an element for our purposes.

Now ask if the actual poundcake is an element. Again, wait for responses with explanations. The answer is that it is not, because it's made of various ingredients.

11. Ask what are people are made of. Wait for the students to respond and provide explanations. The truth is that we're made of a lot of the elements on the periodic table, many in the form of compounds like water.

    Ask the students where they think these elements came from. Wait for ideas. They may remember from Session 7 that the lightest elements (hydrogen, helium, some lithium) were created in the Big Bang and then heavier elements (up to iron) were formed in stars. Anything heavier than that was formed during supernova explosions. So the elements in our bodies — like carbon, hydrogen, nitrogen, oxygen, and trace amounts of many other — came from the explosion of stars!

    We are made of star stuff!

II. *Universe Trail Mix* activity (15-20 minutes)

1. Before beginning this activity, everyone should finish eating if they were doing so. Remove all traces of remaining poundcake to avoid distraction.

   Distribute the *Universe Trail Mix* worksheets, the *Universe Trail Mix* keys (so that they know which ingredient represents which element), small cups, and sheets of paper towel.

2. Ask the group what element we have the most of in the Universe. If we grabbed a handful of space particles, what would we have? Solicit ideas.

3. Pull out the trail mix and plastic spoon to serve it.

   Tell the students that this trail mix was prepared to imitate the proportions of the most common elements in the Universe.

   Have each student take a spoonful of the mix and put it in a cup. Back in their own workspace, they empty it onto the paper towel. Students then count or estimate how much of each ingredient (element) they have, and record it on their worksheet.

4. When all have finished, ask how many of them found hydrogen? Helium? Carbon? They should all have mostly hydrogen, some helium, and very few of the others.

   Ask how many of them had any oxygen, nitrogen, or sprinkles (which represent small amounts of other elements). Note that these are rare and not found in every spoonful.

On a blackboard or flip chart, draw a table with a column heading for each element. Have each student come up and record how much of each "element" they found. Have two volunteers come up and tally the entries to arrive at total for each element (having two volunteers should verify the addition).

Student participants counting components of their Universe Trail Mix.

5. With prompting as needed, students should discuss the *relative* amounts of the elements.

   Ask why some of the elements not appear in all of the samples. Do they think this would be similar to when we look out into space? That is, if we looked at one region in space near a star, do you think we would find the same sorts of elements as if we looked where there no stars? The answer is no — where we look is very important and tells us what that region is made of.

6. Have everyone look at a periodic table again, and go through the true percentages of elements in the Universe: Almost 90% of the Universe is hydrogen, and more than 9% is helium. The rest of the elements add up to less than 1%, but that 1% includes ***all*** of the heavier elements that are out there.

III. Follow-up discussion (10-15 minutes)

Discuss with the students how they just used spoonfuls of the *Universe Trail Mix* to try to figure out what the Universe is made of. But we can't get a spoonful of things in space, since they are so far away. We have to figure out what they are made of without touching them. We can do this with light.

Remind them about the Session 5 activity on spectroscopy, if they did it.

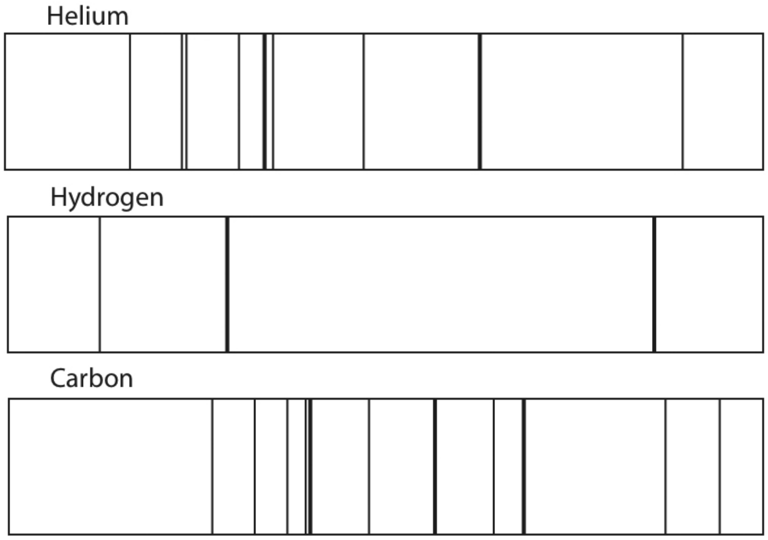
Remind them that one way you can tell what an object is made of is to look at its spectrum. A spectrum is like an element's "fingerprint." Each element produces a unique pattern of specific wavelengths of light, which we see as bright lines in the spectrum. A scientist looking at the spectrum of an object in space, like a star or planet, can figure out which elements are in that object by looking at the different lines in its spectrum — they use spectroscopy.

Hand out papers with the spectra of different elements.

Ask them to describe what they see. Wait for ideas.

It looks like a faint rainbow, with some bright lines here and there. Have them look at the spectrum for hydrogen, and discuss where the bright lines are.

Have them look at the spectrum for helium. Discuss where the bright lines are, and compare this spectrum to the spectrum for hydrogen.



Three examples of different elemental spectra.

So when astronomers look out into space and study the spectra of objects, they can figure out which elements are present from the lines they are seeing. Each element has a unique spectrum and how bright or faint it is tells us how much of that element is present.

Suggestions for Running this Session

- If you are unable to have food in your classroom at all, or if food allergies are a concern, you should be able to do the poundcakium activity with a sponge (spongium), styrofoam (styrofoamium), Play-Doh (pladoium), or some other substance that can be easily cut or broken, and with easily recognizable properties.

- Even though the trail mix is not consumed, and none of the ingredients are ones that have significant allergy risk, there is an alternate recipe which uses beads instead of food products. This recipe contains a different ratio of ingredients, because the difference between elements is expressed entirely by color, and not by size. While this is a longer-lasting alternative, it is more expensive to construct, and the supplies are not as readily available from local stores. If you are interested, this recipe is available from the *Big Explosions and Strong Gravity* program (linked below).

- If dark matter comes up, explain that we still don't know exactly what it is, and we are only talking about normal matter in these activities.

Misconceptions

- Elements are substances made up of all one type of atom, that cannot be separated into simpler substances. Compounds are substances made up of two or more elements joined together, like water (hydrogen + oxygen) or table salt (sodium + chlorine). When you're discussing elements, some students will have the idea that compounds are elements, and will name substances like water alongside elements like oxygen or iron.

- In this session, we've invented a fictitious element called Poundcakium to illustrate basic concepts about elements and atoms. In reality, poundcake is a mixture - two or more substances that are mixed together but not chemically joined. Some of the ingredients in poundcake, like sugar and salt, are compounds. We don't go into much depth in this session about compounds or mixtures, because our focus is on elements.

Useful websites for background or activity extension

- **Los Alamos National Laboratory**
  Great interactive periodic table, with much information about each element
  http://periodic.lanl.gov/

- **University of Colorado Physics 2000**
  Good follow-up site if you would like to see spectra for more elements, as well as for white light.
  http://www.colorado.edu/physics/2000/quantumzone/index.html

- ***Imagine the Universe!***

  - Extended activity about composition using beans and rice, with bottles full of objects on Earth and space:
    http://imagine.gsfc.nasa.gov/docs/teachers/elements/imagine/OutThere/outthere.html

  - Good explanations of the electromagnetic spectrum and spectroscopy:
    http://imagine.gsfc.nasa.gov/docs/teachers/lessons/xray_spectra/background-spectroscopy.html

  - Lesson plan at high school level on the origin of the elements and our connection to them:
    http://imagine.gsfc.nasa.gov/docs/teachers/elements/elements.html

  - High-school level activity and discussion of the formation of elements in stars and their release in supernovae:
    http://imagine.gsfc.nasa.gov/docs/teachers/calcium/calcium_intro.html

Session 9 – Galaxies

General Description

Students learn what a galaxy is and also learn that we live in a galaxy called the Milky Way Galaxy. They work individually or in pairs to make a model of our Milky Way Galaxy and see how our Sun and the Earth fit into it. They learn that our galaxy is only one of billions of galaxies, and that galaxies have different shapes.

Objectives

- To ensure understanding that we live in a galaxy.
- To understand that galaxies are made of stars like our Sun.
- To show that there are a very large number of galaxies in the Universe.

Concepts Addressed

- A galaxy is a very large collection of stars, gas, and dust
- Hierarchy of structure in the Universe
- Basic shapes of galaxies
- The effect of galaxy orientation on appearance

Materials

- Index cards, 1 per student
- Sturdy paper plates, about 10″–12″ diameter (alternatively you can use any other round flat board, such as cardboard, foam board, etc) — 1 per student or pair
- Diagram of Milky Way Galaxy arms (included in Appendix F) — 1 per student or pair
- Colored pencils or crayons or markers — 3 different colors per student or pair
- Yellow or red markers (or water color paints) — 1 per student or pair
- Small stickers of stars and circles/ovals — 1 packet per student or pair
- Styrofoam ball (1.5″ diameter) — 1 per student or pair
- Blunt cutter to cut Styrofoam ball in half — 1 per student or pair
- Toothpicks — 2 per student or pair
- Ruler — 1 per student or pair
- Hubble Ultra Deep Field image (included in Appendix F)
- Image of types of galaxies (included in Appendix F)
- Image of different orientations of spiral galaxies (included in Appendix F)
- Blackboard/whiteboard or flip chart
- Chalk or markers

Background

A galaxy is a large group of stars, gas, and dust bound together by gravity. Our Sun (a star) and all the planets around it are part of a galaxy known as the Milky Way Galaxy. It is called the Milky Way since it appears as a milky band of light in the sky when you see it in a really dark area. All the stars we see in the night sky are in our own Milky Way Galaxy.

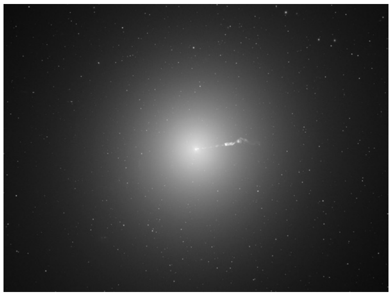
The Milky Way is made up of approximately 100 billion stars that have formed a large disk whose diameter is 100,000 light years — this means that light takes 100,000 years to go from one side of our galaxy to the other side. Our Solar System is about 25,000 light years away from the center of our galaxy — we live in the suburbs of our galaxy. Just as the Earth goes around the Sun, the Sun goes around the center of our galaxy. It takes 250 million years for our Sun and the solar system to go all the way around the center of the Milky Way. Remember that **light years are a measure of distance, not time**. A light year is the distance light travels in one year through space — about 10 trillion kilometers, or 6 trillion miles.

There are billions of other galaxies in the Universe. Only three galaxies outside our own Milky Way Galaxy can be seen without a telescope, and appear as fuzzy patches in the sky with the naked eye. The closest galaxies that we can see without a telescope are the Large and Small Magellanic Clouds. These satellite galaxies of the Milky Way can be seen from the southern hemisphere. Even they are about 160,000 light years from us, i.e., it takes light 160,000 years to get to us from those galaxies. The Andromeda Galaxy is a larger galaxy that can be seen from the northern hemisphere (with good eyesight and a very dark sky). It is about 2.5 million light years away from us, i.e., it takes light 2.5 *million* years to reach us from one of our “nearby” galaxies. The other galaxies are even further away from us and can only be seen through telescopes.

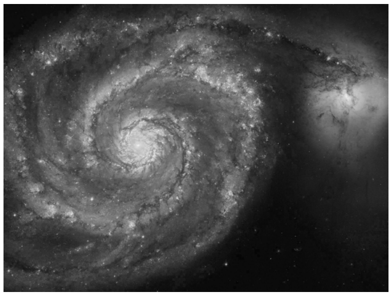
The smallest galaxies may contain only a few hundred thousand stars and be several thousand light years across, while the largest galaxies have trillions of stars and may be hundreds of thousands of light years across. Also, it is very rare to find stars in the space in between galaxies.

The color of a galaxy is determined partially by the color of the stars in it. Older stars are usually redder and younger stars are usually bluer. The presence of dust can also make a galaxy appear more red in color.

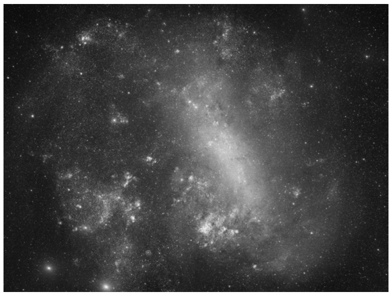
Galaxies are classified by shape. There are three general types: elliptical, spiral, and irregular. As their name suggests, elliptical galaxies are round or oval, with stars distributed fairly uniformly throughout. Spiral galaxies have disks that contain spiral arms, and a central “bulge.” This bulge has a large concentration of stars, usually older stars. Our Milky Way Galaxy is a spiral galaxy. Irregular galaxies



Elliptical Galaxy



Spiral Galaxy



Irregular Galaxy

have no identifiable shape or structure to them. The different shapes and orientation of galaxies are a result of their history, which may have included interactions with other galaxies.

Galaxies sometimes collide with each other, with interesting results. These collisions can trigger bursts of star-formation in addition to changing the shapes of the galaxies that collide. However, when galaxy collisions occur, individual stars *do not* collide, due to the vast distances between them.

There are no pictures of the Milky Way Galaxy. The reason for this is that we are inside of it, and there is no way for us to go outside of it to take a picture. We sometimes compare other spiral galaxies to our galaxy, and people will sometimes get confused, but these are **not** images of our galaxy.

Session Overview

Students start by writing down their home address — or the address of the afterschool program location. They learn what a galaxy is and make a model of our Milky Way Galaxy. This model helps them visually understand how our Sun and the Earth fit into our galaxy. Then they write their full "Universal Address." The model also helps them understand that how things look depends on how they are oriented to our line of sight — galaxies we see "head-on" look different from galaxies we see from the side. Students learn that our galaxy is only one of billions of galaxies and that galaxies have different shapes.

Preparation

- Cut each styrofoam ball in half with a blunt cutting instrument, such as a sturdy metal ruler. You can smooth the halves by rubbing the cut edges together.
- If using cardboard or foam board, cut out the circles for the galaxy models.

Activity

(*Adapted from the activity "Make Your Own Milky Way Model" developed by Dr. Kumiko Usuda at the Subaru Telescope facility.*)

I. Introduction (10 minutes)

1. Give the students index cards, and ask them to write down and identify parts of their home address. Alternately, you can write out the address of your program location on the blackboard/whiteboard/flip chart. Emphasize that typical parts include house number (or an apartment number), street, city, state. Now ask what we would need to add if we had to send things to other countries? (We would have to add the name of the country.) If we had to send something to other planets, what would we add? (Name of the planet.) Now tell them that we will study our full address in the Universe.

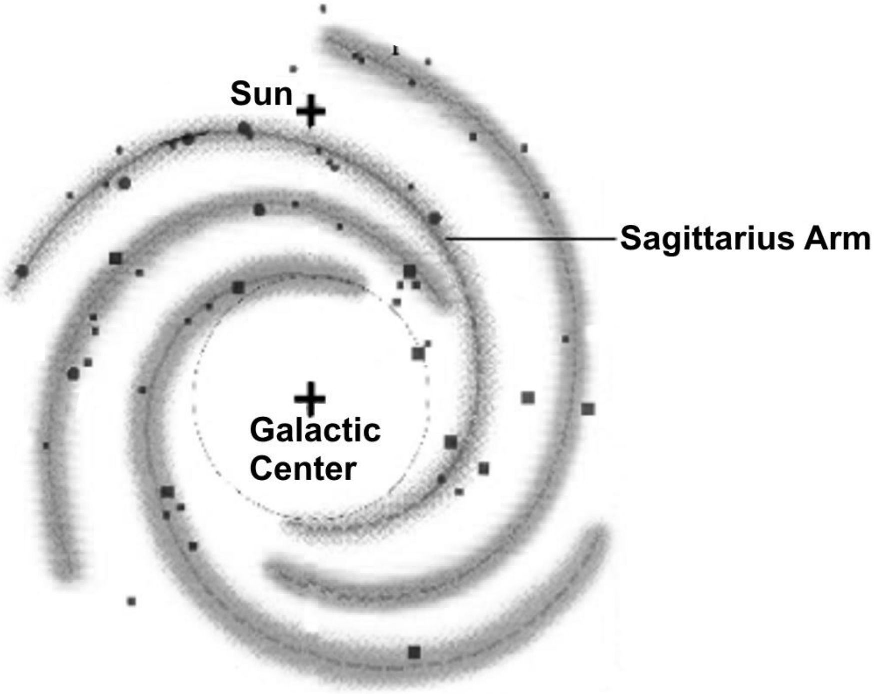
2. Ask students if they know what a galaxy is. Have they heard of the Milky Way? Do they know what it is? Lead a discussion about galaxies and our Milky Way Galaxy. Tell them

that we will now make a model of our Milky Way Galaxy. For this activity, students can work individually or in pairs.

II. Make Your Own Galaxies Activity (25 minutes)

1. Distribute one paper plate (or other circular board), the diagram of the arms of the Milky Way (to use as a model), stickers, color pencils/markers, styrofoam ball halves, toothpick, glue, and a ruler to each student or pair of students.

   It is worth noting that this diagram of the arms of the Milky Way is highly simplified. The point is to understand that our solar system is a small part of something much larger, which has a definite structure, not to understand all of the details of the structure of the Milky Way. If you want to know more, there are a number of more detailed diagrams on the internet.



The Milky Way Galaxy with its arms, showing the location of the Sun.

2. The 12″ circular board represents the full width of our Milky Way Galaxy.

3. Paint your Styrofoam ball yellow or red (to look like the actual bulge of the galaxy).

4. Poke 1–2 toothpicks through the very center of the circular board. Now place one half of the ball on the board on each side of the center so that the toothpicks hold them in place. This is the central bulge of our galaxy.

5. The stars, dust and gases in the galaxy are not distributed evenly, but are in spiral bands or "arms." Using the image as a model, draw each of the four bands using colored pencils or markers, making sure that they show well on the board.

6. Now place the star and gas cloud stickers along the arms as close as possible to where dots are seen on the drawing.

7. Notice where the Sun is in the diagram — it is in the arm labeled "Sagittarius Arm" and is marked with a "+" sign. This is the location of our Sun and of our Solar System (it corresponds to 25,000 light years from the center of our galaxy). Place a sticker here to mark the location of the Sun. This can be a different color to show where our Sun is in our galaxy.

A sample Milky Way Galaxy model.

NOTE: If you look on the internet at other diagrams of our Milky Way Galaxy, you will frequently see our solar system listed as being on the Local or Orion Spur, which is a smaller spur or arm coming off of the Sagittarius Arm. We have chosen not to go into this level of detail here, but we do want to note it in case you or your students do extra reading and become confused.

8. This is your model of our Milky Way Galaxy!

III. Discussion (15-20 minutes)

1. While looking at this model, lead a discussion of where the Sun is in the Milky Way. Explain that galaxies are similar to "cities of stars." The Washington, DC metropolitan area (or pick the city that your students might be most familiar with) has more than 5 million (change this number as appropriate for the city you are using as an example) people living in it. Some are organized in groups of 2, 3, or more (families — much like groups of stars). Some are single individuals. Similarly, galaxies are made of huge numbers of stars. Cities have very busy places, and other places where fewer people live that are relatively quiet. Similarly, galaxies have "busy" and crowded places, usually (but not always) at their centers. You can describe our neighborhood of the Milky Way as relatively quiet. Our Sun and the solar system are in the suburbs of our Milky Way Galaxy!

2. Lead a (brief) discussion to get across some sense of distances in the galaxy. Space is so big that we discuss distances in terms of how many years it takes light to reach from one point to another. The speed of light is extremely fast! It is 300,000 km/sec (186,000 miles/sec). It can travel 7 times around the Earth in 1 second. The distance it can travel in a year, which is about 9.6 *trillion* kilometers (6 *trillion* miles), is known as a light year. Remember that a light year is defined as the *distance* light travels in one year. Sometimes the term light year sounds more like a measure of time. If you would like to draw an analogy for your students, you can have one kid walk for a second and measure that distance. The distance he or she covers in a second can be called a "kid-second." You can draw any other parallel analogy that makes sense.

   Even though light travels very fast, it takes light a fixed amount of time to reach us from its source because space is so vast. Remind students that you discussed this concept in Session 3. Here are some examples of light travel time:

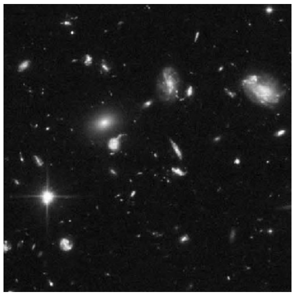
   - Moon to Earth: 1.3 seconds
   - Sun to Earth: 8 minutes
   - Mars to Earth: 12 minutes
   - Pluto to Earth: 5.5 hours
   - Nearest star to the Sun: 4.3 years

   As we go farther away from our Solar System, the distances in space become even larger. The distances within our galaxy are large and the distances between galaxies are even larger!

   - Center of the Milky Way from our Sun and the Solar System: 25,000 years
   - From one end of our galaxy to the opposite end: 100,000 years
   - Our galaxy to the "Magellanic Clouds" (our "satellite" galaxies):
     - Large Magellanic Cloud — 160,000 years
     - Small Magellanic Cloud — 200,000 years
   - Milky Way Galaxy to the Andromeda Galaxy, the nearest large galaxy from us: 2.5 million years

   Also, remind students of the Session 2 activity with the cards when they categorized objects by their distance to us. What was the closest? Farthest?

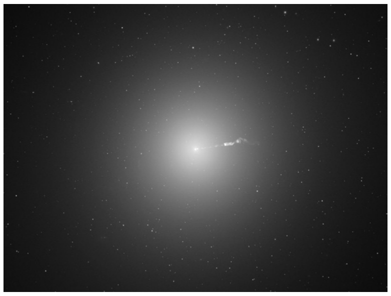
3. Show the Hubble Ultra Deep Field image. Explain that this is only a tiny portion of the sky (less than 1/100 of the area of the full moon). How many galaxies do they think there are in the Universe? There are **hundreds of billions of galaxies** in the Universe. Remind students that because galaxies are so far away, any images of galaxies they see represent the galaxies as they were a very long time ago — "looking out is looking back" (from Session 3).



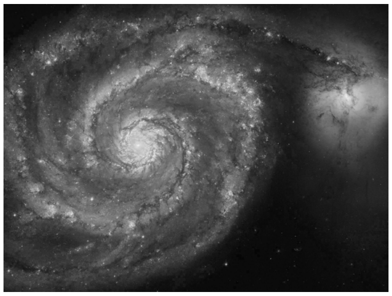
Small portion of the Hubble Ultra Deep Field image.

4. Show the images of the different types of galaxies (the picture titled "Types of Galaxies"). Ask students to examine the images and convince themselves that some have arms, some are round and some have no consistent shape at all.

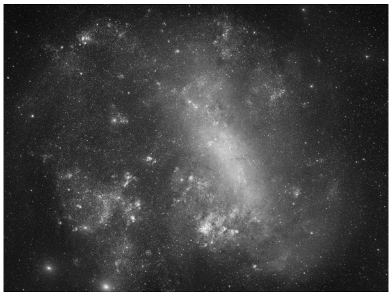
There are sub-divisions within these categories, but all galaxies fall into these three types. By far most galaxies are either elliptical or spiral. Many studies say that 60–70% of all galaxies are elliptical, with the majority of the remaining ones being spiral.



Round or oval galaxies are called ***elliptical galaxies****.*



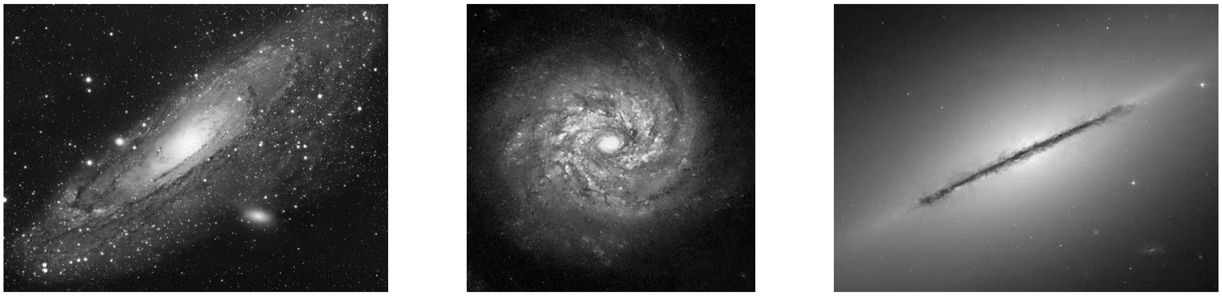
Those showing a pinwheel structure are ***spiral galaxies****. They have two or more arms winding out from a central disk*



An ***irregular galaxy*** *is one with no definite structure*

5. Ask students to hold their Milky Way model and figure out what type of galaxy it is. (Our Milky Way is a spiral galaxy.) Now have them hold their model at different angles and see if it looks the same. (It won't — the angle matters a great deal.)

6. Use the picture of the 5 different spiral galaxies to show the individual variation that can exist. Ask students why the images appear so different. Help students see that differences are mainly due to the angle or perspective from which we see these galaxies.



Three different spiral galaxies each with a different angles of viewing.

7. Ask students what they would add to their mailing address to represent their "address in the Universe". At this point, they should add the planet ("Planet Earth"), star system ("Solar System"), location in our galaxy ("Sagittarius Arm"), galaxy ("Milky Way Galaxy") and finally, "Universe"! If you would like to make this another postcard activity, that is also possible. The United States Postal Service will correctly deliver items with this lengthy address!

Suggestions for Running this Session

- If you want to, you can put a stamp on the postcards addressed with the full galactic address and put them in the mail. We've sent out a number of these postcards, and the postal service seems to be able to deal with all of the extra address elements (though they probably think we're a little weird)! It gives students a kick to receive a card at their "real" address.

Misconceptions

- In some students' minds, there is no significant difference between a solar system, a galaxy, and the universe. We hope that the sessions prior to this one will have discouraged this belief, but it can be a lasting one! We've designed this session to specifically address the hierarchy of these objects - that a solar system contains planets going around a star, a galaxy contains many stars (and therefore many solar systems), and the universe contains many galaxies.

- When we look at astronomical images, we often see a mixture of stars and galaxies in the same image. This can be confusing - where are the stars, and where are the galaxies? In these images, the individual stars we're seeing are all within our own galaxy, the Milky Way. You can think of this as being like the foreground of a painting - the flowers in the field aren't in the forest in the background. Stars exist almost entirely within galaxies, and when you see a galaxy you're seeing a collection of billions of stars so dense and so distant that you can't resolve the individual stars within.

- We live in one galaxy, the Milky Way, and all of the other galaxies exist outside of our galaxy. They are like different cities of stars.

- Most students have seen images that purportedly depict the Milky Way Galaxy, such as the "you are here" posters and shirts. As we are unable to travel outside of the galaxy, there are no photographs of our galaxy from an outside perspective. The images depicting the Milky Way are either artist's renditions or an image of another spiral galaxy that looks similar to what we think the Milky Way should look like. The only images of the Milky Way that are real are ones taken from within our solar system, and therefore only seeing a piece of the galaxy (either the disc or the bulge).

- Space is so big that we discuss distances in terms of how many years it takes light to reach from one point to another. The speed of light is extremely fast! It is 300,000 km/sec (186,000 miles/sec). It can travel 7 times around the Earth in 1 second. The distance it can travel in a year, which is about 9.6 trillion kilometers (6 trillion miles), is known as a light year. Remember that the light year is is a measure of distance. Sometimes the term light year sounds more like a measure of time. If you would like to draw an analogy for your students, you can have one kid walk for a second and measure that distance. The distance s/he covers in a second can be called a "kid-second." You can draw any other parallel analogy that makes sense.

Useful websites for background or activity extension

- **"Amazing Space" from the Space Telescope Science Institute**
  Online games, pictures to download, and explanations about galaxy shapes — from the Hubble Space Telescope
  http://amazing-space.stsci.edu/capture/galaxies/

- **HubbleSite**
  Spectacular images of galaxies taken by the Hubble Space Telescope
  http://hubblesite.org/gallery/album/galaxy/

- **Visualizing large numbers**
  Make sense of the huge numbers used in astronomy with examples from everyday life
  http://kokogiak.com/megapenny/

- **Cosmic Distance Scale**
  Gives a feeling for how immense our Universe is, starting with an image of the Earth and then zooming out to the furthest visible reaches of our Universe — as in the "powers of 10" films.
  http://heasarc.gsfc.nasa.gov/docs/cosmic/

- **Galaxy collisions and mergers**

  - Images of colliding galaxies (the "Antennae Galaxies" and "The Mice")
    http://hubblesite.org/gallery/album/entire/pr1997034d/
    http://hubblesite.org/gallery/album/entire/pr2002011h/

  - Animation of colliding galaxies
    http://chandra.harvard.edu/photo/2004/antennae/animations.html

- **Galaxy Zoo**
  Help astronomers catalog new galaxies
  http://www.galaxyzoo.org/

- **Make Your Own Milky Way Galaxy Model**
  http://www.naoj.org/staff/kumiko/MilkyWay/milkyway.html

Session 10 – Black Holes

Brief Description

Students learn about black holes, the densest objects in the Universe. They learn that the collapsing core of a star forms a black hole and do an activity that shows how the density of a stellar core increases as the core collapses even though the mass remains the same. They then engage in a kinesthetic activity to model how a black hole affects the objects near it. This session ties into Sessions 6 and 7. Students work in groups of 2 or 3 for the first part of the session, and as a larger group later.

Objectives

- To show that black holes are the end points in the life cycle of the most massive stars.
- To understand that black holes have the same gravity as other objects of the same mass, but are much smaller and are hence denser.
- To show that a black hole's gravity is similar to other objects in the Universe – it is dependent on the mass and distance from the object.
- To understand that nothing can escape from a black hole, not even light.

Concepts Addressed

- Black holes as end points of stellar evolution for the most massive stars
- Gravity
- Escape velocity

Materials

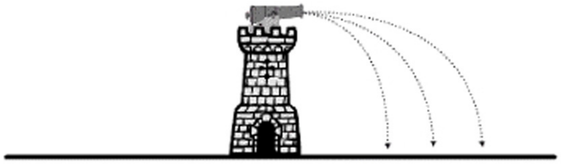
- Blackboard/whiteboard or easel with flipchart
- Chalk or markers
- Round balloons, 1 per group of students
- Roll of aluminum foil
- Balance/scales, 1–2 for the class
- Cloth/flexible tape measure, 1 per group of students
- Student worksheet (included in Appendix E)
- Index cards to use for making up role cards
- Piece(s) of yarn or rope that totals about 20 feet

Other Requirements

- A room or other space where students can move around freely

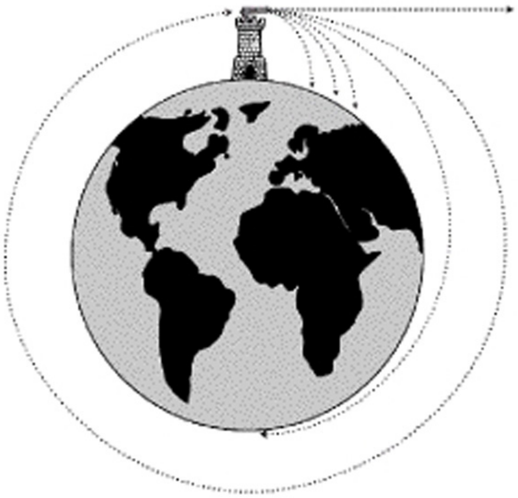
Background

On Earth, when you throw a ball into the air, it falls back to the ground. This is because the Earth's gravity pulls the ball back down. The higher and faster you throw it, the longer it will take to fall back to the ground. The same principle applies to the cannon balls in the following image. The faster the cannon balls are shot, the farther they will go.



Faster cannon balls getting farther as they are shot off a tower.

If you could throw the ball with enough speed, it would not come back down. If you could shoot the cannonball fast enough, it would continue around the planet (in orbit.)



If a cannon ball were shot fast enough, it would go all the way around the Earth.

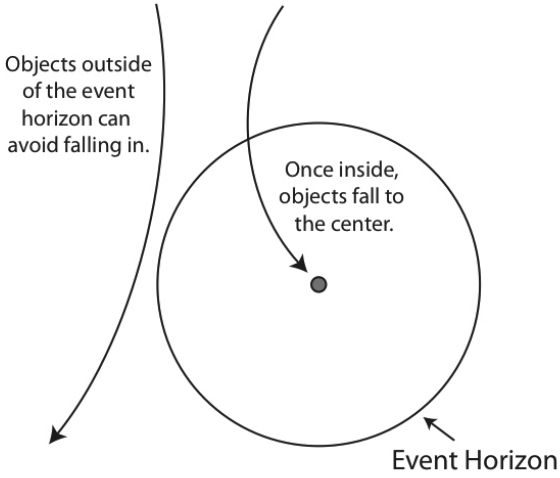
For every body in the Universe, there is a certain speed necessary for objects to escape its gravitational pull. This special speed is called the "escape velocity." Any object going slower will fall back to the surface. The reason we are able to send rockets into space is because they achieve speeds greater than this velocity. On Earth this speed is 11.1 kilometers per second (or 40,200 kilometers per hour), which is the same as 7 miles per second (or 25,000 miles per hour). Other objects have different escape velocities. The escape velocity for any object is dependent on its mass — the more massive something is, the higher the escape velocity from that object. The Moon is smaller than the Earth and the escape velocity is only 2.4 kilometers per second (1.5 miles per second). The Sun, which is much more massive than the Earth, has an escape velocity of 621 kilometers per second (386 miles per second). So, objects need to have more speed to escape from a more massive object.

Black holes are objects so dense that their gravitational pull is very large. The gravitational pull is so high that the escape velocity from black holes exceeds the speed of light! This means that not even light can escape the gravity of black holes. Since Einstein showed that nothing can travel faster than light, nothing can escape from inside a black hole!

There is strong observational evidence for two types of black holes — stellar mass black holes, which are typically 5–15 times as massive as our Sun and are formed when large stars explode as supernovae and collapse; and supermassive black holes that are millions to billions times the mass of our Sun. These are always found at the centers of galaxies. For example, our own galaxy, the Milky Way Galaxy, has a central black hole. This black hole is 3 million times the mass of our Sun, but in size it is only about the size of our solar system. This is very small in relation to the size of our galaxy. The formation of these supermassive black holes is still mysterious and the subject of a great deal of current research.

A third type of black hole, known as an intermediate mass black hole, is also thought to exist. These black holes are predicted to weigh about 1000 times the mass of our Sun. This is an active area of research.

The event horizon of a black hole is the spherical boundary between the black hole and the outside universe. It is the point of no return in the sense that any object (or even any light ray) that strays inside of the event horizon must fall inwards towards the center of the black hole. At the very center of the black hole is a region where the infalling matter is destroyed and our current laws of physics probably become invalid.



The gravitational effect of black holes.

It is important to realize that outside of the event horizon a black hole exerts the same gravitational force on nearby objects as any other object of the same mass. For example, if the Sun were magically crushed until it had a radius of only 3.2 kilometers (2 miles), it would become a black hole but the Earth would feel the same gravitational force and hence remain in the same orbit as before the Sun was crushed. In this sense, black holes are not cosmic vacuum cleaners that reach out and suck everything into them. But our Sun is not big enough to ever become a black hole, so don't worry about that!

Black holes can be very challenging objects to detect as space is also black! If there were no stars or gas near a black hole, we would not be able to detect them. Astronomers detect black holes through their gravitational effect on nearby gas and stars. A particularly important example is when a normal star (like the Sun) is orbiting close to a stellar-mass black hole. In this case, the gravity of the black hole can pull gas from the surface of the star. As the gas spirals into the black hole, it gets extremely hot and emits a large amount of X-rays. These X-rays can be detected by modern X-ray telescopes. Observations also reveal the normal star's "wobble" as it orbits around the unseen black hole.

Session Overview

In the first activity, students model and measure the collapse of a star into a black hole to understand its incredibly high density. Students then engage in a kinesthetic activity to learn that black holes exert their gravitational pull only on objects that get close to them.

Preparation

- Set up stations ahead of time — student stations with activity materials (balloons, aluminum foil, measuring tape, and worksheets), and separate stations with the scales for use during the activity.
- Make up "role cards" for the students for the black hole kinesthetic activity. You can either use index cards or fold up small slips of paper and write the name of a role to play in the activity. For a group of 20 students, a good distribution of roles might be as follows: 4 students are the "black hole," 4 students are the "distant stars" that never feel the black hole, 6 students are "nearby stars" that feel some tug from the black hole, and 6 students are "orbiting stars" that go around the black hole without falling into it.

Activity

I. Discussion (10 minutes)

1. Ask your students what they know about black holes. After a brief discussion where you write down their ideas on the black board or chart, tell them that we are going to do some activities to see if their ideas are correct.

2. Review the general process of stellar evolution from Session 6. Ask them if they remember if/how/when black holes formed during the process of a star's evolution. Confirm (or remind them) that black holes form when the cores of very large stars collapse at the end of the star's life (as they modeled in Session 6). Briefly introduce the concept of a black hole as an object that has a huge mass but is very small (i.e., has incredibly high density) — imagine the mass of a star, but scrunched into the size of a city!

   If appropriate, you can draw some comparisons between heavy but small objects and larger but lighter objects that they may be familiar with to demonstrate that larger doesn't always mean heavier. Some common examples are lead fishing weights (small but very heavy) and balls or other objects made out of styrofoam, which can be very large but still not be heavy. If you have them available, science supply stores have sets of similarly-sized items (cubes, balls, etc) made from different materials to make this point in a different way.

II. Modelling the formation of a black hole (20 minutes)

(*Adapted from Imagine the Universe's activity on black holes*)

▶ Check our online resources for a video about the foil and balloon black hole.

1. Tell students that they will use aluminum foil and balloons to model the collapse of a star on its way to making a black hole. This is similar to the way that the core of a star makes a black hole when the massive star reaches the end of its life. They are going to note what happens to the circumference and mass of the core as it is collapsing on its way to a black hole. Split the students into groups of 2–3 and have them follow your lead as you go through the activity.

2. Distribute the balloons, aluminum foil, measuring tape, and a worksheet to each team of students.

3. Start by blowing up the balloon until the diameter (distance across the balloon) is about 6″, no larger (it is harder to cover a larger balloon with foil). Tie off the end. Now cover the inflated balloon with several sheets of aluminum foil. Be generous with the foil and cover the balloon thoroughly. It works best if you use several 12–15 inch long sheets and wrap around at least twice. Tell the students that the foil covered balloon represents the core of the star.

A participant wrapping her balloon in foil.

4. Using the scales, weigh the balloon. Measure its circumference (distance around the balloon) by wrapping the tape measure around the middle of the balloon. Record these two measurements on the worksheet.

5. Tell the students that they are the "Giant Hands of Gravity." Have the students gently squeeze the balloon. Since it is still inflated, it should resist being squeezed. Tell the students that this is what happens during the normal life of the star — gravity is balanced by pressure within the core of the star.

A participant gently squeezes his balloon.

6. You are now ready to simulate the end of the star's life as the enormous mass of the star's core collapses inward on itself. Tell the students that their star has just died — it has run out of fuel in its core and so the pressure will disappear. Tell the students to simulate this by popping their balloons without crushing the aluminum foil. The sharp end of a pencil should work well. Push the tip gently through the foil to pop the balloon inside.

7. Tell the students to, again, be the "hands of gravity" by gently squeezing their aluminum ball. Instruct them to make the ball approximately 1″ smaller. But ask them to squeeze it carefully so that it stays roughly spherical as it gets small. This time, since there is no pressure to resist the collapse, the aluminum ball will be crushed.

8. After crushing it a little bit, ask the students to measure its circumference and its mass, and note these values on their worksheet. Ask the students to continue to crush their ball little by little (about 1 inch each time), making measurements of the circumference and mass and recording these on their worksheet each time.

A participant weighing and measuring a ball of foil.

9. By this time, students should be noticing that the mass is not changing as they squeeze the ball into a smaller and smaller size.

10. After a few minutes, ask the students to crush their ball as much as they possibly can. They should end up with an aluminum ball that is just an inch or two across.

Participants measure the circumference of their aluminum ball.

11. Discussion: Remind the students that their ball could not be crushed while the balloon was still inflated — this represents a star during its normal life in which pressure (generated by the nuclear fusion in its core) balances gravity. When fusion stops in the core of the star, the pressure can no longer be maintained. This is like popping the balloon. The students should be led to the conclusion that the collapse of the core could start once the pressure in the core vanished.

    Once the collapse started, the core kept a constant mass as it got smaller. Their measurements on their worksheets should show that the mass remained the same even as the circumference got smaller. So this is similar to what happens when a star explodes in a supernova and the leftover core collapses to become a black hole. The core keeps getting smaller and smaller even though it is not losing mass.

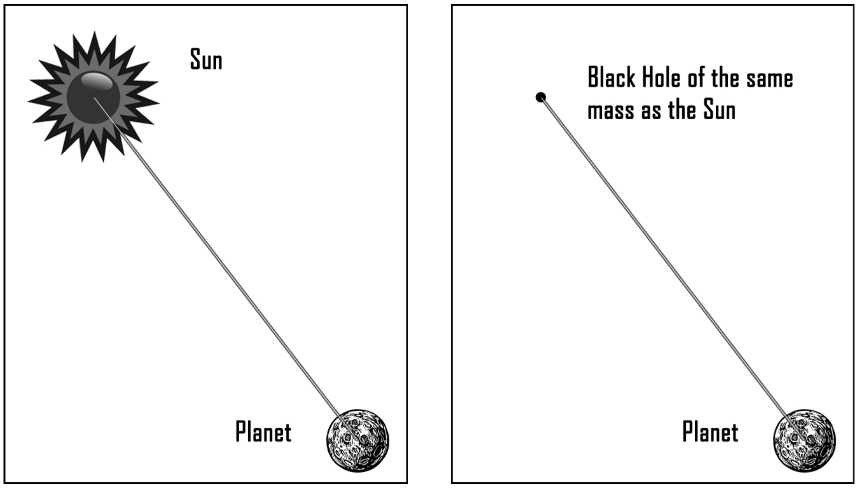
    The students should be told that to make an actual black hole with the effective size of their final (squashed) aluminum ball, you would need to start with several times the mass of the Earth!

III. Black Hole Effects Kinesthetic Activity (20 minutes)

Check our online resources for a video about this black hole kinesthetic.

Now that they know black holes are very dense objects, review the list of ideas written down on the blackboard or flip chart. If they have mentioned that black holes "suck things in," ask them why they think that may be true. Remind them that the previous activity showed that a black hole has the same mass as the star it originally came from. But it has been scrunched into a much smaller area. Ask them if they think the Sun will "suck" the Earth into it.

A black hole's gravity is just like anything else in the Universe — it is dependent on the mass and distance from the object. You need to get very close to a black hole to notice it is there or to suffer any severe effects! While our Sun will never turn into a black hole, if we could magically replace it with a black hole of the same mass, the orbit of the Earth would not change.



The gravitational attraction for a planet stays the same with both the Sun and a black hole of the exact same mass.

Ask the students if they know why a black hole is called a "black" hole. Do they think anything comes out of a black hole?

Using the information provided in the background material, lead a discussion about escape velocity and how it applies on the Earth, moon and the Sun. Then talk about the escape velocity from the black hole.

Tell them that they are now going to model the effect of a black hole on its surroundings. Hand out the role cards to the students.

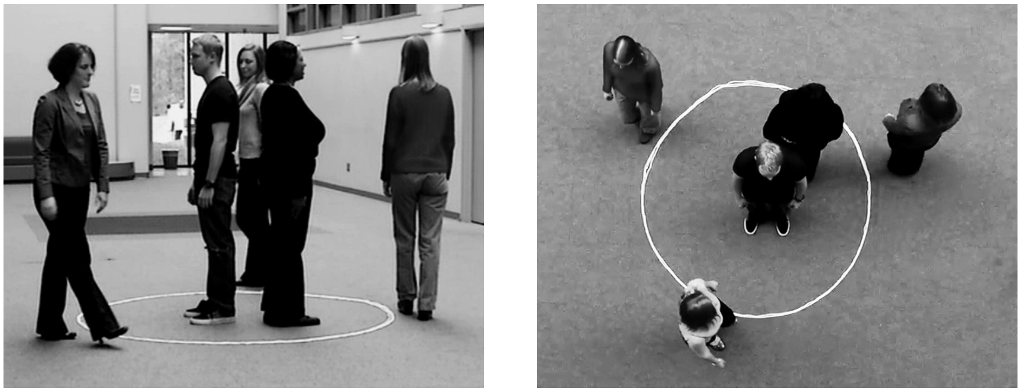
Note to program leader: The description of this activity below assumes a group of 20 students. The distribution of roles is intended to be only an example. Adjust the numbers as needed for the number of participants that you will be working with.

1. Ask the students what role they have been assigned. What happens to them depends on the role they have been assigned, so run through the activity for each group separately the first time around.

2. Have the 4 students who are going to be the black hole stand in the center of the room facing outwards with their arms stretched out. Tell them that they represent the black hole. Their "zone of influence" extends only as far as their arms stretch out.

3. Use the length(s) of yarn or rope to mark a circle that is just outside the reach of this group of students.

4. The 6 students who represent the "orbiting stars" should go around the black hole just outside the rope circle.



Participants in the role of "orbiting star" walk around the black hole just outside the rope circle.

5. Now the 4 students who have been assigned the role of "distant stars" should scatter about the outer edges of the room away from the black hole.

6. The 6 students who will act as the "nearby stars" should be in between the "distant stars" and the "orbiting stars."

7. Now ask the students who represent the "distant stars" to start wandering around the room. These stars at the edges of the room are unaffected by the black hole as they are too far away from it. They never know that there is a black hole in the vicinity and just go about their business.

8. The students who have the role of "nearby stars" will feel some pull from the black hole and their path will be altered slightly. But they don't all get attracted to the black hole and fall into it. These students should wander the space between the "distant stars" and the "orbiting stars," altering their direction a little when they come close to the "orbiting stars."

9. The students who are playing the "orbiting stars" have been captured by the gravitational pull of the black hole. Tell students that these stars behave similarly to how the planets orbit our Sun. These stars orbit the black hole and go around the rope circle.

10. Have the students get into these roles and proceed calmly for a few minutes so that they know what each type of star does.

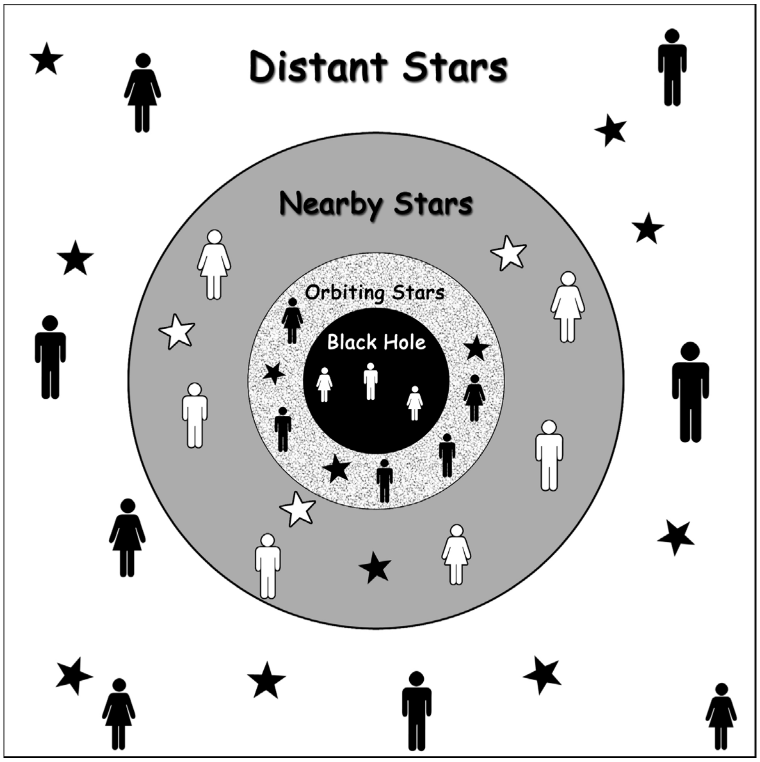
11. Now, call on one of the "nearby stars" to come close to the rope circle and bump (gently!) one of the "orbiting stars." This will push this orbiting star inside the rope circle and it falls into the black hole. When this happens, the students who form the black hole should take this student inside the black hole. This star has now become a part of the black hole and can never escape. The nearby star that bumped the orbiting star can go back to its wandering after delivering the bump.

12. Call on another "nearby star" to come close to the rope circle and bump (gently!) another one of the "orbiting stars" to push it inside the black hole. This nearby star can now take the place of the orbiting star and fall into an orbit around the black hole. You can repeat this once or twice more if you wish. ***Be very careful to emphasize that these interactions***

are caused by very rare alignments between the objects. Therefore make sure that all the students do not end up either orbiting or inside the black hole as that would defeat the point of showing that black holes do not grab and suck up everything in their vicinity!

13. The student who is now inside the black hole cannot get out. Ask the students what will happen to the light from the star that spiraled into the black hole. Can the light get out of the black hole?

14. End this activity by saying "Freeze!" and leading a discussion on what happened. What did the different types of "stars" do? Did the black hole reach out and grab all the stars in the room? The students should get the point that the black hole exerts an influence on only a limited area.



The approximate locations of students for the black hole kinesthetic.

15. To ensure maximum understanding, treat the first run through as a trial run and repeat the activity. Students can switch role cards if they wish so that they can play a different object in this second round.

16. Now ask the students what color they think a black hole is (this is easy!), and why it is this color. They should be led to the idea that it is black because it absorbs all light that falls within the event horizon. They should realize that *nothing* can escape from a black hole, not even light.

    After reminding them that space is also black, ask them how they would go about trying to find a black hole. What happened to the stars that came close to the black hole? They felt a tug or fell into an orbit around the black hole. Lead them to the idea that you have to find black holes by looking at their effect on other objects.

If the stars in this orbit happen to go inside the rope circle (say a passing "nearby star" bumps them a little and nudges them inside the circle), the gas from the surface of the star starts to get ripped off and it starts to spiral into the black hole.

Wrap up the discussion by re-iterating that the mass of black holes is not that different from the stars they formed from, but they are much denser. Also, objects have to come close to a black hole to feel its gravitational effect.

Advance preparations for Session 11

The next session (Session 11) is focused on a visit by a space scientist and making a "cosmic quilt" about what they have learned during the course of this program. See Session 11 for a description of the cosmic quilt and what it entails. Some advance preparation is needed and the steps below are ideally done at the end of Session 10.

- Form teams of two students (pairs) who will work on pieces of the "cosmic quilt." You can either assign topics or ask them to choose topics that they will represent in the quilt. These can include any of the topics studied over the course of the program – light, telescopes, spectroscopes, elements, stars, stages in a star's life, galaxies, or black holes. Each pair of students will create two "quilt" pieces — they should have a pictorial representation of their topic on one piece (a drawing, an image, etc.) and a written description on their other piece (this can be a song, a poem, a straight-up description, etc.). The students should spend some time before the next session thinking about their topics and what they might draw and write for their quilt pieces.

- Let the students know that a scientist will be visiting them for the next session. Ask the students to prepare for the scientist visit by preparing a list of questions they might wish to ask the scientist. These questions can be about their quilt topic or cover anything they have studied over the course of this program. They can also ask the scientist questions about careers in science or any other questions that are relevant to the program.

Suggestions for Running this Session

- Make sure you count out your role cards before the session, and scale them appropriately for your group size. The manual provides suggestions for this distribution.

- The purpose of this activity is to show that a black hole does not gobble up everything around it. Unfortunately, one of the fun parts of this activity for the kids is getting to pull orbiting stars into the black hole. In order to maintain a balance, you may need to monitor and restrain their enthusiasm to ensure that only a few orbiting stars get bumped into the black hole. Likewise, only a few nearby stars should become orbiting stars.

- If you feel that the role of 'nearby stars' is too confusing, or you would like fewer roles overall, it is safe to eliminate the 'nearby star' role entirely. The key points of the activity will be maintained with only the roles of 'black hole,' 'orbiting stars,' and 'distant stars.'

- It can sometimes be hard to keep the attention of those participants who are assigned the role of 'distant stars,' since they don't really have anything to do but watch. It can be very easy to zone out, when you're hanging out in the distant parts of the galaxy! Try to work on keeping them engaged, and don't let them spread out too far.

Misconceptions

- Black holes are not cosmic vacuum cleaners. Outside of the event horizon, they exert the same gravitational pull as any other object of the same mass.

- Gravity affects objects in space with a specific set of rules, and those rules aren't changed when we're talking about a black hole instead of a star. Imagine a planetary system with a large star, with planets orbiting around the star. If that star were replaced with a black hole with the exact same mass, the orbits of those planets would not change. Gravity is directly related to the mass of an object - the bigger an object is, the greater the gravitational force it will exert on the things around it. If the mass does not change, then the gravitational force doesn't change. A black hole will only increase in gravitational effects on the objects around it as it increases in mass. Students are frequently convinced that a black hole "sucks in" all of the objects around it, and we use our kinesthetic activity in this session to address what a black hole can - and cannot - do.

- Whenever we start talking about black holes, people quickly come up with a variety of fantastical ideas about what happens inside a black hole and what black holes can do. But really, we don't know what happens inside a black hole, because we can't get any information from inside of one (remember, we get information from light, and black holes are "black" because light cannot escape). Scientists would love to know what happens inside a black hole! It's a hot topic in astronomical theory and research.

Useful websites for background or activity extension

- **Floating Bowling Balls at Steve Spangler Science**
  A fun demonstration of density using bowling balls.
  http://www.stevespanglerscience.com/experiment/00000067

- **NASA's Universe Education Forum**
  A good discussion about black holes — starts with an introduction to what they are and moves on to how we find them.
  http://www.cfa.harvard.edu/seuforum/blackholelanding.htm

- ***Imagine the Universe!***
  An introduction to black holes
  http://imagine.gsfc.nasa.gov/docs/science/know_l1/black_holes.html

- ***Imagine the Universe!***
  Aluminum Foil, Balloons, and Black Holes
  http://imagine.gsfc.nasa.gov/docs/teachers/blackholes/imagine/page12.html#al

- **Hubblesite: Black Holes**
  An interactive multi-media exploration of black holes
  http://hubblesite.org/discoveries/black_holes/

- **Real Images of [The Material Around] Actual Black Holes**
  The Universe Education Forum has created a Power Point slide show with real images of (the material around) actual black holes. Although black holes themselves are invisible, they reveal themselves by their influence on the matter around them. NASA's Chandra Observatory, which is designed to detect X-ray light, has recorded stunning images of hot gas being pulled into orbit around actual black holes throughout our Universe.
  http://www.universeforum.org/einstein/resource_journeyblackhole.htm

Session 11 – Visit from a (Space) Scientist + Making a Cosmic Quilt

General Description

This session is an opportunity for students to interact with a scientist and ask any questions that may have built up over the program. In addition, they will pick one of the topics they have learned about during the course of this program and do an activity demonstrating their understanding of this topic.

Objectives

- To provide students with a direct connection to a scientist.
- To offer students an opportunity to ask questions about program concepts or other related topics.
- To discuss and explore possible careers in science, technology, engineering, and math.

Materials

- Construction paper (at least 2 pieces for each pair of students)
- Glue
- Scissors
- A large bulletin board or wall space to post many sheets of construction paper
- Markers, crayons, colored pencils, and any other craft supplies that might be useful for the students to decorate their pieces

Session Overview

During this session, the students will interact with a scientist or engineer and learn about what they do. They can also ask questions of the scientist or engineer about any of the topics they have studied during this program. After the talk, students will work on their pieces for a "cosmic quilt" based on what they have learned in this program.

Preparation

- Invite a local scientist or engineer to come and visit your student group. Physics and astronomy departments at local universities are a good place to start if you don't know any local scientists. Some companies, such as Raytheon, ITT, Hughes, and Boeing, might also have programs related to space technology. They will mostly employ engineers rather than scientists, but this may be a good option if you are unable to find a local scientist. **Be sure to make the invitation early so that you can get on their calendars** (at least a month ahead of time is a good guideline).

- Give the scientist an overview of the topics you have covered as part of this program. Point them at the website for the program, and in particular at the outline of session topics and the manual. Be clear about what you expect of their visit — you would like them to discuss STEM careers with the students and answer questions related to space science and space technology that students might have. See our website for a document of helpful suggestions that might help your scientist prepare for his or her visit to your program.

- Have the students prepare a list of questions that they wish to ask the scientist — these can range from questions about the material they have studied over the course of this program, questions about careers in science, or any other questions relevant to the program.

- Prior to this session, pair up the students and ask them to pick a topic that was covered in one of the sessions they attended through the course of this program. These can be light, telescopes, spectroscopy, elements, stars, galaxies, black holes, or anything else that has been covered. Tell your students that they will be creating a "cosmic quilt" where each pair of students will design two "quilt" pieces that illustrate their understanding of their topic via art and writing.

- Ask your students to spend some time before the scientist visit thinking about their topic, what questions they might like to ask the scientist who visits, and what they might draw and write for their cosmic quilt.

- Remind the scientist one week before their visit and provide directions to your location and any other information or instructions you might wish to give them. Also, tell them about the cosmic quilt activity and that you would like them to help the students make up their "cosmic quilt."

Activity

I. Discussion with a Scientist (25 minutes)

Moderate a discussion between the students and the visiting scientist. The students should feel free to ask the scientist questions about any topics you have covered in this program, about careers in science or engineering, or any other questions relevant to the program.

II. Cosmic Quilt (25 minutes)

(*Adapted from the High Energy Groove Cosmic Quilt developed by the RXTE EPO program*)

This activity will get students thinking about the various topics they have studied and the characteristics of the objects in the Universe that they have learned about. Students will learn to articulate their understanding of their selected topic.

1. Each student should have picked a topic that was covered in one of the sessions they attended through the course of this program. Ask the students if they have any questions about their topic for the visiting scientist.

2. Tell the students and the scientist that they will now work together to create a piece of a "quilt" that relates to their topic. Each pair of students gets two "quilt" pieces.

3. On one piece of construction paper they should create an art piece related to the topic they've picked.

4. On the other piece of construction paper they should create a literary piece also related to their topic. This can be done in any literary form they wish to use. They can write a poem, a story, a comic strip, a straight factual description, or anything else they can think of. This should be written as neatly as possible, preferably in ink. If they would like to write a draft on other paper first for neatness, this is fine.

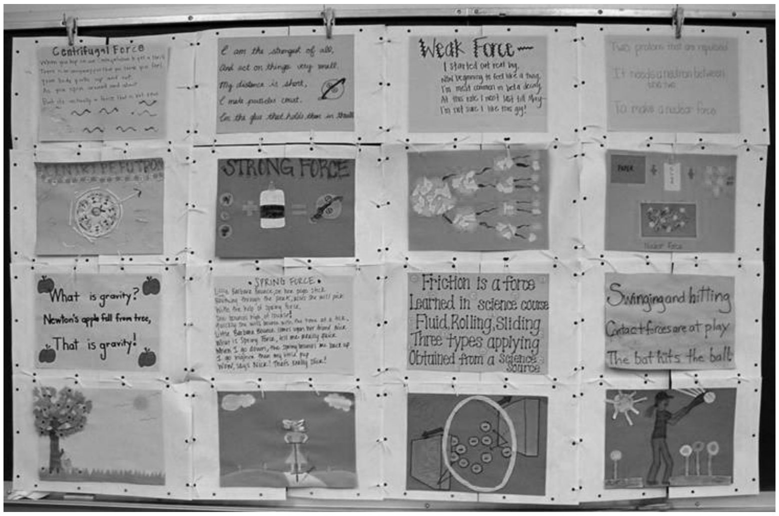
5. Encourage students to be creative in decorating their quilt pieces, and to talk to the visiting scientist about their design and any questions they may have.

6. Once all pieces are finished, piece together the quilt and post it for everybody to see. You can make it look like a real quilt by punching holes on the sides of the paper and "sewing" the pieces together with yarn or string. The following pictures illustrate what the finished "cosmic quilt" will look like.

Example of a Cosmic Quilt Layout:

Picture: Black Hole	Story: Black Hole	Picture: Supernova	Story: Supernova
Picture: Star	Story: Star	Picture: Galaxy	Story: Galaxy
Picture: Telescope	Story: Telescope	Picture: Electromagnetic Spectrum	Story: Electromagnetic Spectrum
Picture: Scientist	Story: Scientist	Picture: Red Giant	Story: Red Giant

Example of a Cosmic Quilt stitched together:



You can find a color version of this image, as well as other examples, in Appendix F.

Suggestions for Running this Session

- If you do not have a number of students in your class that makes a square or rectangular quilt possible, don't worry about it. Quilts can be any size or shape. Be creative in the placement of pieces.
- If you want your students to create their quilt pieces to all be either portrait or landscape, you will need to tell them this ahead of time. It is not necessary, and is up to you.
- Many students will draw or write all the way to the edges of their quilt pieces, and it's a shame if you have to punch holes through their hard work! If you punch the holes beforehand, you can set the margins for their artwork and writing. Also, it helps to punch the holes with even, consistent spacing, so your stitches will line up later.
- If something comes up and your scientist is unable to attend after all, you might want to think of backup activities for the session. Consider a kinesthetic activity or craft project with minimal prep work and supplies. For some ideas, see our website, and email us with your ideas if you have them. Did something work particularly well for you? Let us know so that we can share the idea with other program leaders.

Useful websites for background or activity extension

- **High Energy Groove Cosmic Quilt**
  http://heasarc.gsfc.nasa.gov/docs/xte/outreach/HEG/cq/cosmic_quilt.html

Session 12 – Modelling the Universe: The Sequel

General Description

This is a repeat of the first session where students were challenged to create a model of the universe. Now that students have participated in the sessions of the *Afterschool Universe* program, this activity will illustrate what students have learned about where we fit in the universe. As before, the activity has three major steps: discussion, modelling, and sharing models with the group. Students work in groups of three or four.

Objectives

- To revisit students' understanding of the current scientific model for the structure of the Universe and the evidence that supports that model.
- To reflect on the concepts and activities covered in previous sessions.

Concepts Addressed

- Earth's physical place in the solar system and Universe
- Astronomical size and scale

Materials

- Copy of *Universe Model Analysis Student Worksheet* for each group of students (included in Appendix E)
- A variety of crayons/colored pencils/markers
- Model construction supplies — these should be the same supplies (or as close as possible) that were used during Session 1
- Large sheet of sturdy paper on which students create their models — one per group
- Scissors, glue, and tape
- Models from Session 1 (or photos of them)

Other Requirements

- Enough table or floor space for several groups of students to work together on their models.

Session Overview

Students draw on the knowledge they have gained during the *Afterschool Universe* program to make physical models of the universe. They then analyze their own and others' models with regard to what they represent and misrepresent, what they omit, and what questions they raise.

Students and the program leader also engage in a comparison of their original models and the new ones they create during this session. This will allow a discussion of how their ideas about the Universe may have evolved.

Preparation

- Make copies of the Universe Model Analysis Student Worksheet for each group
- Set out all listed materials equally among the groups

Activity

(*Adapted with permission from the Cosmic Questions Educator's Guide*)

1. Lead a discussion about the modelling activity. Remind students of what they did in their first session.

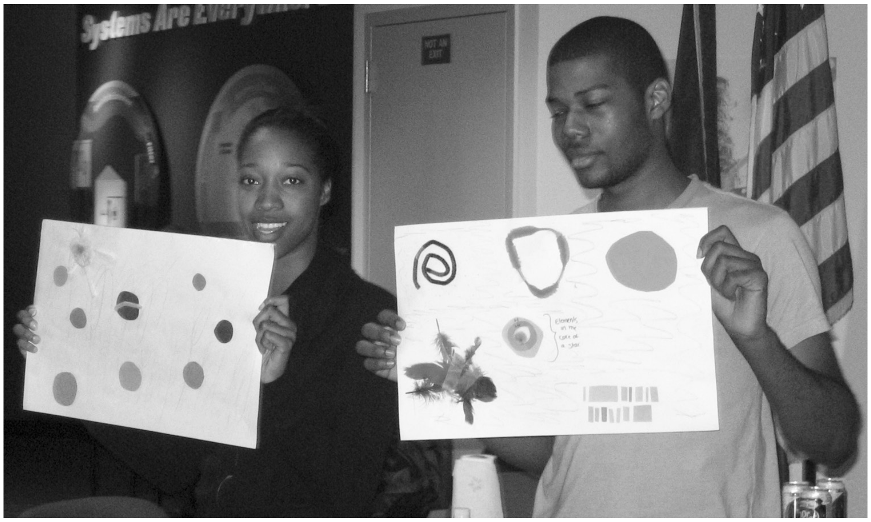
2. Now challenge the students to create a model of the Universe based on all they have learned during the course of the *Afterschool Universe* program, showing the organization or hierarchy they have learned about. This activity is the same as before — with students working in groups of 3–4. Groups should decide among themselves who will fill the roles of Model Maker, Recorder of Model Features, and Spokesperson. Students may have more than one role, but all three must be filled.

3. As they work, the Recorder in each group should use the *Universe Model Analysis Student Worksheet* to list information about the features of their model, and any questions or other thoughts that arise on this topic.

A student model after they have gone through the program.

4. Now, ask the spokesperson in each group to present their model. As they do so, ask them to comment on these four questions:

   - *What features of the Universe does your model represent?*
   - *What things — that you know of — does your model misrepresent?*
   - *What things — that you know of — does your model omit, or not represent at all?*
   - *What questions came up as your group worked on your model?*
   - *How does this model compare to the one you did at the beginning of the program?*



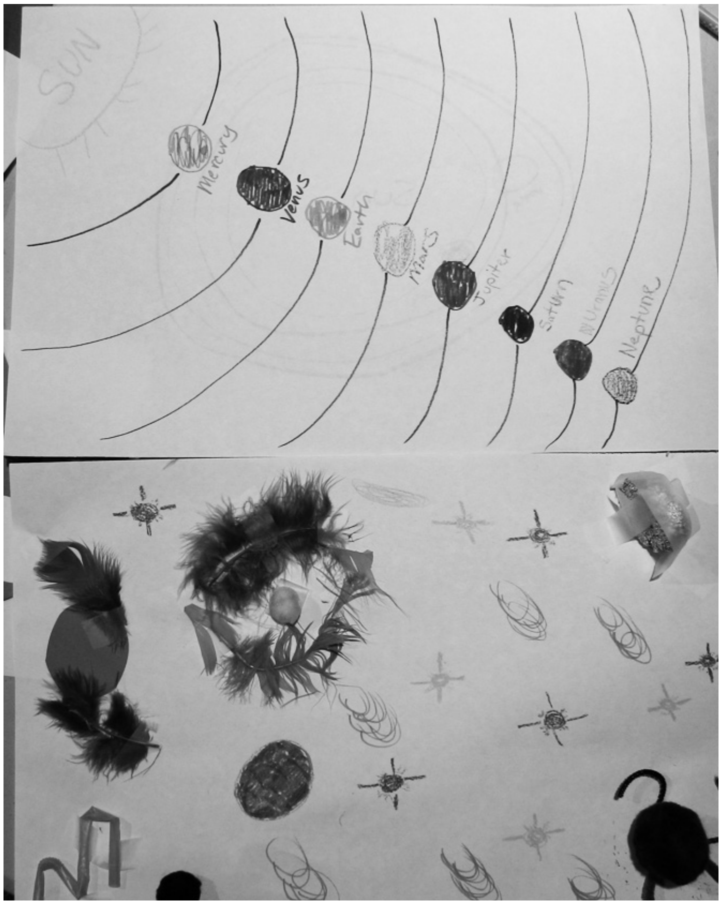
Participants comparing their models from Session 1 and Session 12.

5. Use the following questions with the whole group to further probe students' understanding of their models:

   - *Do you see any patterns?*
   - *Which parts of the models do you think represent the "real thing" particularly well? Why?*
   - *Which parts of the models do you think misrepresented the "real thing"?*
   - *Are these models to scale or not to scale? Why?*
   - *Why is making a model of the whole Universe so difficult?*
   - *How can these models be used to predict what might happen in the Universe?*
   - *What would an observer on Earth see if they lived in this Universe? (Where is Earth in your model?)*
   - *What would you need to know to design a better model?*

   These new models represent students' revised understandings of the universe, which should be thought-provoking for them and for you as the facilitator. During Session 1, we advised that there were no right or wrong answers in their original models - it was just the collection of ideas. This time, you should ask more probing questions about their models and what has changed, especially if the content seems contradictory to what they learned during the program.

   For example, if they've put a galaxy in the middle of the solar system, ask, "Where is that galaxy?" and lead them through a recollection of what they learned about galaxies in Session 10. You don't want to put any students on the spot or make them uncomfortable, but it's alright to challenge their ideas and ask questions wherever appropriate. Make sure that you understand why they've made their models the way they have - and make sure they understand, too.



One group's models from Session 1 and 12. Note the increasing complexity, and the expansion from just the Solar System to more of the Universe.

6. Make notes on students' ideas and how they have evolved from the first session. If you still have the models from the first session (or even photographs of the models), ask the students to comment on any similarities or differences between the two.

7. At the end of the activity, ***collect and save the model (or take a digital photo of them)***. You can compare them with their model from the first session to evaluate student progress.

Suggestions for Running this Session

- As much as possible, you should use the same supplies that you used in Session 1, as the types of supplies will affect what they think to put in their model. Likewise, you should try to have the same groups of people work together, whenever possible.

Appendix A – Glossary

Atom: The smallest particle of an element that still has the characteristics of that element.

Black hole: A region in space where gravity is so strong that not even light can escape from it. Black holes in our galaxy are thought to be formed when stars more than 20 times as massive as our Sun end their lives in a supernova explosion. Evidence indicates that supermassive black holes (with masses of millions to billions Suns) exist in the center of most galaxies.

Compound: A material consisting of atoms of two or more different elements that are chemically bound together.

Detectors: Something that is able to tell light is there.

Diffraction Grating: A material that separates the light from a source into the full range of visible light, making it possible to see individual lines in the source's spectrum.

Element: A material consisting of all the same atoms.

Field of view: The viewing area seen through a telescope or microscope.

Galaxy: A giant collection of gas, dust, and hundreds of thousands to billions of stars.

> **Elliptical Galaxies**: Those that are round or oval in structure, with stars spread relatively uniformly with stars distributed fairly uniformly throughout.
>
> **Spiral Galaxies**: Those showing a pinwheel structure are spiral galaxies. They have two or more arms winding out from a central "bulge," which has a large concentration of stars, usually older stars.
>
> **Irregular Galaxy**: Those that have no identifiable shape or structure to them.

Gravity: The force of attraction between all masses in the Universe; for example the attraction of the Earth's mass for objects near its surface.

Hubble Galaxies: Representing a narrow "keyhole" view stretching to the visible horizon of the Universe (at the time), the Hubble Ultra Deep Field image was taken by the Hubble Space Telescope. It covers a speck of the sky only about one-tenth of the diameter of the Moon. Gazing into this small field, Hubble uncovered an amazing assortment of at least 10,000 galaxies at various stages of evolution from billions of years ago.

Lens: A curved piece of glass, plastic or other transparent material used in cameras, glasses and scientific equipment, that makes objects appear closer, smaller, bigger, etc.

Model: A simplified imitation of something that helps explain and understand it better. Models can take different forms, including physical devices or sculpture, drawings or plans, conceptual analogies, mathematical equations, and computer simulations.

Molecule: Two or more atoms of the same or different elements that are chemically bound together.

Neutron Star: The compressed core of an exploded star made up almost entirely of neutrons. Neutron stars are very dense and have a very strong gravitational field.

Photon: The smallest (quantum) unit of light/electromagnetic energy. Photons are generally thought of as particles with zero mass and no electrical charge.

Planet: A spherical ball of rock and/or gas that orbits a star. The Earth is a planet that orbits the Sun.

Pleiades: A group of stars (technically called an open star cluster) in the constellation Taurus, consisting of several hundred stars, of which six are visible to the naked eye. The Pleiades are named for the seven daughters of the mythological god Atlas (Maia, Electra, Celaeno, Taygeta, Merope, Alcyone, and Sterope), who were said to have been transformed into stars.

Refraction: The change of direction when light travels through another medium, such as when it bends going from air to water.

Resolution: The degree to which fine details in an image can be seen as separated or resolved. Resolving power is the ability of a telescope to separate two closely spaced objects. For example, a bright star to the naked eye might actually be two closely spaced stars when seen in a telescope.

Satellite: An object that moves around a larger object. There are natural satellites such as moons around planets, and there are man-made satellites such as the Hubble Space Telescope.

Shields: Materials that do not let any light through.

Solar System: The system of the Sun and its orbiting planets, their satellites, the minor planets, comets, meteoroids, and other objects revolving around the Sun. (solar = having to do with the Sun).

Sources: Something that produces its own light.

Spectroscope: A viewing instrument that looks at the spectrum of a light source.

Spectrum: The range of all the wavelengths of energy possible, from the shortest wavelengths (highest energies/frequencies) to the longest wavelengths (lowest energies/frequencies) (plural = spectra).

Star: A giant ball of hot gas that creates and emits its own radiation through nuclear fusion. Our Sun is a star. Most of the bright objects you see in the night sky are stars, and they come in many different varieties. Even though you cannot see the stars during the daytime, they are still present. The intense light of the nearby Sun simply overwhelms the light coming from distant stars.

Supernova: The explosion of a star that can shine millions of times brighter than the original star. (plural = supernovae).

Telescope: A device that allows us to see far away objects we cannot see with the naked eye.

> **Refracting vs. reflecting**: A refracting telescope focuses light by refracting light through a lens. A reflecting telescope focuses light by reflecting it off a mirror. The amount of light that a telescope takes in is determined by the size of the lens or mirror collecting the light.

Transmitters: Materials that let light through.

Trillion: One thousand times one billion, represented as a one followed by 12 zeros: 1,000,000,000,000.

Universe: The summation of all particles and energy that exist and the space in which all events occur.

Wavelength: The distance between the two peaks (or crests) of a wave.

Appendix B – Materials Checklist

This checklist will help you assemble and review your supplies for each session. Quantities of each item are not listed, as that will be determined by the size of your group. Additional details about the materials needed are available in the session write-ups. Information about sources for the materials is available in the materials spreadsheet on the *Afterschool Universe* website.

Session 1 – Modelling the Universe

☐ Universe Model Analysis Student Worksheets
☐ Examples of models
☐ Crayons/colored pencils/markers
☐ 8.5" × 11" white paper
☐ Construction paper and other craft supplies
☐ Large sheets of sturdy paper
☐ Scissors, glue, and tape
☐ (Optional) Clay or Plah-Doh

Session 2 – Cosmic Survey

☐ Cosmic Survey images (laminated or reinforced)
☐ Cosmic Survey Student Worksheets

Session 3 – Telescopes

☐ Telescope kits
☐ Rulers
☐ Rubber bands
☐ White or light-colored tissue paper
☐ Light source (clear light bulb or Maglite flashlight)
☐ (Optional) 3" square pieces of paper
☐ Postcards
☐ Stamps

Session 4 – Invisible Light

☐ The Electromagnetic Spectrum handout
☐ Flashlight
☐ Plain white paper
☐ Infrared light (heat lamp)
☐ Alligator jumper clip cables

☐ Photocell or solar cell
☐ Amplifier/speaker
☐ Audio cable
☐ Remote control(s)
☐ Digital camera or camera phone
☐ Ultraviolet lamp
☐ Invisible ink pens or other items which are sensitive to ultraviolet light (ultraviolet reactive beads, glow-in the-dark stars, credit cards, laundry detergent, etc.)
☐ Batteries (for flashlight, UV lamp, remote controls, and amplifier/speaker)
☐ Visible Light worksheet (for leaders)
☐ Invisible Light worksheets
☐ Pencils/pens
☐ Sheets of material to test (clear plastic, black plastic, aluminum foil, paper, cloth, wax paper, plastic bag, etc.)

Session 5 – Spectroscopy

☐ The Electromagnetic Spectrum handout
☐ Paper towel tubes (or other tubes)
☐ Aluminum foil
☐ Masking tape
☐ Diffraction grating
☐ Diagram of paper tube spectroscope
☐ Light sources

Session 6 – Stars and Their Lives

☐ Blackboard, whiteboard, or a flipchart on an easel
☐ Chalk or markers
☐ 8.5" × 11" sheets of cardboard or thick construction paper
☐ Two identical light sources
☐ The Lives of Stars handout
☐ Images of stars at different stages in their life cycles
☐ Scissors

Session 7 – Stars and Their Lives (Part II)

☐ Periodic table
☐ Clay
☐ Hotplate
☐ Heavy oven mitts or tongs
☐ Clear bowl
☐ Water
☐ Ice
☐ Empty soda cans
☐ Tennis balls
☐ Ping pong balls

Session 8 – Our Cosmic Connection to the Elements

☐ Poundcake
☐ Knife
☐ Gloves or wet wipes
☐ Paper plates
☐ Example of a pure element (copper tubing)
☐ Periodic table
☐ White rice
☐ Split peas
☐ Elbow macaroni
☐ Black beans
☐ Pink beans
☐ Colored sprinkles
☐ Large bowl
☐ Paper towels
☐ Plastic spoons
☐ Universe Trail Mix key
☐ Universe Trail Mix worksheet
☐ Elemental spectra handout
☐ Note paper

Session 9 – Galaxies

☐ Index cards
☐ Paper plates (or other round, flat pieces such as cardboard, or foam board)
☐ Scissors or box cutter
☐ Diagram of Milky Way galaxy arms
☐ Crayons/colored pencils/markers
☐ Yellow or red markers (or watercolor paint)
☐ Stickers of stars and circles/ovals
☐ Styrofoam balls
☐ Blunt cutter
☐ Toothpicks
☐ Rulers
☐ Hubble Ultra Deep Field image
☐ Image of types of galaxies
☐ Images of galaxies different orientations of spiral galaxies
☐ Blackboard/whiteboard or flip chart
☐ Chalk or whiteboard markers

Session 10 – Black Holes

☐ Blackboard/whiteboard or flip chart
☐ Chalk or whiteboard markers
☐ Round balloons
☐ Aluminum foil
☐ Balances/scales
☐ Cloth/flexible tape measures
☐ Student worksheet
☐ Index cards
☐ Approximately 20-foot length of rope (or yarn, jump ropes, etc.)

Session 11 – Visit from a Scientist

☐ Construction paper
☐ Glue
☐ Scissors
☐ Crayons/colored pencils/markers
☐ Decorative craft supplies

Session 12 – Modelling the Universe, The Sequel

- ☐ Universe Model Analysis Student Worksheets
- ☐ Crayons/colored pencils/markers
- ☐ Model construction supplies (construction paper, balloons, balls, marbles, string, straws, pipe cleaners, pasta, etc.)
- ☐ Large sheets of sturdy paper
- ☐ Scissors, glue, and tape
- ☐ Models from Session 1 (or photos of them)

Appendix C – Shopping Information

The activities in *Afterschool Universe* are designed to utilize readily accessible materials – most items can be purchased at a supermarket, mass merchandiser, or craft store. A few items are a little more challenging to find, and this section provides detailed information about possible places to purchase them. Since this information can change quickly, you should consider these suggestions as a starting points only. Check our website for any updates to this.

Session 3 – Telescopes

The refracting telescope kits required for this session are distributed by Science First. They are available in single kits (to build one telescope) or sets of 10 kits. Bulk purchasing can be arranged directly with the company.

Items:

- 654-0010: Refracting Telescopes (set of 10)
- 654-0000: 1 Complete Telescope Kit

Science First
95 Botsford Place
Buffalo, NY 14216
Phone: 800-875-3214
Fax: 800-799-8115
http://www.sciencefirst.com/

Session 4 – Invisible Light

Some of the components of the infrared-detecting circuit are available from RadioShack. Your local store may carry the parts, or you can buy them on the company's website.

Items:

- 278-1157: 24" Insulated Test/Jumper Leads (alligator clip cables)
- 277-1008: Mini Audio Amplifier (amplifier/speaker)
- 42-2434: 6-Ft. Shielded Cable, 1/8" Plug to Stripped Wires (audio cable)

RadioShack
Phone: 800-THE-SHACK
http://www.radioshack.com

The infrared receiver circuit requires an encapsulated solar cell with two wire lead. Our previous supplier for this item is no longer in business, but the item is still being produced by its manufacturer. Until we have verified a new supplier, we recommend that you check out the product information below, and do an internet search for this model, or a similar item. You can also check our website for any updated recommendations.

Items:

- SOL1: Encapsulated Solar Cell (0.5V/400mA)

Velleman, Inc.
http://www.vellemanusa.com/

The ultraviolet light-reactive beads and portable UV light can be purchased from many educational retailers. One source is Educational Innovations, Inc.

Items:

- UV-AST: UV Beads, Assorted Colors
- UV-640: Portable UV Light

Educational Innovations, Inc.
5 Francis J. Clarke Circle
Bethel, CT 06801
Phone: 203-229-0730
Fax: 203-229-0740
http://www.teachersource.com

Ultraviolet pens (which can also be called invisible ink pens or sometimes counterfeit marking pens) can be found in a number of places, but unfortunately, the specifics tend to fluctuate quickly. Try doing an online search to see what is available at the time that you need them.

Session 5 – Spectroscopy

This session requires diffraction grating, a thin plastic film. This can be purchased from various science supply stores online. A couple options are listed below, and a quick internet search will likely turn up others. Purchase at least 1 square inch per spectroscope.

Items:

- PG-400: Single Axis Diffraction Grating (6" x 24" sheet)

Educational Innovations, Inc.
5 Francis J. Clarke Circle
Bethel, CT 06801
Phone: 203-229-0730
Fax: 203-229-0740
http://www.teachersource.com

OR

Items:

- 3052116: Diffraction Grating Film (200' x 6" sheet)

Edmund Scientific
60 Pearce Ave.
Tonawanda, NY 14150
Phone: 1-800-728-6999
http://www.scientificsonline.com

OR

Items:

- 01505: Diffraction Grating Film Sheet – 500 lines per mm (6" x 12" sheet)

Rainbow Symphony Store
6860 Canby Ave. Suite 120
Reseda, CA 91335
Phone: 818-708-8400
Fax: 818-708-8470
http://www.rainbowsymphonystore.com

Appendix D – Black and White Handouts and Worksheets

These are the worksheets and handouts for your use in this program. These black and white pages can be photocopied, and are also available for download from our website.

- Session 1 – Universe Model Analysis Worksheet
- Session 2 – Cosmic Survey Worksheets
- The Electromagnetic Spectrum
- Session 4 – Visible Light Worksheet
- Session 4 – Invisible Light Worksheet
- Session 5 – Spectroscope Diagram
- The Lives of Stars
- Periodic Table
- Session 8 – Universe Trail Mix Worksheet
- Session 10 – Black Holes Worksheet
- Session 12 – Universe Model Analysis Worksheet

Afterschool Universe Session 1 - Universe Model Analysis Worksheet

Date: ____________ Name: ____

A model is a simplified imitation of something designed to help us understand it better. It may represent the whole or only part of a system. Because a model is not the real thing, it can always misrepresent some features of the real thing.

As you create your model of the Universe, you should have an explanation for why you are doing something. It is completely ok if you are taking a guess – but you should explain why you guessed that way.

You will be asked to explain your model to the rest of the class, commenting on these questions:

- What features of the universe does your model represent?
- What things does your model not represent well?
- What things about the universe does your model leave out, or not represent at all?
- What questions came up as your group worked on your model?

<table>
<tr><th>Features Represented</th><th>Misrepresented Features</th><th>Features Omitted by Model</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Questions we had</td></tr>
</table>

Afterschool Universe Session 2 - Cosmic Survey Worksheet 1

How Big?

Working with your group, try to arrange the pictures in order by size of the object (or group of objects) pictured. When the group generally agrees on the order, record the objects below, along with any questions that arise during your discussion.

Objects Ordered by Size:

1.

2.

3.

4.

5.

6.

7.

8.

9.

Questions:

Afterschool Universe Session 2 - Cosmic Survey Worksheet 2

How Far?

Working with your group, try to arrange the pictures in order by distance to the object (or group of objects). When the group generally agrees on the order, record the objects below, along with any questions that arise during your discussion.

Objects Ordered by Distance:

1.

2.

3.

4.

5.

6.

7.

8.

9.

Questions:

Afterschool Universe Session 2 - Cosmic Survey Worksheet 3

How Old?

Working with your group, try to arrange the pictures in order by age pictured. When the group generally agrees on the order, record the objects below, along with any questions that arise during your discussion.

Objects Ordered by Age:

1.

2.

3.

4.

5.

6.

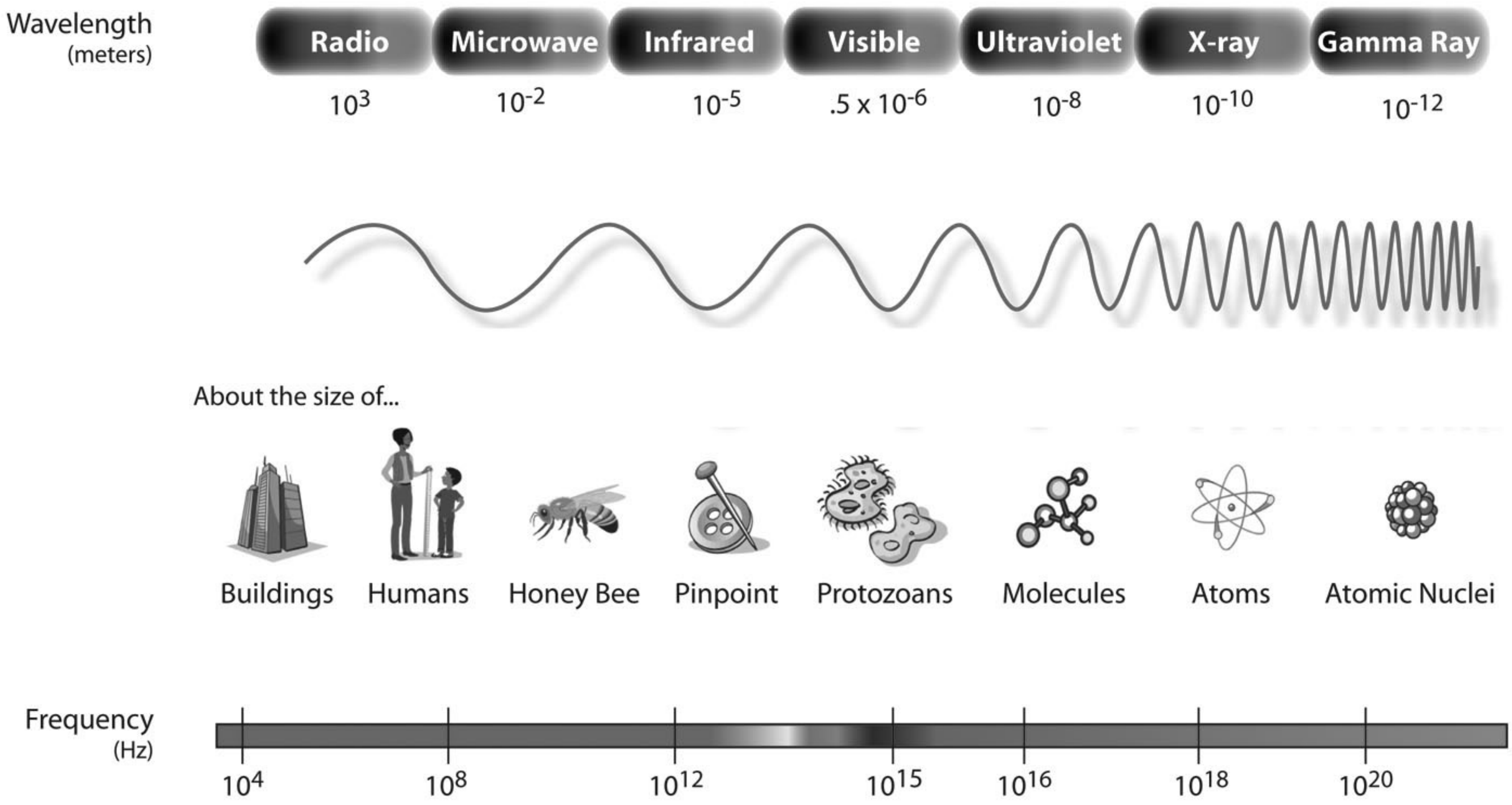
7.

8.

9.

Questions:

THE ELECTROMAGNETIC SPECTRUM



Code: **T** = Transmitter; **S** = Shield

Test Shields

Visible Light		Clear Plastic	Black Plastic	Aluminum Foil	Paper	Cloth	Wax Paper	Plastic Bag	(Other)
Flashlight (visible light)	Prediction								
	Result								

This worksheet is for leader demonstration only.

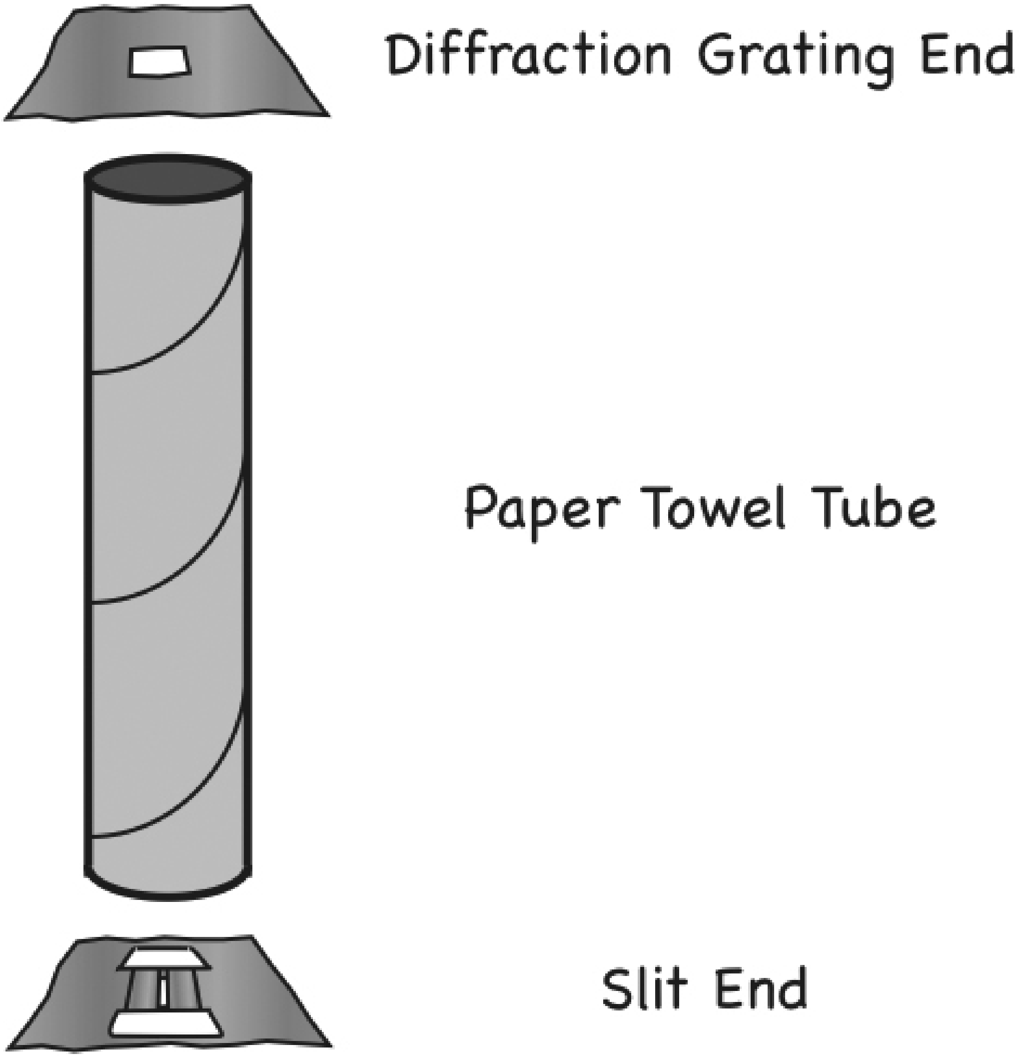
Copy and distribute invisible light worksheet (following page) to students.

Code: **T** = Transmitter; **S** = Shield

Test Shields

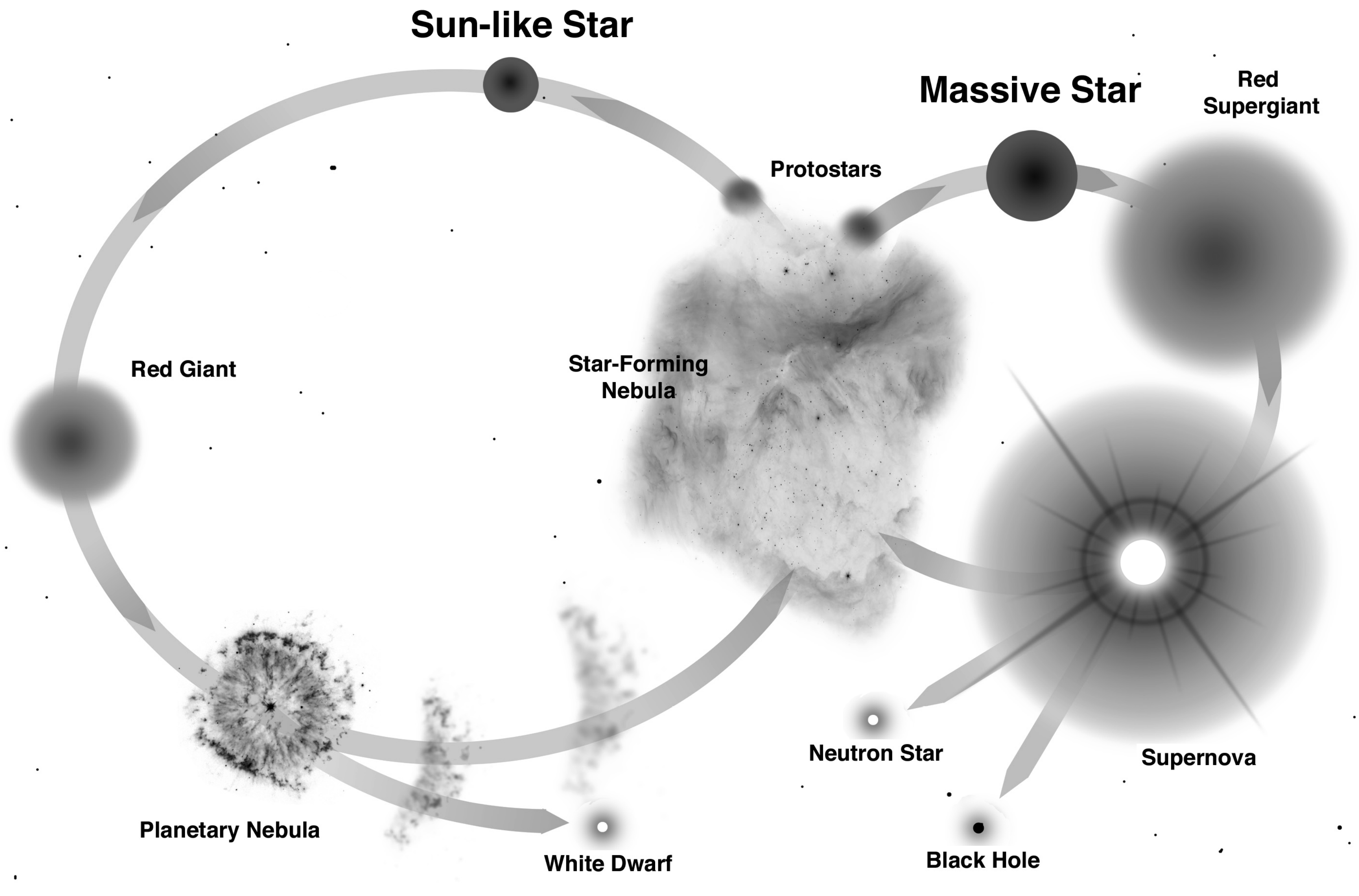
Invisible Light		Clear Plastic	Black Plastic	Aluminum Foil	Paper	Cloth	Wax Paper	Plastic Bag	(Other)
Black Light (ultraviolet)	Prediction								
	Result								
Heat Lamp (infrared)	Prediction								
	Result								
Remote Control (infrared)	Prediction								
	Result								

Afterschool Universe Session 5 — Diagram of Paper Towel Tube Spectroscope

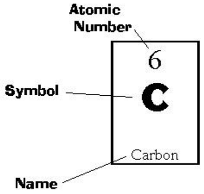


National Aeronautics and Space Administration

the lives of stars



PERIODIC TABLE OF THE ELEMENTS



1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Cesium	56 Ba Barium		72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium		104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Uun Ununnillium	111 Uuu Unununium	112 Uub Ununbium		114 Uuq Ununquadium		116 Uuh Ununhexium		118 Uuo
			57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
			89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Afterschool Universe Session 8 - Universe Trail Mix Worksheet

INGREDIENT	ELEMENT	HOW MANY?
Black Beans		
Blue Sprinkles -		
Green Split Peas -		
Macaroni -		
Orange Sprinkles -		
Green Sprinkles -		
Pink Beans -		
Rice -		
Red Sprinkles -		
Yellow Sprinkles -		

---

1. In my sample, I had the most ____________________ (element)
2. In my sample, I had the second most ________________________ (element)
3. Did you find all of the elements in your sample? __________________
4. Did all of the elements have similar amounts? __________________

Afterschool Universe Session 10 - Black Holes Worksheet

Trial	Mass	Circumference	Change in mass and circumference between trials
1			
2			**Trial 2 - Trial 1** *Mass:* *Circumference:*
3			**Trial 3 - Trial 2** *Mass:* *Circumference:*
4			**Trial 4 - Trial 3** *Mass:* *Circumference:*
5			**Trial 5 - Trial 4** *Mass:* *Circumference:*

Afterschool Universe Session 12 - Universe Model Analysis Worksheet

Date: ___________ Name: _____________________________________

A model is a simplified imitation of something designed to help us understand it better. It may represent the whole or only part of a system. Because a model is not the real thing, it can always misrepresent some features of the real thing.

As you create your model of the Universe, you should have an explanation for why you are doing something. It is completely ok if you are taking a guess – but you should explain why you guessed that way.

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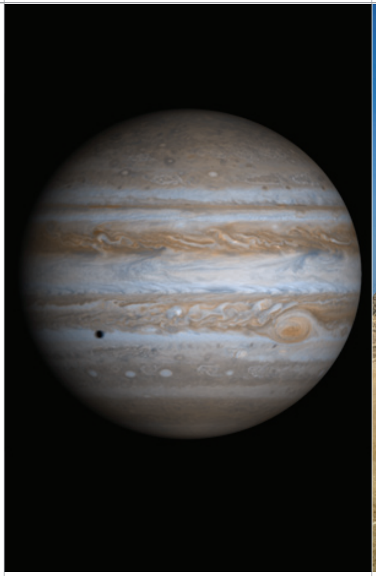
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Questions we had</td></tr>
</table>

Appendix E – Color Images and Handouts

These are the color images and handouts for your use in this program. These pages are also available for download from our webpage.

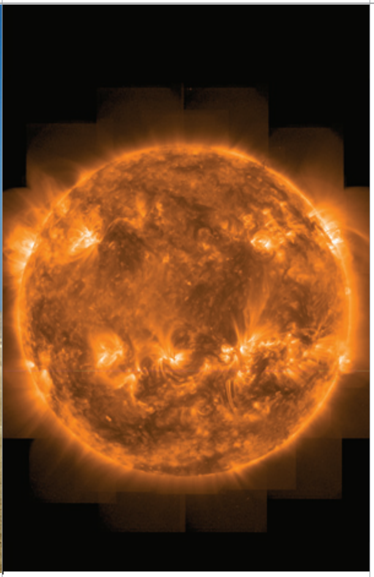
- Session 2 – Cosmic Survey Cards
- The Electromagnetic Spectrum
- Examples of Elemental Spectra
- The Lives of Stars
- Session 6 – Stars at Different Stages
- Periodic Table
- Session 8 – Universe Trail Mix Key
- Session 9 – Diagram of the Milky Way Galaxy arms
- Session 9 – Hubble Ultra Deep Field Image
- Session 9 – Types of Galaxies
- Session 9 – Different Orientations of Spiral Galaxies
- Session 11 – Examples of Cosmic Quilts

Cosmic Survey Cards

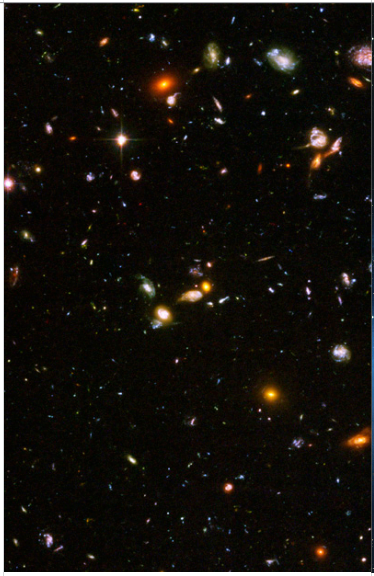


JUPITER

PYRAMIDS (EGYPT)



SUN



HUBBLE GALAXIES

PLEIADES STARS

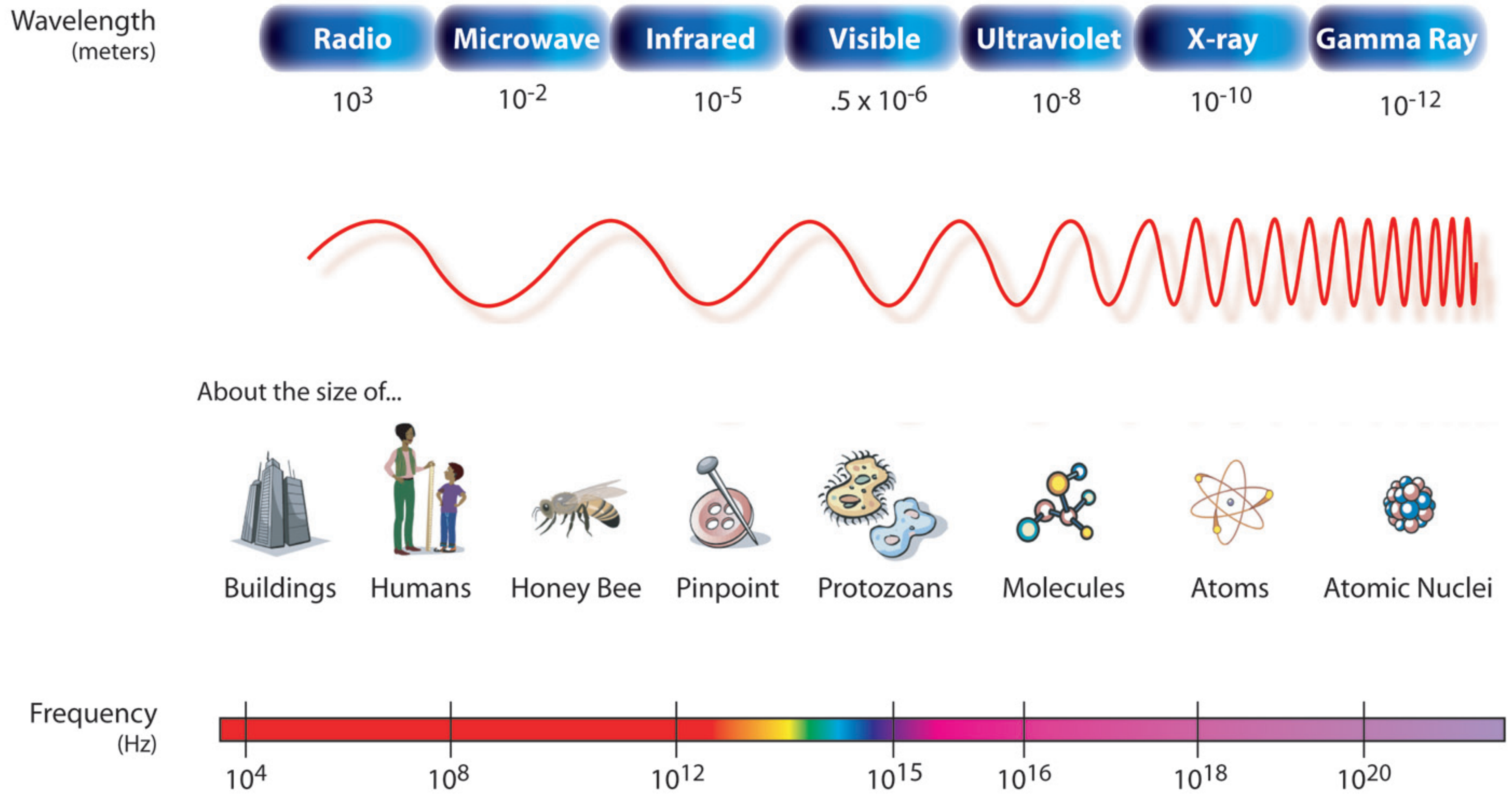
MOON

HUBBLE TELESCOPE

WHIRLPOOL GALAXY

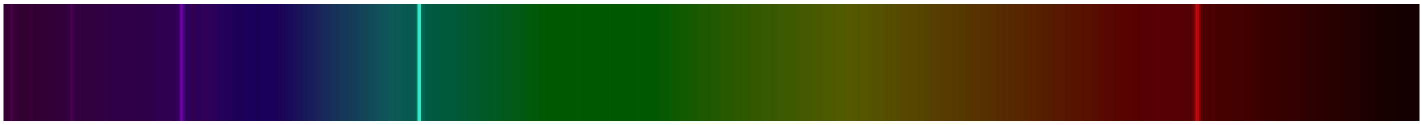
NEW YORK CITY

THE ELECTROMAGNETIC SPECTRUM



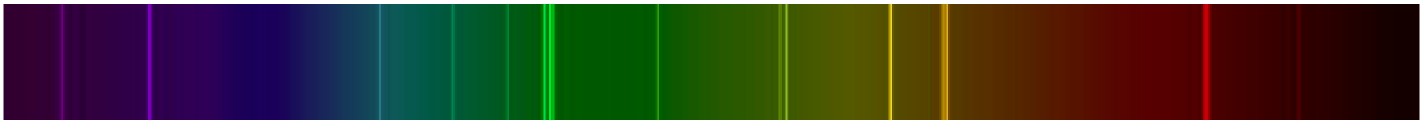
Spectra of Common Elements

Hydrogen

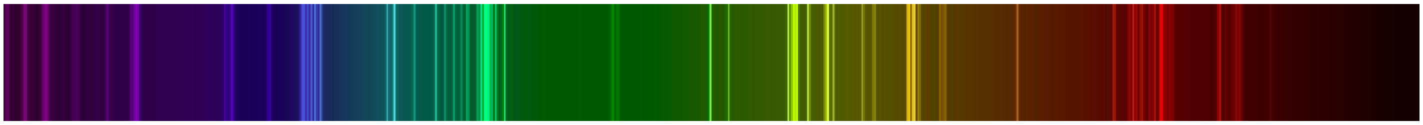


Helium

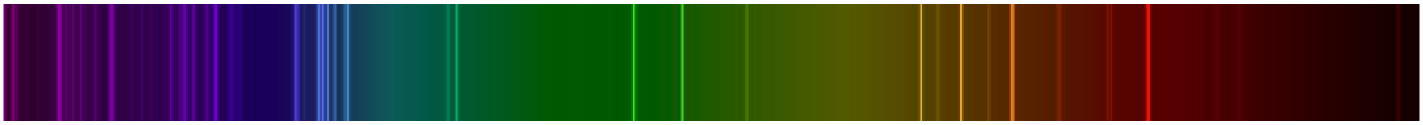
Carbon



Nitrogen



Oxygen



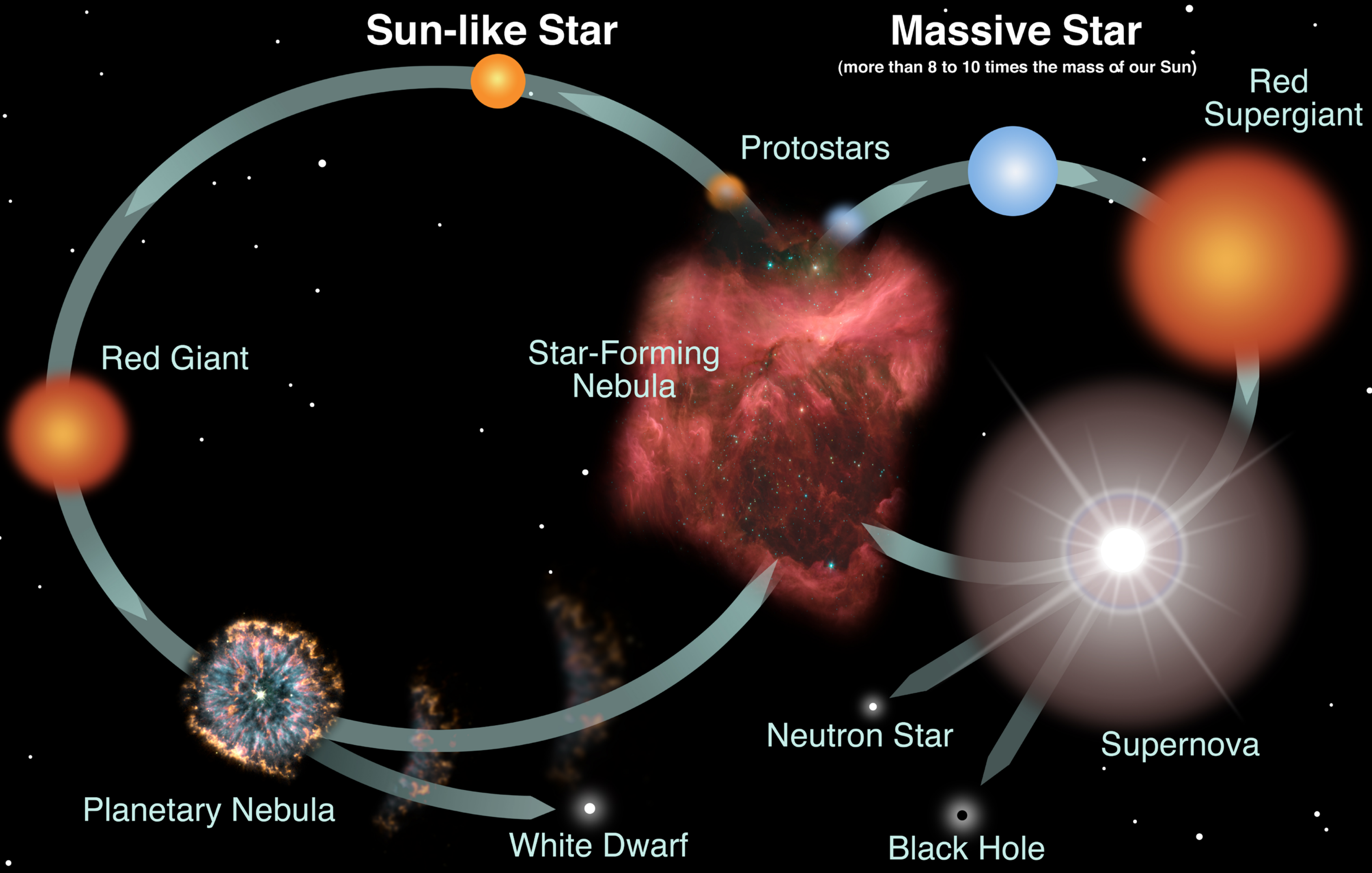
Neon

Sodium

Mercury

the lives of stars

National Aeronautics and Space Administration



Sun-like Star

Massive Star

(more than 8 to 10 times the mass of our Sun)

Protostars

Red Supergiant

Red Giant

Star-Forming Nebula

Supernova

Neutron Star

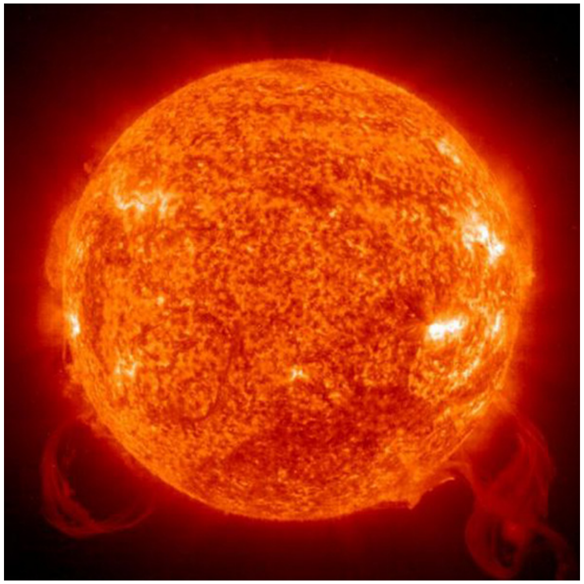
Black Hole

Planetary Nebula

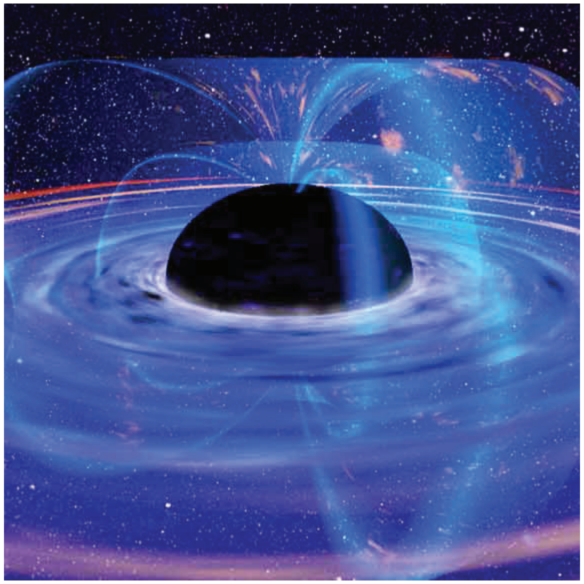
White Dwarf

Afterschool Universe **Session 6 – Stars at Different Stages**

Orion Nebula



Our Sun



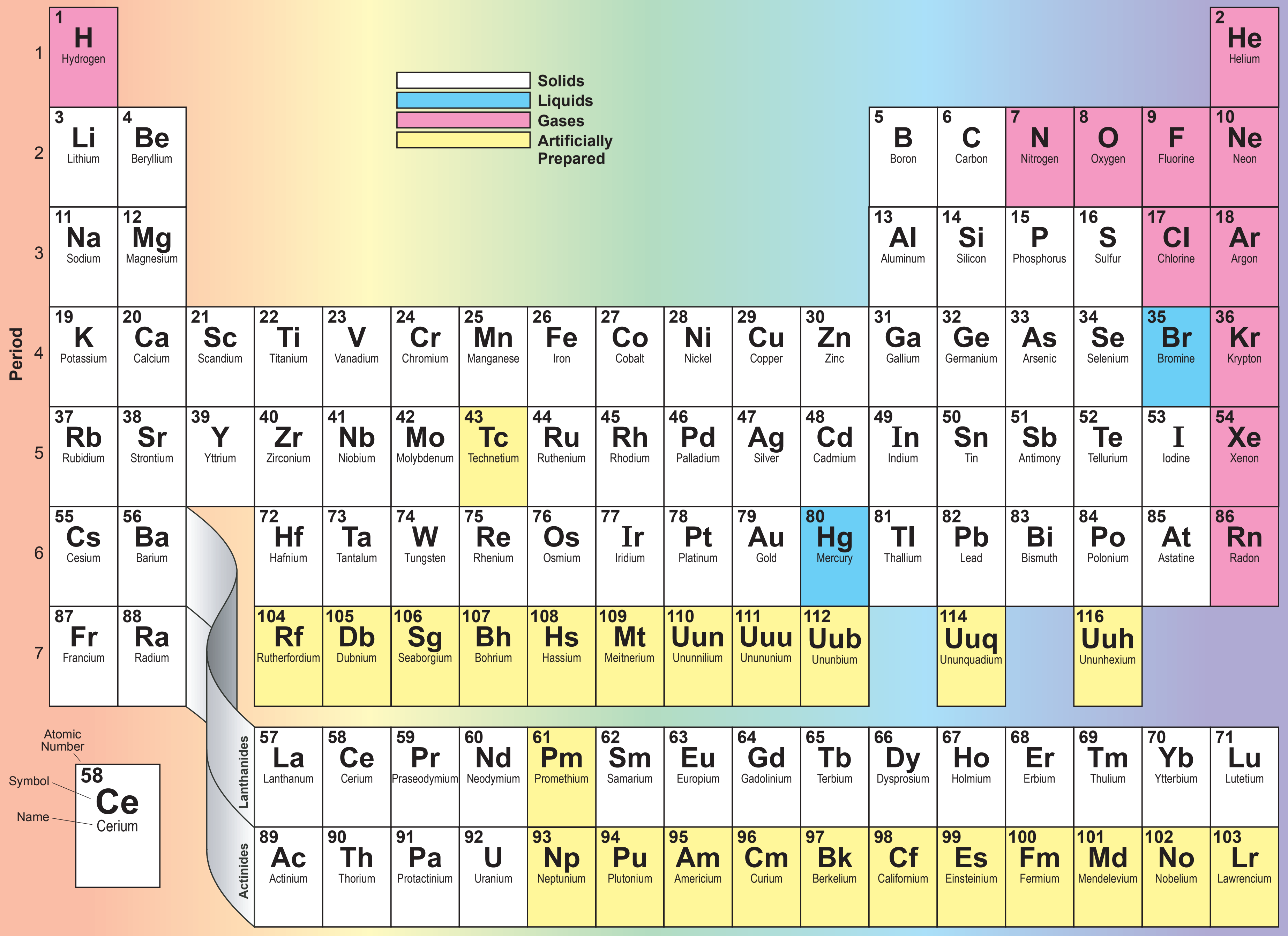
Black Hole (artist's visualization)

Cat's Eye Planetary Nebula

Supernova (artist's visualization)

PERIODIC TABLE

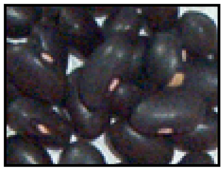
Atomic Properties of the Elements



⬜ Solids
🟦 Liquids
🟥 Gases
🟨 Artificially Prepared

Period																		
1	1 H Hydrogen																	2 He Helium
2	3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
3	11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
4	19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
5	37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
6	55 Cs Cesium	56 Ba Barium		72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
7	87 Fr Francium	88 Ra Radium		104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Uun Ununnilium	111 Uuu Unununium	112 Uub Ununbium		114 Uuq Ununquadium		116 Uuh Ununhexium		
			Lanthanides	57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
			Actinides	89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

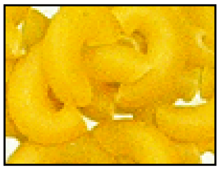
Universe Trail Mix Key



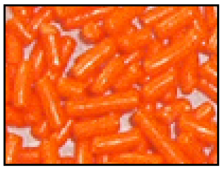
Black Beans = Oxygen (O)

Blue Sprinkles = Magnesium (Mg)

Green Split Peas = Helium (He)



Macaroni = Carbon (C)

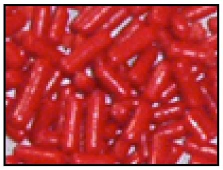


Orange Sprinkles = Silicon (Si)

Green Sprinkles = Neon (Ne)

Pink Beans = Nitrogen (N)

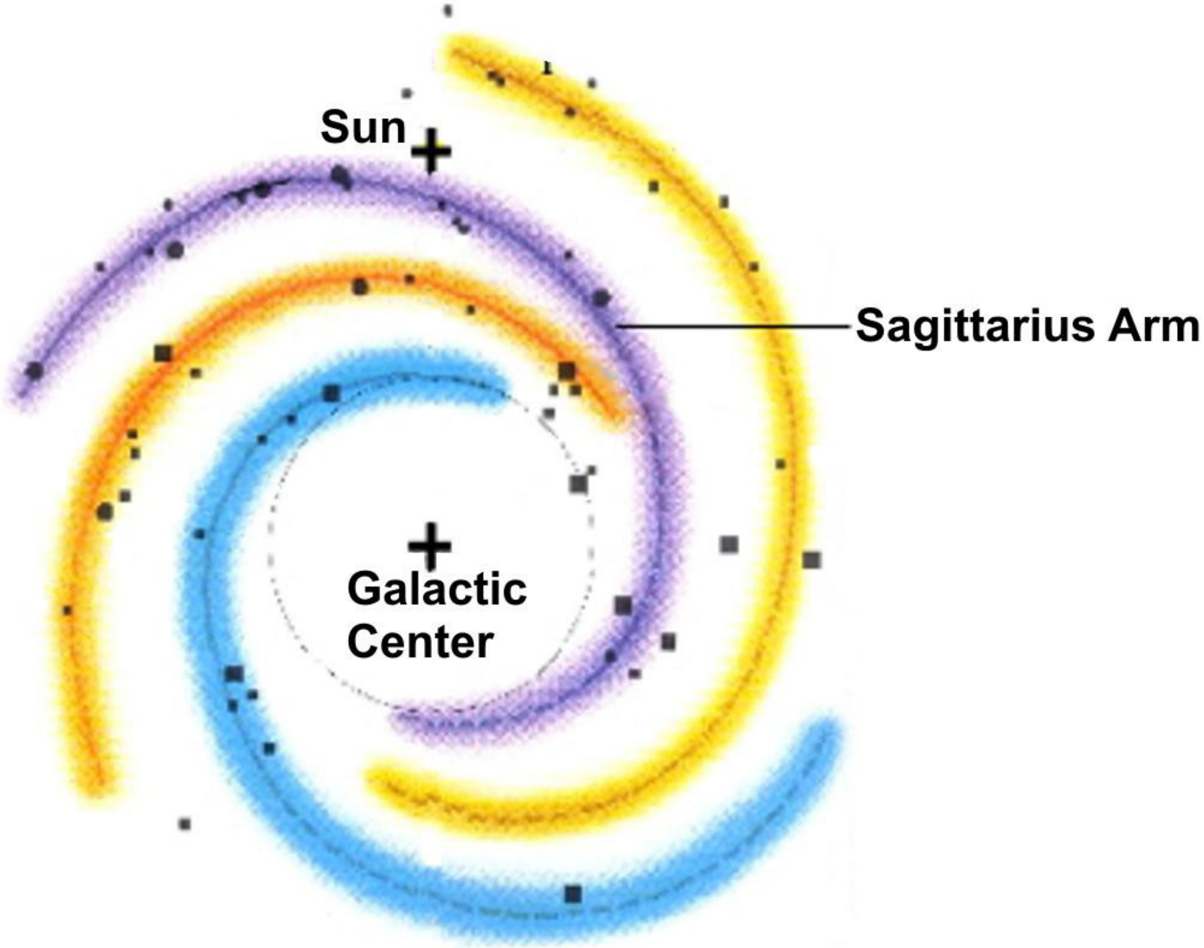
Rice = Hydrogen (H)



Red Sprinkles = Iron (Fe)

Yellow Sprinkles = Sulfur (S)

Afterschool Universe Session 9 — Diagram of Milky Way Galaxy Arms



Hubble Ultra Deep Field

Hubble Space Telescope • Advanced Camera for Surveys

NASA, ESA, S. Beckwith (STScI) and the HUDF Team

STScI-PRC04-07a

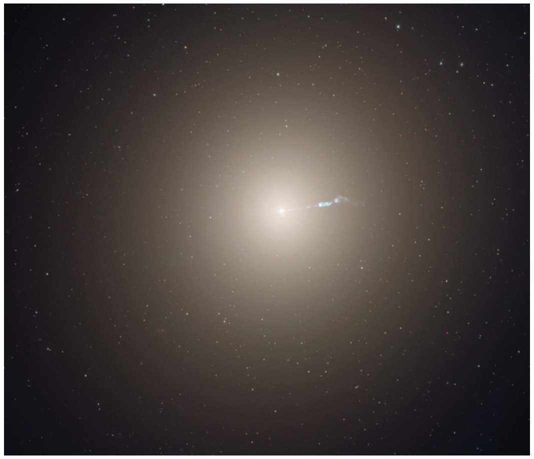
Types of Galaxies

Spiral Galaxies

Whirlpool Galaxy
Credit: NASA

Andromeda Galaxy
Image courtesy and copyright: Rob Gendler
http://www.robgendlerastropics.com/

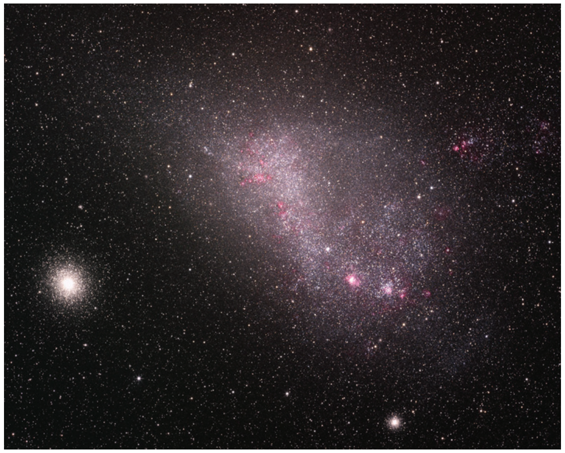
Elliptical Galaxies



M87
Credit: NASA

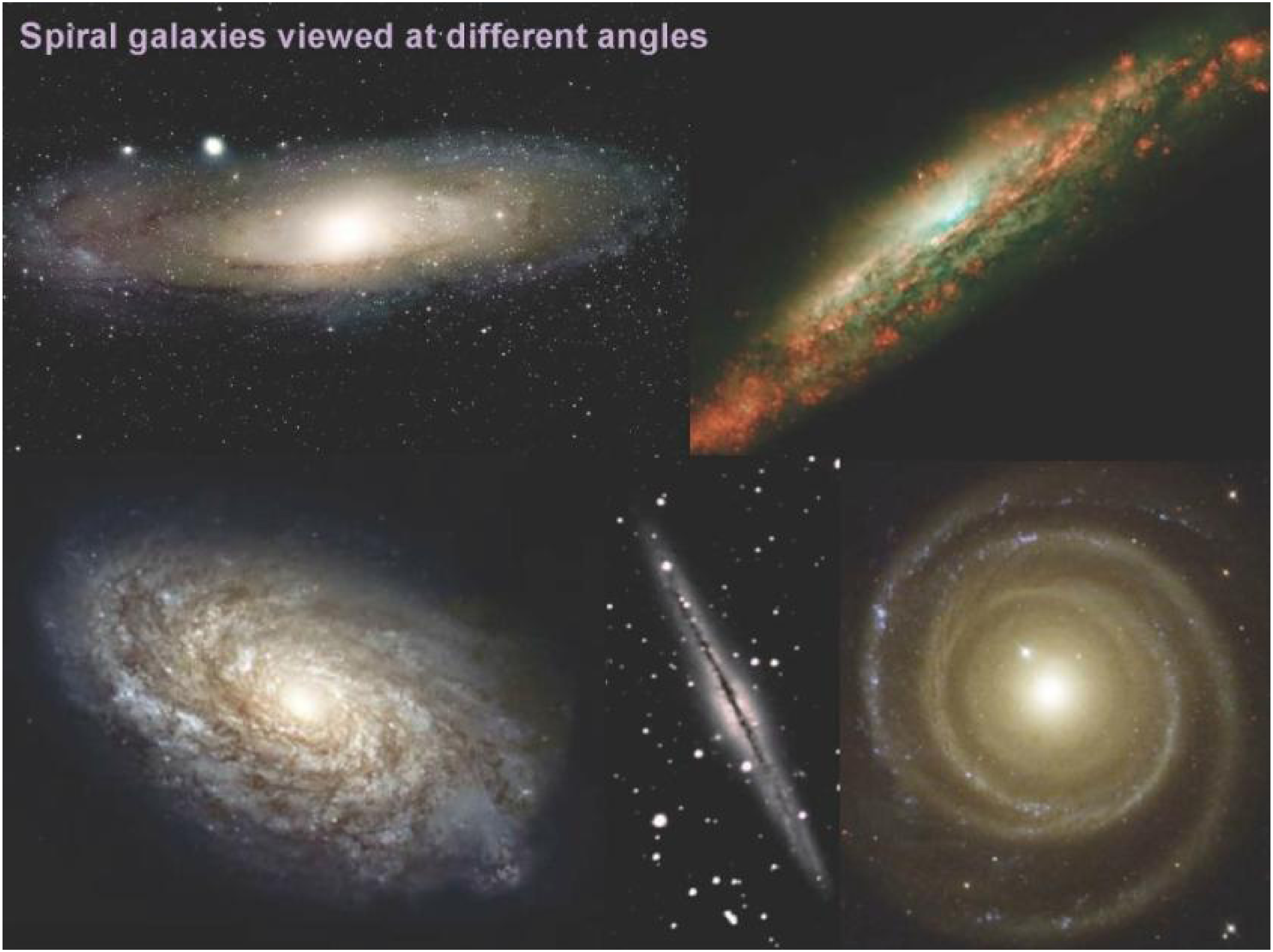
Irregular Galaxies

Large Magellanic Cloud
Image courtesy and copyright: Rob Gendler
http://www.robgendlerastropics.com/



Small Magellanic Cloud
Image courtesy and copyright: Stéphane Guisard
http://www.astrosurf.com/squisard/

Spiral galaxies viewed at different angles



Afterschool Universe Session 11 – Examples of Cosmic Quilts


galaxies
You Touch The Core of my Heart
Galaxies, Galaxies
Glorious and True:
You Amaze me with
Your Awe-inspiring
Wonderous Ways.
Galaxies, Galaxies
Glorious and True:
Full of Super Novas
White Dwarfs
Black Holes
Found in Hubble's Ultra
Deep Fields
You Touch the Core of my Heart
Giant
And
Lots of variety
All stars, planets and everything space
X-treemly old
Yours and My home
Fu- Fu- Fu- Fusion
Gr- Gr- Gr- Gravity
Is Balanced....
It-Burns-Burns-Burns
To A Big Red Giant
And as Ends-Ends-Ends
As a White ~~Dwarf~~...
Dwarf...
Rob's Fears
Galaxies stay away!! Leave the Milky Way alone!! No bumper-galaxies please!!
More x-rays please!! Is that black hole going to get to close to us!!
The helium might run out! Please Fusion, Don't Stop!
I'm so afraid!!
I'm so afraid.
Took 14 Billion years to be made
The universe is vast
I'm 27 years old
I just want the planet to last.
Our Sol is 5 billions yrs old.
But other stars will soon fold
I just want to know what the future will hold.
Black holes will be formed
Stars will explode
Is our planet really in trouble?
Maybe I should build me a bubble!!


Spectra
?
What is X-ray
THE USES OF TELESCOPES
There once was a budding astronomer
Who studied celestial phenomena.
Imagine her glee
When she managed to see
The wonders on far-off
Andromeda.
IT ALL STARTED WITH A...
Bang!
Galaxy
3 types of galaxies
Earth in Milky Way galaxy
Milky Way = spiral galaxy
Galaxy made of stars, gas, dust + gravity
Billions of galaxies in Universe
Spiral
Elliptical
Barred Spiral
Irregular
SPIRAL GALAXY VIEWS
People are made of stardust
The Elements in our bodies,
like carbon, hydrogen, nitrogen
oxygen came from the
explosion of earlier stars!