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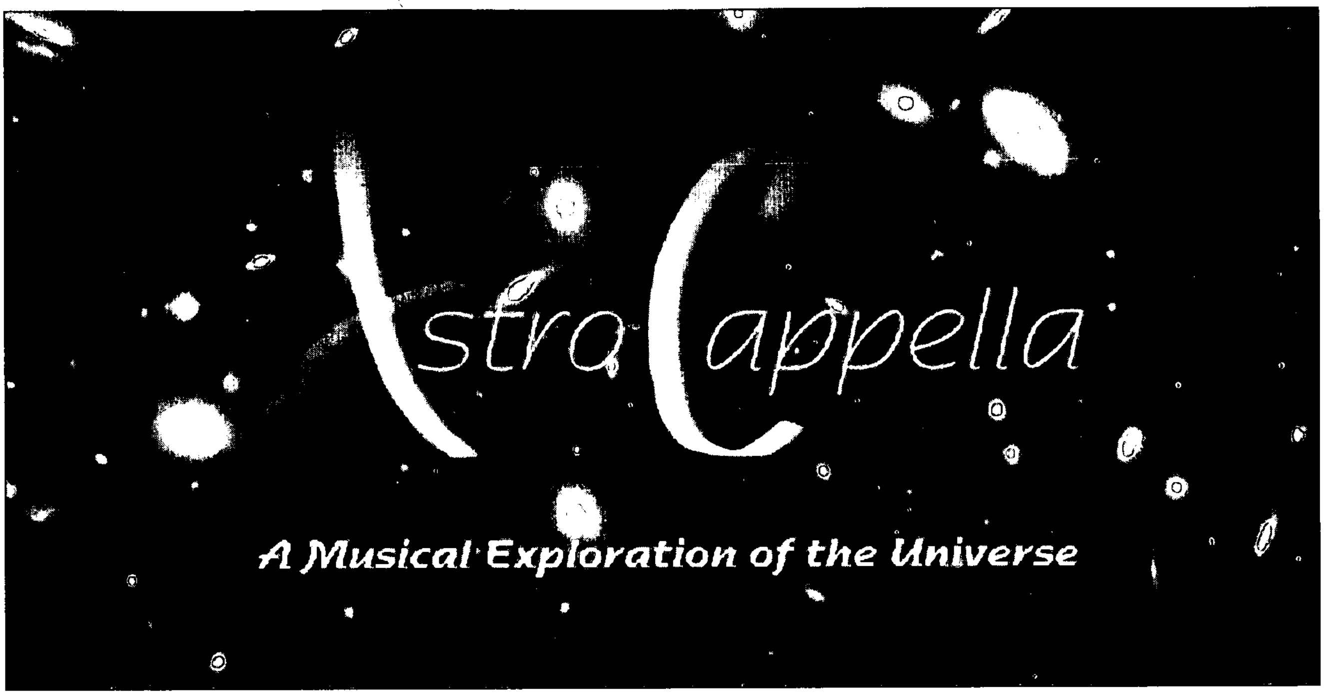
ABSTRACT

AstroCappella combines the love of music with the love of astronomy. The booklet contains hands-on activities that can be done in the classroom coupled with rocking, high-energy, professionally recorded and produced songs written and performed by an established vocal band. The lesson plans help students learn how convection works, how radio telescopes work, how a payload landing is protected on another planet, and what scientists learn by looking for x-rays from the skies. Students build and test a type of communication system called a parabolic dish receiver, demonstrate the Doppler effect, model the preparation needed for a soft landing on a planet or object in space, learn about the technique known as sampling, examine convection in a bowl of soup, and learn about high energy astronomy. AstroCapella song lyrics are included. (DDR)



Activities and Information to accompany the AstroCappella CD

Grades 7-12

Songs by The Chromatics

http://www.pagecreations.com/astrocappella/

AstroCappella

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This booklet is intended to be used in conjunction with the AstroCappella music CD. To obtain copies of the CD, write to the Chromatics at the address listed above.

Welcome to AstroCappella!

Science and music. Astronomy and A Cappella. A winning combination!

Astronomy captures the imaginations of young and old alike and encourages people to consider deep and far-reaching questions: how did the Universe begin? How big is it? How does the sun shine? What are the stars nearest us? How many stars are there in our Galaxy? What is a black hole? And the enduring popularity of Sesame Street shows that music can make learning fun. Songs can help to explain concepts simply, and provide mnemonics to aid memory. (Perhaps *you* learned the words to the Declaration of Independence by singing along to Schoolhouse Rock!)

AstroCappella combines the love of music with the love of astronomy. Here you'll find hands-on activities that you can do in the classroom, coupled with rocking, high-energy songs written and performed by an established vocal band, professionally recorded and produced.

There are many ways you can use AstroCappella. The lesson plans can stand alone, helping you teach your students about convection, how radio telescopes work, how to protect a payload landing on another planet, what scientists learn by looking for X-rays from the skies, and more.

Or you can just use the music CD as a starting point for classroom activities. The songs cover the full spectrum, from radio astronomy, through optical observations with the orbiting Hubble Space Telescope, to the powerful pulsars, black holes and quasars of high-energy X-ray astronomy. And they provide a springboard for you and your students to explore the Sun and the nearest stars. You can use the songs as a soundtrack to a science skit written and performed by students, as a vocabulary exercise, or as a review tool.

But we believe AstroCappella works best when you use both parts together. You might want to begin a lesson by playing a song—say, "Doppler Shifting", discuss it briefly, then turn to "Here it Comes, There it Goes!" in this booklet and work through a hands-on classroom activity that vividly demonstrates how the Doppler shift works. You can discuss how scientists use the Doppler shift to understand our Galaxy and universe, and end the lesson by replaying the song. The second time around, the students will understand the lyrics much more completely, and perhaps leave the classroom humming "Blueshifts come, and redshifts go ..."

The stars and galaxies may seem far away to your students, but AstroCappella brings them down here to Earth. The classified section of a newspaper can show students how scientists count the stars in our Galaxy. Convection in the Sun can be demonstrated by taking a look at convection in a bowl of Miso soup. You can show how a radio telescope works using a microphone and an umbrella. And you can show how engineers protect delicate instruments (or humans!) landing on another planet by trying to land an egg safely in the classroom.

We would also like to encourage you to share the AstroCappella material with your music department. We can provide vocal arrangements of all the AstroCappella songs on request. Since science and music are inter-related, this can be an opportunity to teach both.

Finally, we have a complete Web site on the Internet. You can visit us at http://www.pagecreations.com/astrocappella/, and find sound files, lyrics, classroom activities, and images all ready to go. When you're ready for more, thousands more pages of astronomical facts, pictures, movies and sounds are available at NASA's award-winning "Imagine the Universe" site, at http://imagine.gsfc.nasa.gov.

The AstroCappella music CD, lesson plans, and arrangements are available to schools and bona fide educators free of charge for use as part of a multi-disciplinary learning experience for students. We'd welcome your feedback on the project and your experiences with it; write to us by paper mail or Email, or fill out our form on the Internet! (See the Credits page at the back for our contact information.)

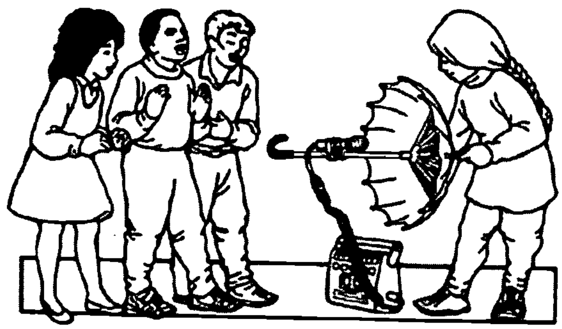
We hope you find AstroCappella useful and fun!

-Alan Smale & Padi Boyd

Astro Cappella

An Astronomy Education Project

presents....



The Communications Lab

An activity by Kara C. Granger
related to:
'Cosmic Radio Show'

Activity Summary:

During this activity, students will build and test a type of communication system called a parabolic-dish receiver. This type of system is similar to radio telescopes, which are discussed in our song. In particular, students will understand how signals are transmitted and captured with this system.

Objective:

Students will perform an outdoor experiment in which they will directly encounter technology that forms the backbone of many basic communication system components.

Materials for each group of students:

- light source such as sunlight or an incandescent light
- scissors
- meter stick
- portable tape recorder with detachable microphone
- batteries for tape recorder
- headphones for tape recorder
- umbrella with mylar or aluminum foil coating inside
- thermometer

(we recommend thermometers such as the temperature probe for CBL - Calculator Based Laboratory, or an electronic thermometer. If neither of these devices is available, use an ordinary thermometer, but make note of the directions in step 3 of the procedure.)

Procedure:

1. Direct students to come together as a team of four to construct a parabolic-dish receiver.

2. Students should open the umbrella, coat the inside of it with mylar or aluminum foil, and position it so that the mylar or aluminum foil coating inside is facing the light source.

3. Students should take the thermometer and move it up and down the umbrella pole, noting the temperature at each location. Tell students that what they are doing is searching for the focal point of the umbrella the point on the pole where the transmitted light is focused to its greatest strength.

   Make sure that the students either use the temperature probe from the CBL or an electronic thermometer. If neither of these devices is available, make sure that the students 'shake down' the thermometer after each reading on the umbrella pole.

4. Students should mark this focal point with a piece of tape. Why would this point be the hottest?

5. Students should next tape the microphone to the focal point on the pole of the umbrella. Make sure the microphone is in a position where the head is facing the inside of the umbrella, and plug the microphone and headphones into the tape recorder.

6. Now students should have 3 members stand shoulder to shoulder, while the 4th team member puts the headphones on and holds the parabolic microphone (umbrella with microphone) so that the inside of the umbrella faces the other 3 members. This student should hold the umbrella by its sides or by the knob at the top. Make sure nothing blocks the line of sight between the parabolic microphone and the other 3 team members.

7. Next, the student holding the parabolic microphone should push the record button on the tape recorder, and the group of three team members should begin singing their favorite AstroCappella song. Adjust the volume on the tape recorder so that the song is clear. The person holding the parabolic microphone should then slowly move directly backward and away from the singers until the song can no longer be heard through the headphones. Measure the maximum distance that the sound traveled and record this information.

8. Remove the microphone from the umbrella handle and hold it in your extended hand about the same distance from your body as it was when taped to the umbrella focal point. Make sure that the microphone is facing the singers. Repeat steps 6 and 7, using the hand-held microphone instead of the parabolic microphone.

   Make sure NOT to record over the first song. Later, you might need both.

Extensions or Further Discussion:

1. Why was the song recorded with the parabolic microphone clearer?

2. How did the sound get to the microphone?

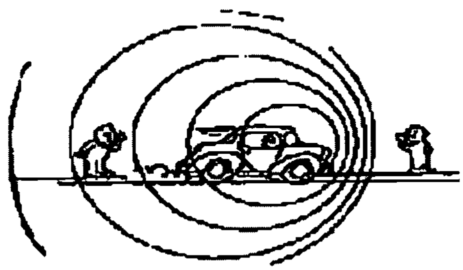
3. Where have you seen parabolic microphones used before? (e.g., sporting events, outdoors for recording birds or other animals, etc.)

4. If a parabolic dish is a good device for receiving a sound signal, why would it also be a good device for transmitting a signal? (Think about the way in which the umbrella focused the sound signal.)

Reference:

The general idea for this lesson plan was adapted from a lesson located in the "JASON VII: Adapting to a Changing Sea" curriculum. More information about the JASON project can be obtained from your local NASA Educator Resource Center, or on the World Wide Web. The URL for this site is http://www.jasonproject.org/

AstroCappella
An Astronomy Education Project presents....



Here it Comes, There it Goes!

An activity by Kara C. Granger
related to:
'Doppler Shifting'

Activity Summary:

Every student can demonstrate the Doppler effect! During this interactive outdoor procedure, students will use an ordinary toy to reveal the Doppler effect. The connection is also made to moving cars, and to the shifting of the lines in the absorption or emission spectrum of the light from a star when the distance between the star and Earth is increasing or decreasing.

Objective:

Students will perform an experiment in which they will demonstrate the Doppler effect. They will also understand the connection to everyday-life examples.

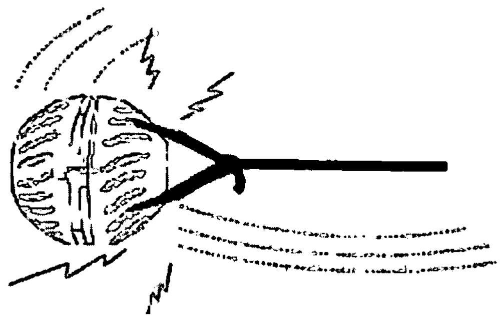
Materials for each group of students:

- 'splash out' ball**
- electronic noise making mechanism with pure tone (from Radio Shack, or other electronics store)
- 9 volt battery
- 9 volt battery clip
- jump rope
- masking tape

Procedure:

1. Twist the 'splash out' ball open.

2. Thread one end of the jump rope through the holes of the 'splash out' ball and tie the end back to the rope. Next, twist the wires of the electronic noise making mechanism together with the wires of the battery clip. Plug the battery into the battery clip, and tape this assembly to the inside of the 'splash out' ball. You now have a 'Doppler ball assembly'. See the illustration on the next page.



3. The teacher should stand about 5 meters away from the students twirling the Doppler ball assembly in a circle above his or her head. In order to gain enough speed, let out about 1.5 meters of jump rope as you twirl it.

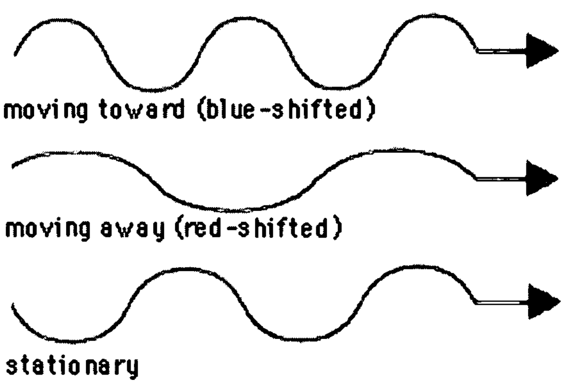
4. Students should observe, record and describe what they hear as the Doppler ball approaches, passes, and goes away from them.

5. Let different students try twirling the Doppler ball. Ask them to describe what they hear.

Discussion:

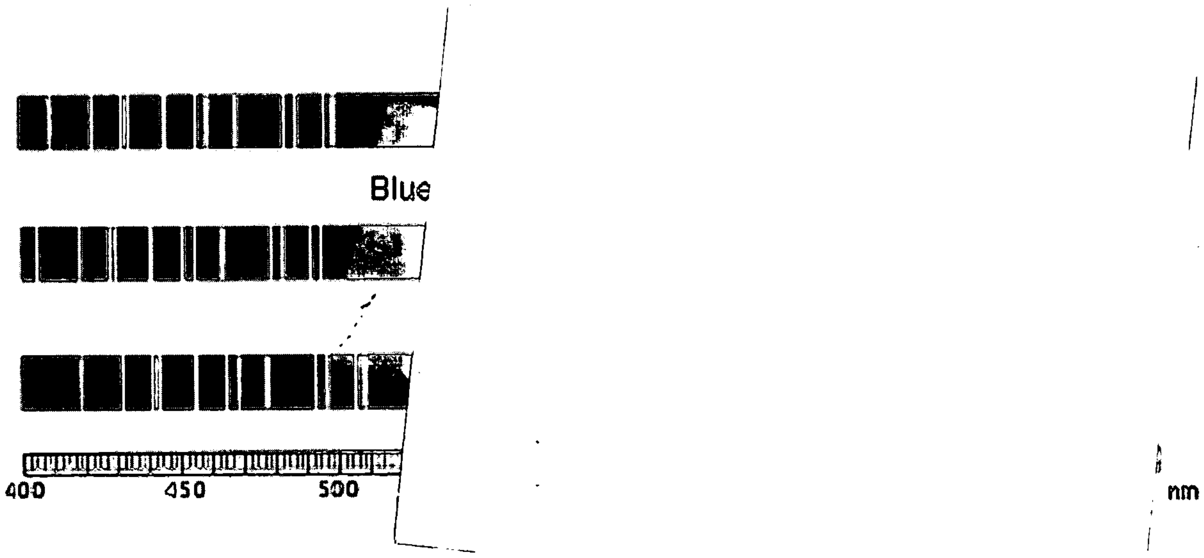
This is a demonstration of a phenomenon called the Doppler effect. It results from the motion of a source coming towards, and going away from an observer. This effect can occur with both sound and light, because both sound and light reveal wave-like behavior. For instance, if a source of light was a moving star relative to an observer on Earth, this would cause the star's spectrum to be shifted toward the red (going away) or toward the blue (coming towards) end of the spectrum.

The number of waves reaching an observer in one second is called the frequency. For a given speed, frequency depends upon the length of the wave. Long waves have a lower frequency than short waves. As long as the distance between the source of the waves and the observer remains constant, the frequency remains constant. However, if the distance between the observer and the source is increasing, the frequency will decrease. If the distance is decreasing, the frequency will increase. The images below illustrate this effect.



Now imagine an everyday-life example such as observing and listening to an approaching car. The sound waves coming from the engine are squeezed closer together than they would be if the car were still. This happens because the car is moving in your direction. This squeezing of the waves increases the number of waves (i.e., the frequency) that reach your ear every second. But after the noise of the car's engine passes, the frequency diminishes. In actuality, the sound waves are stretched apart by the car's movement in the opposite direction. As the observer, you perceive these frequency changes as changes in the pitch of the sound. The sound's pitch is higher as the car approaches, and lower as it travels away. An image contained in this activity plan, located above the title of this activity, illustrates what happens.

A similar situation takes place with stars. If the distance between a star and Earth is increasing, the lines in the absorption or emission spectrum will shift slightly to the lower frequency, or red end of the spectrum. If the distance is decreasing, the lines will shift toward the blue end. The image below shows a simplified star spectrum with red and blue shifting. Notice how the entire spectrum gets shifted to the blue (left) or red (right).



Extensions or Further Discussion:

1. Does the person swinging the Doppler ball assembly hear the Doppler shift? Why or why not?

2. Can the red/blue shift technique be used for objects other than stars?
   Can you tell which way an emergency vehicle is traveling by the pitch of its siren?

3. What has the Doppler shift told astronomers about the expansion of the universe?

Reference:

The general idea for this lesson plan was adapted from a Doppler effect lesson located within 'Space-Based Astronomy: A Teacher's Guide with Activities' associated with the Office of Space Science Astrophysics division of NASA.

Thank you to John Wood for suggesting the use of the Doppler ball assembly.

**This toy is made by Galoob and can be bought at your local toy store. For more information, contact Galoob Customer Service at 1-800-442-5662.

http://www.pagecreations.com/astrocappella/

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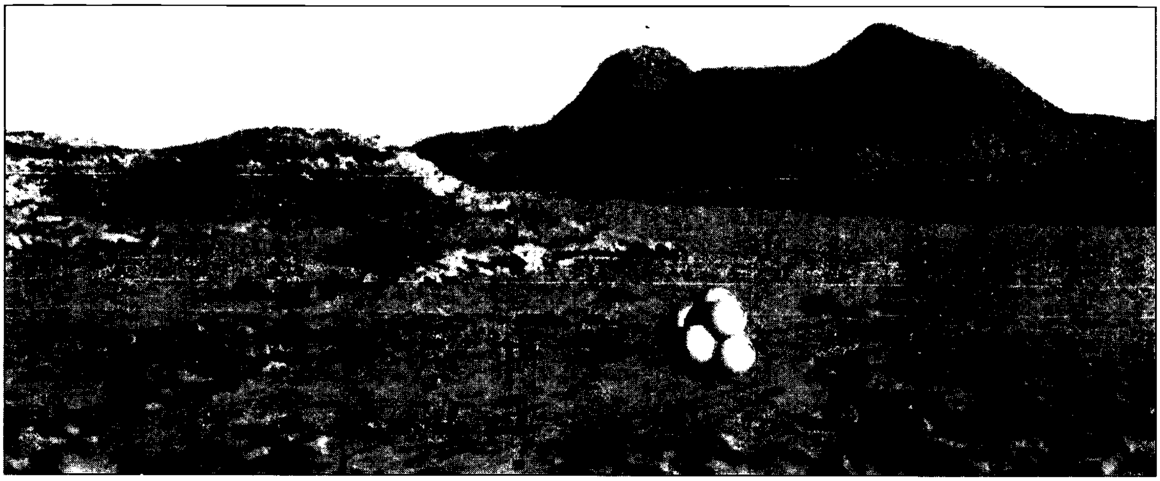

Land Safely...

An activity by Kara C. Granger
related to:
'Wolf 359'

Activity Summary:

During this activity, students will model the preparation needed for a soft-landing on a planet or object in space. They will do this by packaging a raw egg with certain material, and dropping the egg from a given height to test the packaging effectiveness.

Objective:

Students will apply simple physics and mathematics to determine the effectiveness of packaging an object for a soft-landing.

Materials for each group of 12 students:

- 8 index cards
- 8 raw eggs with no cracks
- 8 tape measures
- watch or timer with sub-second timing
- box of tissues
- cardboard
- tape
- string
- bubble wrap
- plastic
- *any other piece of material that one group of students can choose from to package their egg*

Introduction

When launching delicate instruments to soft-land on the moon or other planets, a particular problem exists in packaging these instruments to protect them from vibration, acceleration and deceleration during launch, re-entry, and landing. This same consideration should be given if you are contemplating a trip to Wolf 359. How would you package your cargo in order to have a successful landing?

Activity

In order to prepare for such an event, we must understand the physics behind landing a payload. Simply put, we can create an experiment with raw eggs (where one raw egg represents a human, an animal, or a delicate optical or electronic cargo). Students will be asked to package these eggs to withstand a fall from about 5 meters.

Before dropping the egg, or even before the students actually package their cargo, the teacher should discuss the variables which can be controlled, which can be measured, and which can be calculated. One should discuss which factors have the greatest influence upon the forces of impact and which do not. For example, you may want to ask;

1. Does the mass of the package have any effect?
2. What about the dimensions and shape?
3. What about the falling distance/time?

Procedure

On each of the 8 index cards, place a different packaging assignment (see below). Place students into 8 groups, giving them their assignment from the Chief Scientist of the Egg Drop experiment, which is on an index card.

PACKAGING ASSIGNMENT

A	B	C	D
Major budget cuts have occurred to your experiment. Your group can only rely on luck to save the egg in the soft-landing.	Some budget cuts have occurred to your experiment. Your group can only rely on tissue and tape to package your egg for the soft-landing.	Minor budget cuts have occurred to your experiment. Your group can only rely on tissue, cardboard, and tape to package your egg for the soft-landing.	You are in luck! Your group has been awarded a large budget. You may use any available material to package your egg for the soft-landing.

The use of external devices to increase atmospheric drag such as parachutes, balloons and other air-drag devices should not be used due to the possibility of landing a payload on planets with little or no atmospheres.

1. Package your egg according to your assignment from the Chief Scientist of the Egg Drop experiment, which is on an index card.

2. Follow your teacher to the experimental soft-landing site, which has to be a place where you can drop your packaged egg from about 5 meters.

3. Prepare to time the length of the fall, then drop your egg from approximately 5 meters.

4. Examine the contents of the package to determine the various levels of success:

shell intact, yolk intact...	complete success
shell intact, yolk broken...	brain damage!
shell broken, yolk intact...	paraplegic!
shell broken, yolk broken...	thank goodness it was only an egg!

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5. Make the appropriate measurements and calculations of the gravitational or 'g' forces of impact.

Input:

DF	=	Distance of Fall
TF	=	Time for Fall
CD	=	Crush Distance

Calculate:

AV	=	Average Velocity
TV	=	Terminal Velocity
TC	=	Time to crush
D	=	Deceleration
G	=	g forces
AV	=	DF/TF
TV	=	2 • AV
TC	=	2 • CD/TV
D	=	TV/TC

Output:

	G	=	D/32 feet per second per second
or	G	=	D/9.8 meters per second per second

Discussion:

1. Record each group's calculations in an organized fashion, and where others can observe the results (such as an overhead or chalkboard). Ask students to discuss some commonalities among the data. Ask them if they notice a difference in one variable that protected cargo in any one group.

2. Ask the students to discuss how well this experiment modeled a real-life soft landing of cargo.

3. Discuss with students how they might change the packaging of their egg to ensure a successful soft-landing for every trial and group.

Reference:

The general idea for this lesson plan was adapted from an activity called "The Incredible Light Bulb-Egg Drop" located within the "Live from Mars" Web site. The URL for this site is http://quest.arc.nasa.gov/lfm/teachers/tg/program3/3.1.html

http://www.pagecreations.com/astrocappella/

Astro Cappel

An Astronomy Education Project

Activity Summary:

Can you count every sta ... n Milky Way? During this activit ... numbers by using the characters

Objective:

Students will perform a ... to a billion (and beyond).

Materials for each

- 1 page of classified ads from the newspaper
- 1 piece of cardboard paper ~ 4cm X 6cm
- scissors
- calculator (optional)

Introduction

Step out during the early evening on a clear, moonless winter night in the mountains or in the desert, and you will see a faint milky band of light stretching across the heavens directly overhead. It is light from the billions of stars in our Milky Way Galaxy. The Greek scholar Democritus was the first to guess the true nature of the Milky Way in the fourth century B. C. He wrote, "It is a luster of small stars very close together." It remained for Galileo to turn his new telescope to look at the Milky Way in 1610 to prove that Democritus had been right!

Strangely enough, however, in some ways we know less about our Galaxy than some of those farther out in space because we cannot view it from outside. Interstellar dust clouds prevent us from seeing very far into the Milky Way Galaxy even with the use of our most powerful optical telescopes, such as the Hubble Space Telescope. Observations in other regions of the electromagnetic spectrum have allowed us our best glimpses into the heart of our Galaxy. Some scientists hypothesize that a mysterious source, such as a massive black hole, lies at the center of the Milky Way. Based on more recent evidence, some scientists have theorized that the nucleus consists instead of a very dense concentration of stars, some of which are colliding. Intensive exploration of our Galaxy continues and we can expect to continue to read about new discoveries.

Activity

Today we will use a statistical method called 'sampling' that will enable us to estimate a large number; such as the number of stars in the Milky Way Galaxy, or even the number of stars in our Universe.

Since it is usually impractical to count to such very large numbers, we will use an alternative method. For example, rather than counting all of the characters on newspaper classified ad page, one can count the number of characters in a small area and then mathematically calculate an estimate of the total number on the page.

Procedure (Part 1)- Collection of Data

Your task is to examine a page from the classified section of a newspaper, and to approximate the number of characters on the page by using 'sampling'. Each character (a letter, symbol, or punctuation mark) counts as one. Begin by making an estimate.

1. I estimate that there are ____________ characters on the page.

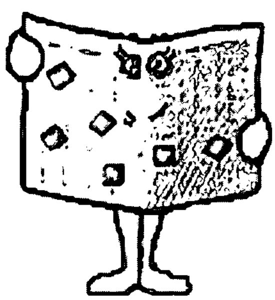
2. The average estimate in our group is __________ characters.

3. Determine the area of the printed portion of your page.

   ________cm X __________ cm = _________ sq. cm.
   length   width   area

4. Cut out six squares of cardboard that measure 2 cm by 2 cm and have an area of 4 square centimeters.

5. Lay the classified ad page flat on the floor. While standing about half a meter from the edge of the page, toss each of the six squares onto the printed portion. All must land within the printed portion of the page to be considered. If a square falls outside the printed portion, toss it again. Carefully trace an outline around each square. This enables us to take a 'sampling' of characters on a newspaper page.



6. Count the number of characters in each square. Where characters are split by the boundary, they are counted only if half or more of the character lies within the square.

7. Find the number of characters in each square, and complete the chart below.

Number of Characters in an Area of 4 Square Centimeters

square #	1	2	3	4	5	6	total	mean
Number								

Procedure (Part 2)- Analysis of Data

1. The mean number of characters per 4 square centimeters is ________.

2. The median number of characters per square centimeter is ________.

3. The calculated number of characters on the page is ________.

4. Using your data, how many such pages would be required to hold 100,000,000,000 characters, the estimated number of visible suns or stars in the Milky Way Galaxy, our home? __________

5. If an average issue of the newspaper has 20 such pages, how many issues would be required to show 100 billion characters? _________

6. If 365 issues are published annually, how many years of publication would be required to display 100 billion characters? __________

7. If such a newspaper had been published long enough to reach the 100 billion character level today, when would it have had to begin publishing? _________

8. If the longest wall in your class room was papered with such pages, what would be the estimated number of characters on the wall? _________

9. How many such wall spaces would be required to display 100 billion characters? ___________

Procedure (Part 3)- 'Real' Count

At this point in the lab, students should compare their estimate using 'sampling' with the 'real' count of the characters on the classified ad page. In order to do this, the teacher should cut the classified ad page into ~30 pieces (equal to the number of students in the class). The teacher should then ask the students to count each character in his or her cut piece of paper, just as they did in Procedure (Part 1), step 6. After that, the teacher should gather, organize, and sum the data gotten by each student on the chalk board or overhead. Finally, the teacher should ask the students to compare the results of their estimate using 'sampling' with the 'real' count of the characters on the classified ad page with such questions as "How close were we when we used 'sampling'?", or "Is 'sampling' a valid statistical measure of the 'real' count? Why or why not?".

Discussion:

1. Scientists believe that our galaxy contains five to ten times as much dark matter as visible stars. This mass they believe, is equivalent to at least 600 billion stars. Other scientists believe there are closer to 200 billion visible stars in our galaxy. To try to comprehend these large numbers, and to compare characters on a newspaper page and the number of stars in our galaxy, complete the chart below.

Number of stars	*Characters per page*	*Number of pages required*	*Number of issues needed*	*Years of publication required*
100 billion				
200 billion				
300 billion				

2. How does estimating the number of characters on a newspaper page relate to the sources targeted by the Hubble Space Telescope such as the stars in the Milky Way? Our Universe? Explain.

____
____
____
____
____

3. Would you recommend the method of 'sampling' to a scientist trying to determine the number of stars in an image of a distant galaxy? Why or why not? Explain.

____
____
____
____
____

Reference:

Some ideas for this lesson plan were adapted from activities located within the AIMS booklet titled "Out of This World".

The image of NGC 2997 and other information found within this lesson can also be found on the StarChild site which is located on the World Wide Web. The URL for this site is http://starchild.gsfc.nasa.gov/

http://www.pagecreations.com/astrocappella/

AstroCappella

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presents...

Activity Summary:

During this activity, students will examine convection in a bowl of soup. The connection is also made to convection in our atmosphere, and convection in the Sun.

Objective:

Students will perform an experiment in which they model convection as it occurs in our Sun. Students will also understand that convection acts where the effect of gravity and heat are present (low density fluids can rise and cool, and high density fluids can fall).

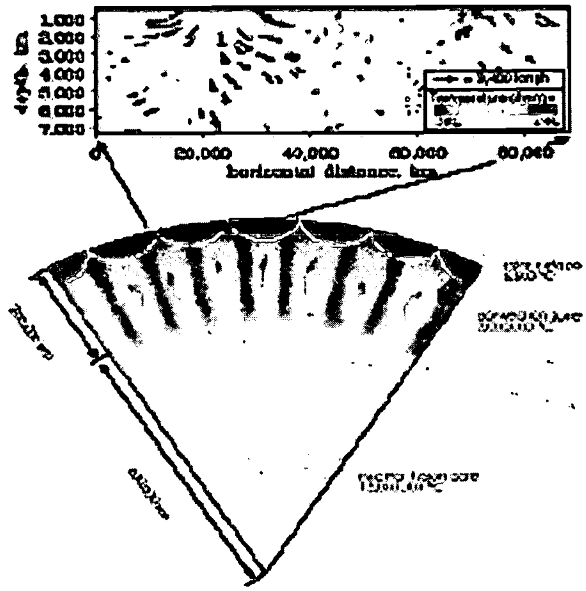
Materials for each group of students:

- packet or bowl of Japanese Miso (soybean paste) soup
- a dark bottomed bowl (it shows the effect best)
- access to a microwave oven, or other heating source

Engagement:

Sometimes a single physical process in nature can explain a variety of events. Convection is one such process. It functions because heated fluids (due to their lower density) rise and cooled fluids fall. A heated fluid will rise to the top of a column, radiate heat away, and then fall to be reheated, etc. Gases, like our atmosphere, are fluids too. A packet of fluid can become trapped in this cycle. When it does, it becomes part of a convection cell.

Convection also occurs on the Sun. A high resolution white light image of the Sun shows a pattern that looks something like rice grains. Very large convection cells cause this granulation (see the first illustration in this activity plan). The bright center of each cell is the top of a rising column of hot gas. The dark edges of each grain are the cooled gas beginning its descent to be reheated. These granules are the size of Earth and larger. They constantly evolve and change. Helioseismology data from SOHO allows us to map these motions underneath the Sun's surface (see the illustration below).



To explain further, this graphic shows the calculated velocity and temperature below the surface. These measurements give us the first clear picture of convection immediately below the surface of a star — possible only because the SOHO spacecraft, free of the distortions of Earth's atmosphere and the interruptions of night, is able to extend our measurements of the Sun's surface motions to scales rarely obtainable from Earth.

But these are large-scale examples of convection, and fortunately, there are examples of convection that can be modeled in the classroom. An excellent example can be seen in hot Japanese Miso (soybean paste) soup.

Procedure:

1. Heat your soup according to the directions, and the instructions of your teacher.

   Be careful, it will be very hot!

2. Keep in mind that the interior of the broth is hot, but the surface of the soup is exposed to cool air. Hot 'cells' of fluid rise out of the interior of the soup to the surface, where they give off heat. Now cooled, they fall down into the bowl to be reheated. This is one of the ways the soup disperses its heat, and will reach room temperature.

   Through conduction with the sides of the bowl, the soup will also dissipate its heat!

3. Watch the granules in your soup. Do you see the rising and descending columns of fluid? What is happening with the cells?

   The soybean paste granules and other ingredients should imitate the convection cells vividly. The cells will evolve and change their positions. If the soup is stirred up students can observe the cells reform. Of course, the demonstration material can be consumed at the conclusion of the lab.

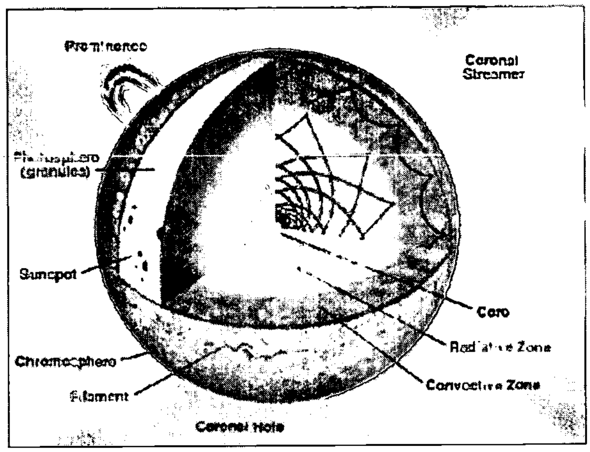
4. Have you ever observed convection within our atmosphere? Think about the cumulonimbus clouds or thunderheads in the sky that seem to evolve over a few minutes. Explain how the process of convection could be causing the changes.

The moisture in this cloud condenses as it cools. The air in this cloud gives up some of its heat to the cold high altitude air, and begins to fall. Next, this cell of air falls to warmer low altitudes where it can be caught up in the rising column of air. This fountain-like cell can form hail. This happens when water droplets (carried by the strong up-drafts) freeze and fall through the cloud, and are caught in the up-draft again. An additional layer of water freezes around the ice ball each time it makes a trip up through the cloud. Eventually the hail becomes too heavy to be carried up anymore, and falls out and to the ground. Large hailstones, when cut apart, actually show multiple layers, indicating the number of vertical trips the stone made while it was caught in the convection cell!

Extensions or Further Discussion:

1. Discuss the major features of the Sun as illustrated in this image below. Point out that the Sun actually consists of mostly hydrogen. Research what other elements are present in the Sun.

2. In diameter, it is over 100 times bigger than the Earth. How many Earths could fit inside the Sun? How many Moons? How many Jupiters?



3. Discuss what the difference is between conduction and convection. For the following, indicate if the situation (mainly) involves conduction or convection.

   a. a boiled pot of water (with its lid on) that has been removed from the stove.
   b. a bag of freshly popped popcorn that is now opened, and has been removed from the microwave.
   c. the effect of a heater in the car (in the winter) once it is warmed up and blowing into the interior.

   • *Convection - Heat transfer through openings such as cracks, gaps, or where pockets of heated air can escape and become cooled.*
   • *Conduction - Heat transfer through materials such as a bowl, cup or wall.*

4. Imagine that you are vacationing at the beach, and you want to predict the wind direction during the day and night. What do you predict? (Hint: Convective currents move air away from hot areas).

References:

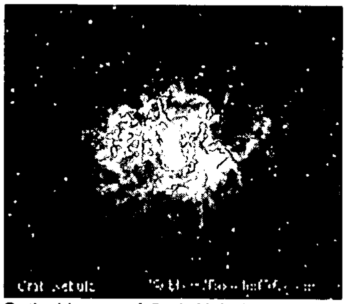
The graphics and other information found within this lesson can also be found on the SOHO site which is located on the World Wide Web. The URL for this site is http://sohowww.nascom.nasa.gov/

The general idea for this lesson plan was adapted from a lesson in the Educator's Guide to Convection which is available from Jet Propulsion Laboratory Public Education Office Mail Stop CS-530, 4800 Oak Grove Drive, Pasadena CA 91109.

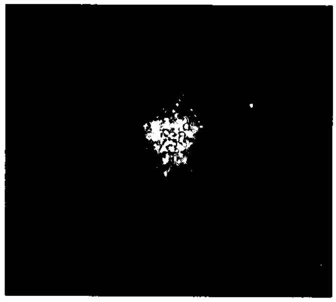
http://www.pagecreations.com/astrocappella/

AstroCappella

An Astronomy Education Project presents...



Optical image of Crab Nebula



Ultraviolet image of Crab Nebula

X-ray image of Crab Nebula

The Universe in a Different Light

An activity by Kara C. Granger
related to:
'High-Energy Groove'

Activity Summary:

Students will become aware of some of the objects studied in, and concepts associated with, high-energy astronomy. They will do this by participating in card games that teach and review these concepts.

Objective:

Students will realize the importance of observing the universe in many regions of the electromagnetic spectrum and understand some vocabulary terms associated with high-energy astronomy.

Materials for each group of 12 students:

- 12 - 36 index cards
- glue
- scissors
- color copies (optional - for esthetics only) of high-energy images
- copies of the text contained in each "Did you know?" and "I have...Who has..."

Introduction:

Some of the objects observed by, and concepts associated with, high-energy astronomy might be new to your students. However, it is essential to share the importance of observing the Universe at wavelengths other than the optical because each region of the spectrum sheds new light on our understanding of the cosmos. For example, some astronomical objects emit mostly infrared radiation, others mostly visible light, and still others mostly high-energy (such as X-ray) radiation. By studying objects at wavelengths other than optical, we are able to understand more about our Universe, including its structure and how it might evolve.

Engagement:

Some of the concepts contained in the lyrics of "High-Energy Groove" are captured in images in this activity plan. These images, along with the "Did you know?" text, and "I have... Who has..." text, can be used to construct and play two card games.

MEMORY

If the teacher wants the students to play "Memory", then he or she should glue the images to one set of 12 index cards, and the "Did you know" text to another set of 12 index cards.

Game procedure for a "Memory" game:

1. Turn all 24 cards face down on a table.
2. Take turns with your group members turning over two cards at a time.
3. In order to collect cards, you must have a match. (For example, the image of the satellite card must be matched with the RXTE satellite "Did you know" text card.)
4. If the cards you chose do not match, put them back, and turn them face down. If the cards do match, you keep them and take another turn at finding a matched pair.
5. The winner is the one with the most cards when all the matches have been made.

I HAVE... WHO HAS?

If the teacher wants the students to play "I have... Who has...", he or she glues the images to one side of a set of 12 index cards, and glues the "I have... Who has..." text to the other side of cards.

Game procedure for "I have... Who has...":

1. Students should be in groups of 12. Each student should be dealt a high-energy card.
2. The teacher chooses who begins, and that student should read aloud the "I have... Who has..." text.
3. In that group of 12, the next person who goes is the one who has the matching image of "Who has...".
4. The group should continue the round until everyone has a turn.
5. The object is to get faster with the round each time.
6. In one class, the group who completes a round in the least amount of time is the winner.

Extensions or Further Discussion:

Students should continue their study and appreciation for observing the Universe in many regions of the electromagnetic spectrum. They may do this by choosing a card and completing a research project that could include an interview with a scientist specializing in high-energy astronomy, or finding additional facts on the chosen card's object and/or images at different wavelengths found that depict that chosen card's object.

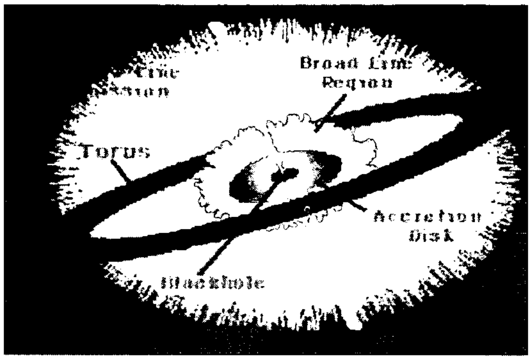
References:

The graphics and other information found within this lesson can also be found on the Imagine the Universe! site which is located on the World Wide Web. The URL for this site is http://imagine.gsfc.nasa.gov/

High-Energy Cards

Did you know?

The cores of active galaxies are now believed to contain very massive black holes. They probably range from a few thousand to a few billion times the mass of our Sun. These black holes grow by pulling in matter from the surrounding regions.



I have...

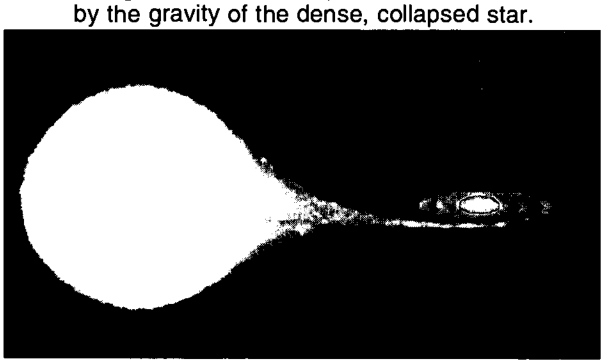
An artist's impression of an active galaxy.

Who has...

A image of a system of stars that can be so close
that interactions produce X-rays.

Did you know?

Binary star systems contain two stars that orbit around one another, or around their common center of mass. Many of the stars in our Galaxy are part of a binary system. If the binaries are made up of a normal star and a collapsed star (a white dwarf, neutron star, or black hole) and are close enough together, material is pulled off the normal star by the gravity of the dense, collapsed star.



I have...

An X-ray binary star system.

Who has...

An image of a tool that scientists use to view cosmic objects
above the Earth's atmosphere?

Did you know?

Black holes are objects so dense that not even light can escape their gravity, and since nothing can travel faster than light, nothing can escape from inside a black hole. On the other hand, a black hole exerts the same force on something far away from it as any other object of the same mass would. For example, if our Sun was magically crushed until it was about 1 mile in size, it would become a black hole, but the Earth would remain in its same orbit.

I have...

An artist's impression of a black hole.

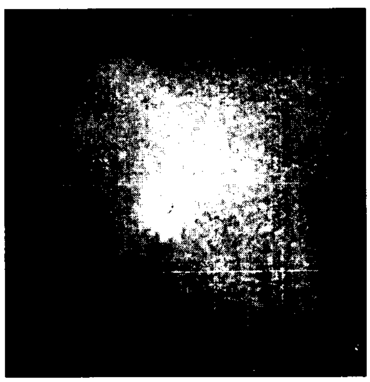
Who has...

The image of an object that (might) contain very massive black holes?

~~~~~~

Did you know?

Pulsars, it is believed, are spinning neutron stars that have jets of particles moving at the speed of light streaming out their two magnetic poles. These jets produce very powerful beams of light. For a similar reason that "true north" and "magnetic north" are different on Earth, the magnetic and rotational axes of a pulsar are misaligned. Therefore, the beam of light from the jet sweeps around as the pulsar rotates, just as the spotlight in a lighthouse does. Like a ship in the ocean that sees only regular flashes of light, we see pulsars turn on and off as the beam sweeps over the Earth.

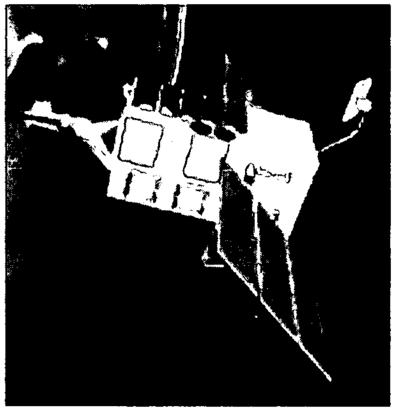


I have...
An image of a pulsar.

Who has...
The image of a source so dense that not even light can escape its gravity?
~~~~~~

Did you know?

Observations of celestial X-ray sources must be carried out above most of the Earth's atmosphere, which absorbs this part of the electromagnetic spectrum. The numbers, sizes, and sophistication of X-ray detection systems have increased rapidly since their simple beginnings in the 1960s.



I have...

The RXTE X-ray Satellite.

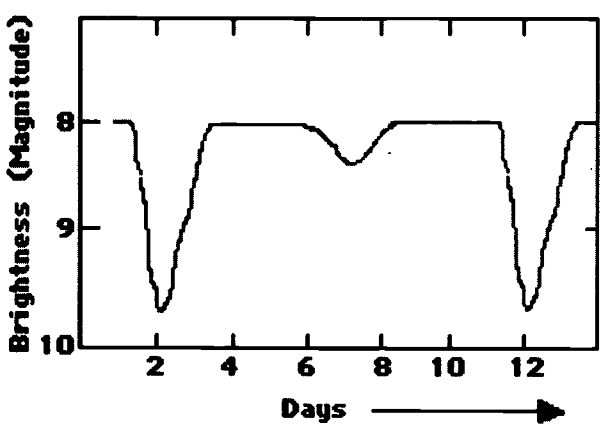
Who has...

The X-ray image of the closest star to Earth?

~~~~~~

Did you know?

A light curve is a graph which shows the brightness of an object over a period of time. In the study of objects which change their brightness over time such as novae, supernovae, and variable stars, the light curve is a simple but valuable tool to a scientist.



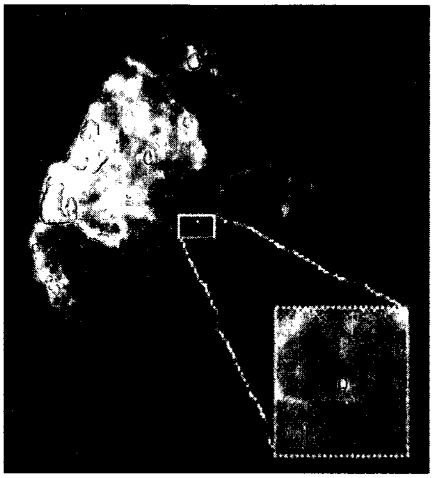
I have...
A sample of a plot called a light curve.

Who has...

The image of the object that produces periodic beams of light?
~~~~~~

Did you know?

Neutron stars are fascinating objects because they are the most dense objects known. They are only about 10 miles in diameter, yet they are more massive than the Sun. One sugar cube of neutron star material weighs about 100 million tons, which is about as much as a mountain.



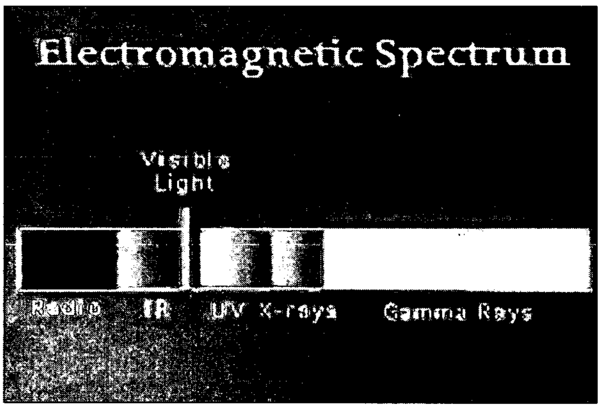
I have...
An image of a neutron star.

Who has...
The tool scientists use to show the brightness of an object over a period of time?

~~~~~~

Did you know?

The electromagnetic (EM) spectrum is just a name that scientists give a bunch of types of radiation when they want to talk about them as a group. Visible light that comes from a lamp in your house or radio waves that come from a radio station are two types of electromagnetic radiation. Other examples of EM radiation are microwaves, infrared and ultraviolet light, X-rays and gamma-rays.

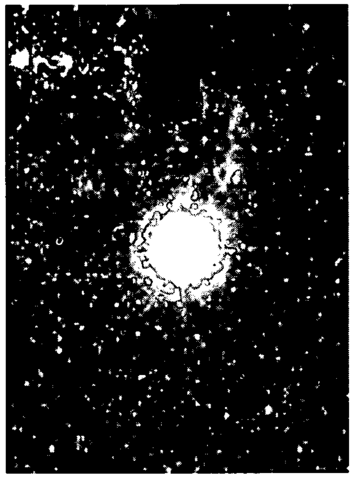


I have...
The electromagnetic spectrum.

Who has...
The image of the explosion that occurs when a massive star nears the end of its life?
~~~~~~

Did you know?

Stars which are 5 times or more massive than our Sun end their lives in a most spectacular way; they go supernova. A supernova explosion will occur when there is no longer enough fuel for the fusion process in the core of the star to create an outward pressure that combats the inward gravitational pull of the star's great mass.



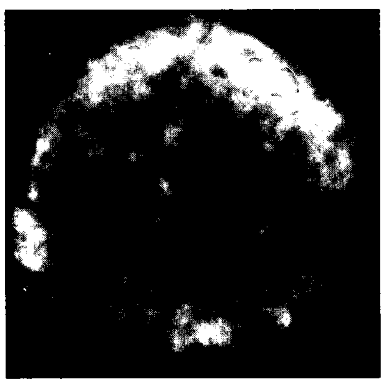
I have...
An image of a supernova explosion.

Who has...
The image and plot of an extremely powerful and very high-energy event?

~~~~~~

Did you know?

Supernova remnants greatly impact the ecology of the Milky Way. If it were not for SNRs there world be no Sun or Earth. Every element found in nature, except for hydrogen and helium, was made in either a star or a supernova explosion.

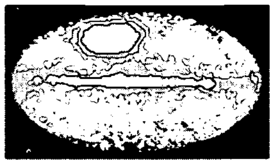


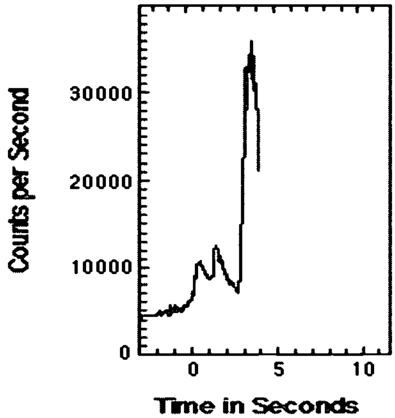
I have...
A Supernova Remnant.

Who has...
The tool that scientists use to determine various wavelengths or frequencies of light?
~~~~~~

Did you know?

Gamma-ray bursts pose one of the greatest mysteries of modern astronomy. About once a day, the sky lights up with a spectacular flash, or burst, of gamma-rays. More often than not, this burst outshines all of the other sources of cosmic gamma-rays added together. The source of the burst then disappears altogether. No one can predict when the next burst will occur or from what direction in the sky it will come.





I have...
An image and a plot of a gamma-ray burst, as measured by a scientist.

Who has...
The image of a very dense star only ten miles across?

Did you know?

The X-rays we detect from the Sun actually come from the solar corona, not the solar surface. The corona, the upper layer of the Sun's atmosphere, is very, very hot (over a million degrees!). Thus, it is an excellent source of X-rays.

I have...
The X-ray Image of our star, the Sun.

Who has...
The image of a star in one of its final stages of life? This stage will leave a trace of material that will 'feed' into the birth of new stars.

AstroCappella Song Lyrics

Cosmic Radio Show

Hey Ho, did you know?
There's a universe in the radio
I'm gonna tell you what you want to know
About the universe in the radio

(Bass solo)
Well a radio photon has a low frequency
Corresponding to a deep voice like me
Foot long wavelength, how can that be?
It comes from processes havin' low energy.
A radio photon has low frequency
'Cuz it has a pretty low energy.

It was 1931 when Dr. Karl Jansky
(He's the father of radio astronomy)
studied radio noise to find out what it could be
and saw that it was comin' from our own galaxy
He wondered what all the static could be
It was the center of the Milky Way galaxy

Those long waves penetrate Earth's atmosphere
Even when it's cloudy it's radio clear
Observatory dishes placed far and near
Let astronomers see how the waves interfere
They penetrate through the atmosphere
down to radio dishes placed far and near

There's a lot of cool gas in the Milky Way
neutral hydrogen atoms leadin' the way
When the proton and electron spins decay
It sends a really long radio wave our way
And we study these photons day after day
to map the regions of our galaxy real far away.

The universe began with a big bang explosion,
particles and energy in furious motion
Then everything expanded and the place cooled down
to three degrees K that Penzias and Wilson found
Still some of those photons hangin' around
and that's the microwave background that COBE found.

That's our cosmic radio show
Of things about the universe we'd never know
If someone hadn't build a dish and sat below
to see the universe unfold in the radio

Hey Ho, did you know?
There's a universe in the radio
I'm gonna tell you what you want to know
About the universe in the radio
Imagine the wonderful things that we know
By observing the sky in the radio

Doppler Shifting

Susan cruisin' down the freeway doing seventy-eight
(go speed racing, go speed racing)
She just likes to drive fast, it's not that she's late
(no tail-gating, no tail gating)
Goes over a hilltop and what a surprise
(too late sister, you're in for it now)
Blue and red flashing lights right in front of her eyes
Nee nee nee nee nee nee nah nah nah nah nah nah
[i.e. police siren, Doppler shifting]

Now Susan's standing by the side of her car
(show me your license, you're in big trouble)
Trucks blowing right by her but she's not going far
(they're still cruisin', Susan's losin')
She's been caught by a speed trap, and now she can hear
(here comes the physics, you're in for it now)
Sound of the Doppler shift right in her ear
Eeeeeeeeeeeeee-owwwwwwwwwww
[i.e. trucks roaring by, Doppler shifting]

That's the Doppler shift -- you've heard it I know
The Doppler shift -- first it's high then it's low

The good cop's gun shoots out only radar
And the beam bounces back off bad Susan's car
Assuming the policeman's standing in range
The gun tells him all about the frequency change
Then Susan's walking, walking
Her speed racing days are done

They're light years away, man, and that's pretty far
(light speed's the limit, the big speed limit)
But there's plenty we can learn from the light of a star
(split it with a prism, there's little lines in it)
By looking at its spectrum at the light that's glowing
(wavelengths of emission, measured with precision)
Its Doppler shift will tell us if it's coming or going
Doo doo doo doo doo-ooo
[i.e. the five notes from Close Encounters,
last note Doppler shifted]

That's the Doppler shift -- you can see it, it's true
The Doppler shift -- to the red or the blue

When a star is approaching and coming our way
Its spectrum seems bluer, won't you hear what I say
But when a star's retreating back out of range
When the scientist measures its frequency change
That's a redshift, redshift
If the star's moving away

By reading Doppler shifts of all we see in the skies
(clusters of galaxies, near and far)
We get the big picture and a big surprise
(redshifts going, redshifts going)
The Universe is growing, expanding away
(the galaxies are speeding, speeding away)
But maybe gravity will shrink it back some day
Owwwwwwwww--eeeeeeeeee
[i.e. reverse Doppler shift noise]

That's the Doppler shift -- to the red or the blue
The Doppler shift -- and our shift's overdue

Now blueshifts come and redshifts go
And that's pretty much everything you need to know
Now we gotta pick up Susan and give her a ride
So you guys remember Doppler, and drive to survive
Now we're shifting, shifting
And our Doppler song is done.

Wolf 359

Hey man, whatcha doin' today
I'm gettin' in my rocket and I'm flyin' away
This planet Earth is much too small for me
so I'm headin' to the stars to see what I can see
to the stars ooo ooo I'm flyin' away
to the stars ooo ooo I'm leavin' today (clap clap)
ooo ooo ooo

The first star from Earth is our big yellow sun
at ninety three million miles it is the closest one
and at 6000 K it's pretty hot stuff
but this just won't do, it's not quite far enough
to the stars ooo ooo I'm not gonna stay
to the stars ooo ooo I'm flyin' further away (clap clap)
ooo ooo ooo

It's Alpha Centauri that's the next one I see
and at 4.3 light years it's a system of three
We think one of those stars is just like our sun
But maybe some one lives there, hey, that might be fun!
to the stars ooo ooo I'm not gonna stay
to the stars ooo ooo I'm flyin' further away (clap clap)
ooo ooo ooo

As I speed in my craft and I'm shifting my gears
I see Barnard's Star out here at 6 light years
it's a dim red dwarf, though not its claim of worth
it's the fastest star we know and it's moving toward Earth
to the stars ooo ooo I'm not gonna stay
to the stars ooo ooo I'm flyin' further away (clap clap)
ooo ooo ooo

The next star out on this trek of mine
is another red dwarf -- Wolf 359.
It's extremely dim and it's not very hot
it's also nice and small, I think I've found my spot

It's a comfortable orbit I'm in
I'll make like a planet and spin
I'm glad I finally found this place
now I have my own time and space
now I have my own time and space
ooo ooo ooo

HST Bop

Well, I see you every night before I sleep
With my lenses and my mirrors or on Web TV
Hey, they say tonight you're rising in the East
You'll be the brightest thing at sixty-six degrees
HST

Do you wanna see the things that no one else has seen?
Well then come and take a look through a real time machine
Hey, theorists say some holes in space are black
Where light goes in but never does come back
HST

Black holes, Cepheids, and quasars
Red dwarfs, giants, and pulsars
Fornax, the Virgo Cluster
Supernova, baby stars
Comas, nuclei, ice trails
Hale-Bopp ion and dust tails
COSTAR corrected your vision
Oh oh oh oh oh HST

Do you wanna touch the edges of both space and time
Do you wanna know the origin of your world and mine
Hey, then find your library or CPU
Switch on the TV, ask your teachers, too
HST

Black holes, Cepheids, and quasars
Red dwarfs, giants, and pulsars
Fornax, the Virgo Cluster
Giant halos, Martian storms
Comets, the Hubble constant
Redshifts measure the distance
Find out what you've been missing
Oh oh oh oh oh HST

The Sun Song

Our star, the Sun is a big ball of gas
And it's 98 percent of our solar system's mass
It's an average star in our Milky Way
Warming the Earth every day

What powers our Sun and makes it so bright?
Come on and tell me, what makes all that light?
Hans Bethe long ago reached the conclusion
It changes Hydrogen to Helium by nuclear fusion
When fusion takes place light is created
And it makes its way out (although rather belated)
Through the Photosphere (that's the part that we see)
The light comes out and shines on you and me

About a million Earths could fit in the Sun
But if you were there you wouldn't have much fun
It's six thousand degrees at the Photosphere
And much hotter inside the solar atmosphere
There are a few places where it's not so hot
Like at the center of a big sunspot
But heat is relative it's still pretty warm
Sitting on a sunspot would do you great harm

Galileo discovered sun spots
What are those things? Those funny dots?
They're cooler parts, scientists feel
Caused by a stronger magnetic field
Those spots move around the face of the sun
Proving to all... solar rotation!
A strange kind of movement, to do a full roll
25 days in the middle, 36 at the poles

What about flares? I've heard of them here
They're like giant explosions in the Chromosphere
The magnetic fields above those sunspots
Reconnecting again after being in knots
Above the Chromosphere the Corona is placed
It's millions of degrees and reaches way into space
It's very thin, but read my lips
That's the part that you see in a solar eclipse

That's the end of our song about Mr. Sun
We hope that you find that learning is fun
But never look at the sun (you could go blind)
Just keep on enjoying that warm sunshine!

High Energy Groove

Chorus:
X-rays, Gamma Rays, High Energy
Hot Stars, Heavy Stars, High Density
Quasars, Black Holes, Supernovae
Powerhouses lighting up the Galaxy
Flashing, bursting, pulsing objects we could see
if we had X-ray eyes, if we had X-ray eyes

Going up the spectrum, repeat after me
Radio, infrared, visible, UV
keep going all the way what do you see?
That's X-rays, gamma rays, high energy
An X-ray photon has a high frequency
which means a shorter wavelength than you could ever see

X-rays come from various processes
like a cloud of gas above about a million degrees
or magnetic fields that send electrons swarming like bees
or even neutron stars emitting like black bodies
& you get X-rays from star stuff that came near to and fell
Into a black hole's gravitational potential well

If we flew above the atmosphere & looked out at the skies
and if we could do it with X-ray eyes
we'd see more flashing and popping than you realize
objects winking on and off like fireflies
the X-ray sky isn't calm and quiet
it's more like a rockin' high energy riot

Chorus

X-rays can show you the roots of your teeth
Shine them through your body see the bones underneath
but don't go thinking that we X-ray the stars
cuz their billions of miles away, much too far!
We collect all the X-rays that they send to Earth
Telling tales of star death, giving hints of star birth

Here's a story of a pair of stars called Cygnus X-1
One's a black hole many times the mass of the sun
With a disk of gas surrounding it, spiraling in
Sucked from the companion star's outermost skin:
We see the high-speed flickering as star stuff flies in
A one way trip beyond the event horizon

A cosmic lighthouse flashes in space
It's an X-ray pulsar with a regular pace
A neutron star 30 miles around at best
Spinning 'round its axis once a second or less
Then way beyond the Milky Way the active galaxies
Are the furthest biggest things our X-ray eyes can see

Point your X-ray specs toward the sun's location
you'll notice that along with its slow rotation
you'll see active loops and plasma arcs
in a solar dance producing X-ray sparks
The X-ray sun isn't serene and smooth
It's a dynamic and changing high energy groove

Chorus

Glossary

Song: Cosmic Radio Show

Photon: a discrete amount of electromagnetic energy, the smallest indivisible amount possible. Photons can behave like both particles and waves. The energy of a photon is inversely proportional to its wavelength.

Frequency: a measurable property of light; the number of waves that pass through any given point in one second.

Wavelength: the distance between two successive maxima or minima of a wave.

Galaxy: an organized system of many hundreds of millions of stars, often mixed with gas and dust. The universe contains billions of galaxies.

Milky Way Galaxy: our Galaxy, of which the solar system is a member. The Milky Way can be seen as a wispy band of brightness on clear moonless nights.

Radio dish: a telescope specifically designed to detect radio emission, made up of a large parabolic dish which focuses long radio waves.

Neutral: having neither a positive nor a negative electric charge.

Hydrogen: the lightest element in the universe, composed of one proton and one electron.

Atom: the smallest indivisible unit of matter that retains the properties of an element.

Proton: a subatomic particle possessing positive charge.

Electron: a subatomic particle possessing negative charge.

Spin: a measure of the magnitude and direction of angular momentum in an atom.

Universe: the entirety of all matter and energy.

Big Bang: the initial explosive event marking the beginning of the universe, and responsible for the observed expansion of the universe.

3-degree Kelvin radiation: an observable remnant of the Big Bang, measurable in every direction of the sky (also known as the Cosmic Microwave Background).

COBE: Cosmic Background Explorer, a NASA satellite designed to measure the infrared and microwave background radiation from the early universe, with great accuracy. COBE was launched November 18, 1989.

Song: Doppler Shifting

Doppler Shift: measurable displacement of spectral lines due to motion along the observer's line of sight. The frequency of a known feature appears shifted from where it should be. Also affects the apparent pitch of sound heard from moving objects.

Radar: a tool that bounces radio waves off objects to determine their speed.

Light speed: the speed of light, a natural limit on how fast anything can travel.

Star: a sphere of gas that shines under its own power, by nuclear fusion.

Prism: a cut of glass used to split electromagnetic radiation into its components so that the spectrum may be observed.

Spectral lines: bright and dark features in a spectrum which correspond to the emission and/or absorption (by atoms of a gas) of photons of specific energies.

Light: the portion of the electromagnetic spectrum which corresponds to what the human eye detects, roughly from 4000 (blue) to 7000 (red) Angstroms. (1 Angstrom = 10^{-10} meters.)

Redshift: an observable shift in a spectral line toward the longer wavelengths due to motion away from the observer.

Blueshift: an observable shift in a spectral line toward the shorter wavelengths due to motion toward the observer.

Spectrum: the array of wavelengths obtained after splitting light (through a prism for example).

Cluster of galaxies: a gravitationally bound collection of galaxies.

Gravity: the attractive force at work between any two objects in the universe, proportional to the product of the two masses and inversely proportional to the square of their separation distance.

Song: Wolf 359

Planet: any large solid body orbiting a star.

6000 K: the temperature, in Kelvin, of the Sun.

Alpha Centauri: the closest star system to the Sun.

Barnard's Star: the second closest star system to the Sun, showing a very high velocity in the direction of the Solar System.

Red dwarf: a faint, cool star, smaller and dimmer than the Sun.

Wolf 359: third closest star to the Sun.

Orbit: path that one body follows about another, due to the mutual gravitational attraction between the two.

Song: HST Bop

HST: The Hubble Space Telescope, a NASA observatory launched into a low Earth orbit by the space shuttle Discovery on 25 April 1990. It has a 2.4m mirror assembly, and high resolution cameras and instruments that observe in the infrared, visible and ultraviolet regions of the electromagnetic spectrum.

Black hole: the end-point of a very massive star's life. Gravity acts to compress a large mass into a volume that gets smaller and smaller, eventually leaving an infinitely dense point in space or "singularity".

Cepheid: a certain type of variable star whose period is related to its absolute brightness. Observing these stars in other galaxies allows us to determine the distances of those galaxies.

Quasar: an extremely energetic object located at the very edge of the observable universe, implying they existed in the early universe.

Giant: a star whose outer atmosphere has expanded to fill a large volume.

Pulsar: a rapidly rotating, magnetized neutron star that gives off radiation in a beam, like a lighthouse.

Fornax: a cluster of galaxies.

Virgo Cluster: a large, irregular cluster of galaxies neighboring the Local Group, of which the Milky Way is a member.

Supernova: the catastrophic explosion of a star, during which the star becomes millions of times brighter.

Comet: a small body of ice and dust, in orbit about the sun, which can develop a tail of vaporized ices, and a coma of dust and gas.

Hale-Bopp: The Great Comet of 1997, one of the largest and most active comets ever observed, visible to most people in the Northern Hemisphere.

Ion tail: a tail of ionized gases in a comet.

Dust tail: a tail composed of liberated dust in a comet.

COSTAR: Corrective optics package placed on HST during the first servicing mission, to correct for the aberration of the 2.4m primary mirror.

Hubble Constant: the constant of proportionality between distance and velocities of remote galaxies. Its precise value defines the age of the universe.

Electromagnetic spectrum: the entire range of electromagnetic waves, from radio to gamma rays.

Song: The Sun Song

Solar system: our sun, and the nine planets, their satellites, asteroids, comets and other minor bodies that orbit the Sun.

Mass: a measure of the quantity of matter in a body.

Hans Bethe: a theoretical physicist who postulated nuclear fusion of Hydrogen to Helium as a power source for the Sun.

Nuclear fusion: a thermonuclear reaction in which nuclei fuse together to form a more massive nucleus. Since the resulting nucleus is less massive that the sum of the initial nuclei, energy is released.

Photosphere: the bright, thin layer of the Sun's atmosphere from which we receive the most visible radiation.

Galileo: a scientist in the early 1600's who first pointed a telescope skyward. He discovered sunspots, craters on the moon, and the four largest satellites of Jupiter.

Chromosphere: the transition region between the Sun's relatively cool photosphere, and the hot corona.

Corona: the outermost region of the solar atmosphere, consisting of ionized gas at temperatures of several million degrees Kelvin.

Song: High Energy Groove

X-ray: the region of the electromagnetic spectrum beyond ultraviolet, where photons possess greater energy.

Gamma ray: region of the electromagnetic spectrum beyond X-ray, where photons possess the greatest energies.

Density: a measure of how much matter is contained in a volume. The density of an object is defined as its mass divided by its volume. A neutron star, in which a solar mass is confined to a sphere whose radius is roughly the size of Manhattan, is a very high density object.

Infrared: region of the electromagnetic spectrum just past the red side of visible, where lower energy photons radiate.

UV: region of the electromagnetic spectrum just past the blue side of visible, where higher energy photons radiate.

Neutron star: end point of a massive star's life, in which a great deal of mass is compressed by gravity into a very small volume, such that individual protons and electrons in the original material fuse to form neutrons.

Black body: an idealized perfect radiator that re-emits all radiation incident upon it. The distribution of this radiation depends only on the black body's temperature.

Gravitational potential well: the deformation of spacetime surrounding a massive object. In Einstein's Theory of General Relativity, it is the spacetime deformation which gives rise to closed orbits about massive objects.

Cygnus X-1: An X-ray source, this binary star system is one of the best candidates for a black hole in the Milky Way galaxy. Scientists have studied its orbital properties and proved that the central X-ray source must be more than 16 times the mass of the Sun.

Event horizon: the distance from a black hole within which nothing, not even light, can escape.

Axis: the line through a sphere about which the solid body rotates. On Earth, the rotation axis passes through the North and South geographic poles.

Active galaxy: a galaxy whose energy output is greater than a normal galaxy, thought to be caused by the presence of a supermassive black hole at the core.

The AstroCappella CD:

Performed by The Chromatics

Copies of the AstroCappella CD, and further copies of this AstroCappella Activities Booklet, may be obtained **free** (while supplies last!), from Alan Smale or Padi Boyd, at the address at the front of this booklet.

All AstroCappella materials are available without cost to teachers and other bona fide educators. Permission is hereby given to photocopy the written materials for classroom use, and broadcast the musical materials, in an educational setting, as long as due credit is given to the performers.

Please contact us if you would be interested in receiving sheet music for the original songs, for use in classroom science or musical programs!

AstroCappella lyrics and original songs were written and performed by The Chromatics, a nine-voice vocal band based in Greenbelt, Maryland. The Chromatics are: Padi Boyd, Lisa Kelleher, Paul Kolb, Steve Leete, John Meyer, Deb Nixon, Angie Russo, Alan Smale, and Karen Smale.

The AstroCappella CD was produced by Jeff Gruber & The Chromatics. It was engineered and mixed at Blue House Productions, Silver Spring, MD.

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Please send us feedback or comments!

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