Let's Get Kids
Excited About Science!

A Poster Guide for Teachers

The LIGO Hanford Observatory has developed the enclosed poster as a way of stimulating the imaginations of young students. Strategies for using the poster might include ….

- **referring to it when introducing a unit on science**
- **using it as a sponge activity when time permits**
- **just leaving it on the wall because of the neat science pictures!**

Some possible introductory discussion questions for students

- **"What does the title of the poster mean to you?"**
- **"Why might the children in the poster look so excited?"**
- **"What questions can you think of about the images on the poster?"**

About the Poster Images

LIGO provides the discussion below for the benefit of you, the teacher, but please don't let our information limit how you might want to use the poster with students. We have listed some questions about the images that might help to engage students in discussions. We have provided basic answers for these; however it is our hope that the poster will be used more for prompting creative thought than for the acquisition of factual information. Feel free to contact us at *outreach@ligo-wa.caltech.edu* or at *509-372-8300 ext 248* if we can assist or support you in any way as you use the poster in your classroom. We're on the Web at http://www.ligo-wa.caltech.edu/.

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The Galaxy Cluster Background

Viewers might logically guess that the points of light in the poster background are stars, but most of the objects are actually entire galaxies. The image is a portion of one "galaxy cluster," the Coma cluster of roughly 1000 galaxies that lies about 330 million light years from earth. You wouldn't see these clusters with the naked eye – nearly all of the naked eye objects in the night sky are individual stars in our own galaxy, the Milky Way.

The Hubble Deep Field

At the top of the poster, within the purple circular border and behind the title, is a highly magnified portion of the sky. This is part of a famous image called the "Hubble Deep Field." The Hubble Space Telescope has orbited about 350 miles (570 km) above the earth since 1990, collecting images through its 2-meter telescope lens and associated cameras and beaming these images to earth. Because the telescope lies outside the atmosphere of the earth, it can see deeper and more clearly into space than can our earth-based telescopes. The deep field image provides a glimpse of a tiny sliver of the sky, equal to the portion of your view that a grain of sand would occupy if you held it at arm's length. Each "splotch" of light in the Deep Field is a galaxy of up to billions of stars! The faint specks of light in the rear of the image represent structures that lie near the edge of the universe. A space ship that could travel at the speed of light would need 12 billion years to reach these objects.

Questions for students

- How many different colors of objects can you see in the deep field? Why might the objects be different colors? *The clusters/galaxies in the photo appear as a variety of colors. The color differences may be due to the chemical composition of the stars and dust, the temperatures of the stars and/or the clusters' distance from us.*
- How many different shapes of objects can you see? *The shapes vary as well, but most tend to be round or disk-shaped. Our galaxy, the Milky Way, is a spiral galaxy that would look like a disk from a distance.*

Lightning Striking the Eiffel Tower, June 3, 1903

Lightning occurs for the same reason that you get shocked on a doorknob after scuffing your feet on a carpet. In fact, if you touch the doorknob in a dark room, you might see a mini-lightening bolt! These processes occur because of the behavior of static electric charge. When you scuff your feet on the carpet, you collect excess electric charges on your body. These charges repel each other. The metal doorknob, which is a good conductor (like a lightning rod), provides a path for the excess charges to escape. If the repulsion between the charges is strong enough, it can overcome the electrical resistance of the air and the charges can leap from your hand to the knob before you actually touch the knob. The passing of this electric current heats up the air very strongly, and the rapid expansion of the hot air creates a shock wave that we hear as a snap. In a similar way, clouds can build up excess static charge as they scuff against each other in a stormy sky. The negative charge tends to sink to the bottom of the cloud, leaving the top part positive. If the difference in charge becomes substantial, lightning can occur within the cloud or from one cloud to another. Sometimes the negative charge on the cloud attracts a stream of positive charge from the earth. When this difference discharges, a huge current travels from the ground to the cloud. Thunder is the shock wave that results from the heating of air during a lightning bolt.

- Tall structures like the Eiffel Tower or the Empire State building are struck many times each year! Lightning conductors (rods) are used on tall structures. These allow electricity to discharge harmlessly into the ground, leaving the building undamaged.
- A bolt of lightning can reach over 5 miles in length, can heat the air to temperatures of approximately 50,000 degrees Fahrenheit (~28,000 Celsius), and can contain 100,000,000 electrical volts.
- Lightning kills about 100 people and injures about 1,000 each year in the U.S.

Some tips for lightning safety

- Get inside! No place outside (including dugouts and open air pavilions) is safe during a thunderstorm.
- If lightning can't be seen, just hearing thunder means you should go inside a house or car. Wait at least 30 minutes after hearing the last roll of thunder before going outside again.

Questions for students

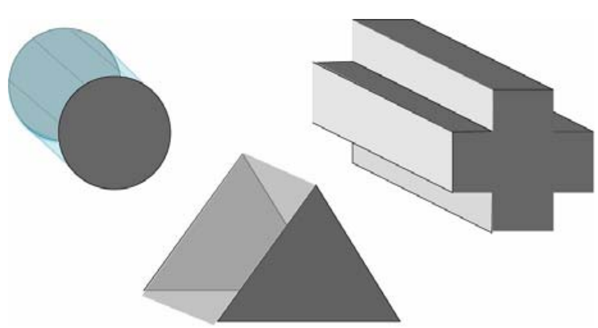
- Why is it that when you see a flash of lightning, it usually takes a moment before you hear the thunder? *Light needs only a fraction of a second to travel 1 mile. Sound needs about 5 seconds to travel 1 mile, so if you count 5 seconds between the lightning and the sound of thunder you'll know that the lightning strike was about 1 mile away.*
- If you count 10 seconds between lightning and thunder how far away is the lightning? *About 2 miles*

Two Children Wearing 3-D Glasses

These kids are wearing polarized 3-D glasses that are used when watching 3-D movies or television. 3-D glasses work because you have two cameras in your head (usually called eyes). These devices take pictures of the same sets of objects from slightly different angles. Your brain is able to synthesize these into a single image with depth perception (3-D). Old-style red-blue 3-D glasses work because the movie film contains two sets of nearly superimposed images, one red and the other blue. Your eyes pick up each set through the colored filters and your brain does the rest. Newer goggles like the ones worn by the poster kids contain polarizing lenses of two different orientations (sunglasses usually use polarizing lenses). Two different movie cameras project differently polarized images onto the screen. Each lens transmits one of the polarizations and blocks the other, so your eyes pick up two slightly different views of the same action, and your brain merges these into a 3-D image. The polarizing technology has the advantage of retaining color. The older system was used for black & white cinematography (where are you now, Creature from the Black Lagoon?).

Questions for students

- You might have heard about or even seen a movie that was in 3-D. What do you think the term 3-D means? *3 dimensional: 3- D glasses along with 3-D photography create the illusion of "depth" along with height and width.*
- Can you draw a 3-dimensional square, which we call a cube? One way to draw a 3-dimensional shape is to draw a pair of identical shapes. Connect the corresponding corners of each shape with lines.
- Using this same idea, what other 3-dimesional shape(s) can you draw? *Possible answers*

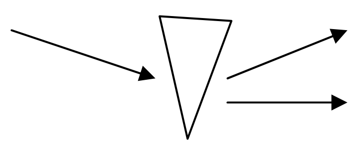


Extension: Make or purchase 3-D glasses and have students explore the effects of drawing 3-D figures using red and blue colored markers! You can usually find red-blue glasses from Web vendors for under $1 per pair

The Prism

You have noticed that your fingers look fatter when you dip them in a glass of water and look at them through the glass from the side. This happens because of *refraction* – the bending of light as it passes from one substance to another at an angle. The bending occurs because the light changes speed as it moves from the one material to the other (glass to water, air to glass). When the light crosses the boundary at an angle, the side of the light beam that crosses first will change speed before the rest of the beam, shifting the beam's direction.

When white light enters a prism at the appropriate angle, all of the light undergoes this bending process. But the different components of light are bent or refracted by different amounts (this is called *dispersion*). What exits from the prism are all the colors of the rainbow. Violet, with its shortest wavelength, is bent the most and red is bent the least.



Refraction and reflection combine in water droplets to cause sunlight to turn into a rainbow. The colors of a rainbow always line up in the same order because each wavelength (color) of light bends by a characteristic amount, red followed by orange, yellow, green, blue, and indigo. Violet bends the most so it always occurs on the side opposite from red. You can recall the order of colors in the spectrum by remembering the name ROY G BIV.

Refraction is used in microscopes, binoculars, eyeglasses and some telescopes (the best telescopes use reflection instead of refraction). Dispersion is very important in the history of astronomy since it allowed scientists to examine the component colors of light from our sun and from other stars. Modern instruments usually use a different process, *diffraction,* which also breaks light into its component colors. Astronomers can determine the chemical composition of stars by looking carefully for 'missing' stripes of color that appear as dark lines in the star's spectrum. These black lines indicate wavelengths that have been absorbed by elements in the star's atmosphere. Chemical elements like sodium, magnesium and iron absorb characteristic wavelengths. The element helium was first discovered through the absorption lines it creates in the sun's spectrum.

Questions for students

- What does the prism teach us about sunlight? *Sunlight is white but it is made of all the colors of the rainbow*
- Where else have you seen rainbows? *Chandeliers, running the sprinkler, films of oil, etc. What's needed is a source of white light and a refracting material.*

The Magnified Ant

A magnifying glass makes objects look bigger by refracting (bending) the light after it has been reflected by an object but before it reaches your eye. Really good magnifying glasses are microscopes. However the ant image wasn't made from a regular light-based microscope. It came from a *Scanning Electron Microscope* (SEM). The (dead) bug is sprayed with a very thin layer of a metal such as gold. Then the microscope fires a beam of electric charges (*electrons*) at the bug. This beam knocks electrons loose from the gold coating. This electric current is processed and leads to a detailed map of the bug's features. The image of the ant is a magnification of about 600. SEM instruments are used to look at a wide variety of materials.

Questions for students

- What surprises you about the way the ant looks under the SEM?
- What kinds of things would you like to look at using this kind of a microscope?
- Ants can carry about 50 times their own weight. If you could carry 50 times your own weight, how much could you carry?

Images of the Earth and Moon

This combined view of the earth and moon is from the Galileo space probe that was launched in 1989. Galileo was the Italian scientist who discovered mountains on the moon. He also was the first to describe the major moons of Jupiter in 1610. These discoveries came from his first use of the telescope. The Galileo probe's 14-year mission produced a string of discoveries about asteroids, Jupiter's atmosphere, and the geologic diversity of Jupiter's four largest moons. NASA directed the probe to crash into Jupiter on September 17, 2003. Scientists were concerned that the aging probe would run out of fuel and crash into one of the moons, possibly contaminating the crash site with microbes from Earth. Sending it into Jupiter would ensure that the probe, microbes and all, would vaporize from the frictional heating of Jupiter's atmosphere.

Questions for students

- Why will the footprints left by Apollo astronauts remain imprinted in the lunar dust for at least the next 10 million years? *There is no atmosphere on the moon and no weather to erase the footprints*
- On earth we have a North and South Pole. Why don't we have an East or West Pole? *The North and South Pole's locations arise from the earth's spin an axis that passes through the center of the earth and through the poles. The spin gives the earth a top and bottom. There is no front and back.*
- If you were on a satellite that was sitting still above the North Pole and you were looking down on the earth, would you see the earth spinning clockwise or counter-clockwise? Support your answer with words and pictures. *Counter-clockwise. Possible explanation: The east coast gets morning light before the west coast.*

Albert Einstein (1879-1955) on the Bicycle

Some students may recognize Einstein as "that really smart scientist". Einstein enjoyed riding a bicycle, just like many third-graders. Third graders (and kids of all ages) can do science, perhaps not as famously as did Einstein, but in a way that is personally meaningful and enjoyable.

For teachers he is included as a reminder that we are responsible for educating students to appreciate the nature of science – it is a process in which ideas change as new evidence arises. Einstein was responsible for a revolution in our thinking about how nature works. His concepts replaced the 200-year old ideas of Isaac Newton. Einstein's General Theory of Relativity wasn't just a modification of Newton's work on gravity – it was a wholesale abandonment of Newton's framework, to be replaced by a completely new and different way of looking at space, time, mass and motion. Revolutions like Einstein's are part of the history and the nature of science.

Questions for students

- You couldn't really ride a bike in space. Why not? *No air to breath, too cold, nothing to push against the bike to help it go forward (this is what the road does on the earth)*

The Clock

Newton's model said that we all experience time the same way. Time was a concept instead of a real 'thing', a way to remember the progress of our lives. Einstein's Special Theory of Relativity made time just as real as quantities like mass, temperature and energy. In the same way that energy can influence temperature, motion and mass can influence time. In the same way that mass can be shaped, time can shrink and stretch. If you speed away from me on a rocket ship, I will say that your clock runs slower than mine. When you get back from your trip, you will have aged less than I. Clocks run slower near the earth than they do in space, and this difference must be addressed in the sending and receiving of Global Positioning System (GPS) signals.

Questions for students

- If you threw a clock out of a spaceship in outer space, what would the clock do? *It would keep moving in the direction that you threw it unless it fell into the gravity of another object like a planet or star. It wouldn't slow down or stop of its own accord. On the earth, objects that we throw always stop because they hit the ground (blame it on gravity) or otherwise get stopped by friction.*
- If the alarm on the clock went off while the clock was floating through space, and if Einstein was riding by on his bike, he wouldn't hear the alarm. Why not? *Sound waves need a mass-based medium such as air in order to travel. Sound won't travel through the vacuum of space. Light <u>can</u> travel through the vacuum of space, so we can see the stars but we can't hear them.*

An Apple in a Space Dimple

Einstein gave us a new model of gravity that replaced the work of Galileo and Newton, who in turn had brought about an earlier revolution that replaced Aristotle's thinking about gravity. Aristotle (384-322 B.C.) taught that heavy objects drop faster than lighter objects and that the earth pulled on an object with a force that depended on the mass and composition of the object. Galileo (1564-1642 A.D.) and Isaac Newton (1642-1727 A.D.) confirmed through experiments that the earth's gravity will affect the motion of a heavy object exactly the same as a light object (in the absence of wind resistance). Einstein (1916) revolutionized our concepts of gravity again, by stating that gravity is the curving or "warping" of space and time that is caused by mass.

The apple has mass, and this mass changes the shape of the space that surrounds it. Now an apple doesn't have much mass, so it doesn't change the shape of space by very much. But a huge mass, like the sun, can curve the shape of space so severely that the paths of nearby objects such as planets are bent into orbits. Einstein suggested that gravity wasn't a force (a pull), but instead it was the curving of the paths of objects through space and time caused by large amounts of mass.

A Gravitational Wave with Surfer

If space and time can curve, then the jiggling of huge masses might create curvature that fluctuates or ripples. LIGO is attempting to measure ripples (waves) in space and time – we call these ripples gravitational waves. The image on the poster represents two neutron stars stirring up ripples in space and time by closely orbiting each other. Measuring these waves may provide important clues that lead to the next leap in our understanding of gravity, mass, space and time. Stay tuned as LIGO continues its quest!

We invented something useful to do with water waves as we watched them come ashore in places like Hawaii – we learned how to surf! Will we someday surf gravitational waves? Most likely not. By the time they get to earth, these waves are very, very weak. Going to places where they are very strong (like the edge of a spinning black hole) would be bad for our health (very hot, enormous gravitational forces – you get the picture). Even if the surfer on the poster isn't 'real', he reminds us that creativity, imagination and a sense of fun are all a part of science.

Questions for students

- A real surfer rides a water wave. How does the water move in a water wave? *The water moves up and down but it doesn't go forward with the wave (until it gets close to the shore)*
- How can the surfer go forward on a wave if the water isn't going forward? *Although the water doesn't move forward, the wave's energy does. The surfer is carried forward by the push of this energy as it continually lifts up new water.*
- Why might surfing in space be a problem? *There wouldn't be any way to stop. A regular surfer is stopped by the beach, but a space surfer would just keep on going. This would make him late for dinner, among other things.*

Resources on the Web

Galaxies and Galaxy Clusters: http://photojournal.jpl.nasa.gov/PIA.html
- *A wide variety of information from space missions, with links to lots of images*

Hubble Space Telescope: http://hubblesite.org/
- *Everything Hubble plus resources for teachers*

Lightning: http://weathereye.kgan.com/cadet/lightning/index.html
- *Visual explanations of lightning*

http://www.lightningsafety.noaa.gov/
- *Lightning safety*

3-D glasses, your eyes and your brain: http://science.howstuffworks.com/3-d-glasses.htm
- *A basic description of the how and why*

Prisms: http://sol.sci.uop.edu/~jfalward/physics17/chapter12/chapter12.html
- *A number of graphics that show refraction and other optical properties*

The Magnified Ant http://www.ms.ornl.gov/htmlhome/mauc/AAnt/Ant.html
- Our poster ant in all its glory, brought to you by the High Temperature Materials Lab of Oak Ridge National Laboratory. Surf the ant!

The Earth and the Moon: http://spaceweather.com/
- *"News and Information about the Sun-Earth Environment." A very nice list of links*

Einstein and Relativity: http://archive.ncsa.uiuc.edu/Cyberia/NumRel/EinsteinLegacy.html
- *One of many sites that discusses the ideas of relativity*

LIGO Hanford Observatory http://www.ligo-wa.caltech.edu/
- *Learn about LIGO's quest to open a new window on the universe based on the General Theory of Relativity*

Einstein@Home: http://www.physics2005.org/events/einsteinathome/index.html
- *Celebrate the International Year of Physics in 2005 by downloading a screen saver that will let you join the search for gravitational waves*

LIGO Hanford's Way Cool Web sites: http://www.ligo-wa.caltech.edu/teachers_corner/web_sites.htm
- *Some of our favorite sites for keeping track of the physical world*

The National Science Foundation: http://www.nsf.gov/
- *The NSF funds a myriad of projects and initiatives in addition to LIGO. It's where discoveries begin.*

A copy of this poster guide is also posted on our Web site, http://www.ligo-wa.caltech.edu/. Click on the "Teachers Corner" link.