Solar Music

Using helioseismology to see inside our Sun

Suggested grades:
3-9?

Goal

Students will be able to state the relationship between the sound an object makes and the physical characteristics of the object, and apply that to the study of the interior of the Sun via helioseismology.

Objectives

Students will:

- Determine the relationship between the sound an object makes and the physical characteristics of the object.
- Explain how listening to an object can tell something about what the object is like inside.
- Apply that knowledge to the story of helioseismology.
- Understand that helioseismology is much more complicated than blowing across a bottle because there are many more notes to distinguish.

Helio = Sun
Seismo = Waves
Logy = Study of
Helioseismology = The study of the waves in the sun.

Background

The Sun is filled with sound, and we can learn about its insides by studying this sound. In fact, this is the ONLY way we can learn about its inside because the light we see from the Sun comes only from its outside. Since the sound is inside the Sun underneath the part we can see, we can use sound to learn about the inside of the Sun.

Just like sound echoing all around in a room or a concert hall, sound is bouncing all around and echoing inside the Sun. Sound is a vibration, It moves things up and down, back and forth. Imagine moving a Slinky back and forth on a desktop. You can actually see the vibration because it makes the Slinky move. As the vibration comes to the end of the slinky, it bounces back the other way, like an echo.

The Sun is like a huge musical instrument. It rings like a bell, and vibrates like an organ pipe. Just like a piano has 88 keys or musical notes the Sun has 10 million keys or notes. Astronomers are measuring the solar music, listening to the Sun's heartbeat, to determine what is happening inside the Sun.

You may be wondering how the sound in the sun gets started. After all, musical instruments must be played by striking, plucking, blowing, or rubbing some part of them. This transfers energy and starts the sound moving. In the sun, it's a process called "convection" that starts the sound in the first place. Convection is very familiar to all of us in the kitchen -- the boiling water in your tea kettle or pasta pot is convecting vigorously. This is obviously a noisy process. In the sun, this happens very close to the surface where the flow of energy that started in the nuclear reactions in the core reaches the surface and suddenly escapes. The solar convection produces huge bubbles on the solar surface (larger than the state of Texas) that can be easily seen, and is called "granulation". The noise from the convection is then trapped and filtered inside the sun to produce the solar music.

Since the vibrations of the solar sound make parts of the outside of the Sun move up and down, astronomers can study the sound by looking at the Sun. This is good, since there is no air between the Sun and the Earth. Since sound does not travel in a vacuum, there is no way for us to actually hear the sound. But, we can use special cameras to watch the outside of the Sun move up and down. It is these up and down motions on the surface of the Sun that tell astronomers about the inside of the Sun.

In the activities your students will be doing as part of this lesson, they will not look at the vibrations the sounds cause on the surface of objects. Instead they will listen to the sounds to gain an understanding of how sound can tell us about the inside of an object, even if we can't see it. Then they will make the generalization to listening to the millions of notes the Sun makes, and how that can tell astronomers what the inside of the Sun looks like.

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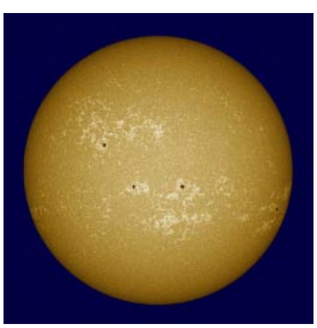
Materials

The greater variety of objects that students have to experiment with the easier it will be for them to make the connection between the sound an object makes and its physical characteristics.

- Triangles of various sizes
- Bottle Harmonicas (bottles filled with water to various levels) strike and blow across the mouth
- Empty round oatmeal boxes of different sizes
- Rubber bands on shoeboxes
- Plastic sound pipes of different sizes (these are plastic tubes that whistle when you twirl them in the air, and can be found at toy stores)
- Tuning forks at various frequencies
- Etc.
- Download the slides for this activity from the NOAO web site: http://www.noao.edu/education/ighelio/slides.html



Slide 1

Procedure

Put out as many of the “sound creating objects” as you have for students to work with. Have them create a table with columns for “Object Name”, “Object Description”, and “Sound it Makes” to be filled out as they experiment with each object. Depending on how open ended you want to be with your students, you may wish to discuss the kinds of observations you want them to make and write down as they experiment. Younger students especially will benefit from some cues such as talking about the size of the object, or its density or length, as well as describing sound in terms of pitch and tone, rather than just loudness.

It is a good idea to give your students clear objectives - i.e. “Today we are going to explore the relationship between the sound an object makes and its physical characteristics.”

After your students have had a chance to try out each of the objects lead a discussion with them about what they observed. You could make a chart on the board and fill it out as students give their answers and observations. You want to guide them to come up with the relationship that larger (longer, denser) objects tend to have lower pitches than smaller (shorter, less dense) objects.

Discussions of hollow versus solid sounds is also appropriate here.

The bottle harmonicas provide a good way to introduce a discussion about what is vibrating and creating the sound. Point out the difference in pitch when you blow across the mouth of the bottle (pitch increases with the amount of water in the bottle, the air is vibrating) versus when you strike the bottle (pitch decreases with the amount of water in the bottle, the water is vibrating).

Once the relationship has been discovered and stated by your students, relate it to helioseismology by showing the slide set or overheads. You can adapt the following script to help tell the story.

Today we would like to teach you about solar music. The Sun is filled with sound, and we can learn about its insides by studying this sound. In fact, this is the ONLY way we can learn about its inside because the light we see from the Sun comes only from its outside. This picture shows how the outside of the Sun looks to us (show slide #1). But, this picture does not tell us anything about the inside of the Sun. That’s because the picture was made using light that comes only from the outside of the Sun. Since the sound is inside the Sun underneath the part we can see, we can use sound to learn about the inside of the Sun.

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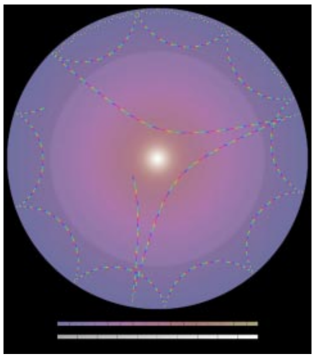
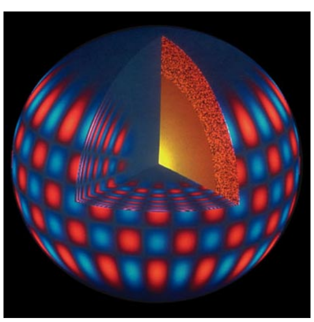
Have any of you ever heard the Sun? (If they answer "yes", ask them what it sounded like. They may say it sounds like a bird or a rooster, since Sunrise generally wakes the birds up. Respond to this answer by saying that the Sun causes the birds to wake up and chirp, but that is not solar music.) Whether they answer "yes" or "no" say: I will be playing a recording of solar sound for you in a little while.



Slide 2

Have any of you heard echoes? Where? (The most likely answer will be "out-doors at a canyon", but ask them if they have heard echoes anywhere else. The answer you are looking for is "inside a room.") Just like sound echoing all around in a room or a concert hall, sound is bouncing all around and echoing inside the Sun. Here is a picture created with a computer that shows how sound echoes inside the Sun. (show slide #2. You can See animations of these sound waves at: http://bigcat.ifa.au.dk/helio_outreach/english/engrays.html).

Sound is a vibration, it moves things up and down, back and forth. I have a Slinky™ here, and I need some help to show you how vibrations move things back and forth. (Get a helper to hold down one end of a slinky on a desk top. Take the other end, and shake it horizontally once to get a wave traveling down to and reflecting off the stationary end.) Did you see how the vibration moved the Slinky back and forth? Also, did you see how the vibration bounced off the end that was being held down? The bouncing is what causes echoes, and it also happens inside the Sun when the sound hits the surface like in the picture. Also, you can actually see the vibration because it makes the Slinky move.



Slide 3

The Sun is like a huge musical instrument. It rings like a bell, and vibrates like an organ pipe. Does anybody know how many keys or musical notes a piano has? Just like a piano has 88 keys or musical notes, the Sun has 10 million keys or notes. Astronomers are measuring the solar music in order to determine what its heart is like. This is like listening to a song to understand the singer. Here is a picture made with a computer showing the pattern of up and down movement from a single solar musical note. (show slide #3) The red and blue colors were put into the picture so you can tell which parts of the Sun are moving up (blue), and which are going down (red). (Animations can be seen here: http://bigcat.ifa.au.dk/helio_outreach/english/engkuglefkt.html)

Pull out the Slinky again (or a jump rope if you don't have a Slinky). Have two students hold each end of the Slinky and stretch it across a long table, or on the floor. One student should hold their end of the Slinky still while the other student moves their end rapidly back and forth, creating a series of waves. Encourage the student to time their movement to create a standing wave where the wavelength matches the length of the slinky. You should get a placein the middle of the Slinky that stays fairly still relative to the motion of the rest of the Slinky around it. Explain to the students that this place (called a node) corresponds to the darker blue lines on Slide #3 that separate the red and lighter blue sections where movement is occurring.

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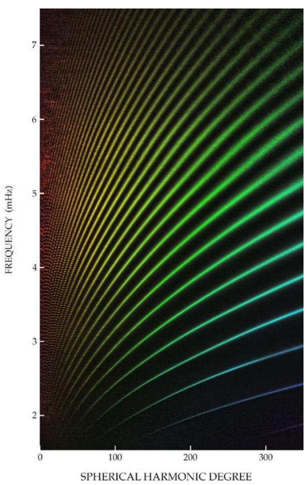
Slide 4



Slide 5

Since the vibrations of the solar sound make parts of the outside of the Sun move up and down, astronomers can study the sound by looking at the Sun. This is good, since there is no air between the Sun and the Earth and so there is no way for us to actually hear the sound. But, we can use special cameras to watch the outside of the Sun move up and down. Here is a snapshot of the outside of the Sun showing the up and down areas from all 10 million solar musical notes (show slide #4). A narrated video of these oscillations can be found at: http://science.msfc.nasa.gov/ssl/pad/solar/p_modes.htm

This picture (show slide #5) is a way for astronomers to sort out and look at all 10 million notes of the solar music at once. This picture sort of looks like the rainbow pictures you saw earlier, and is really a spectrum of sound rather than light from the Sun. You can see a bunch of dots at the left side of this picture. These dots are individual solar notes, like the keys on a piano keyboard. At the right of the picture, the notes blend together and you can't see them very well.

Follow this with a demonstration of how sounds can change. The following demonstration can be adapted to work with other objects of varying sizes.

Explain: Astronomers can get information about the inside of the sun because different objects have different sounds. The way things are changes how they will sound. I am now going to teach you some of the things we can learn about objects by listening to the sounds they make. I will be using some things called musical triangles.

Here are three musical triangles (Get 3 students at the front to hold up the 3 different size triangles).

What do you notice about them? What is different about them?

They are all different sizes

Which one do you think will make the highest musical note?

The smallest one

Which one do you think will make the lowest musical note?

The largest one

Do you think the musical note of this (middle) triangle will be higher or lower than this (smallest) one?

Lower

Do you think the musical note of this (middle) triangle will be higher or lower than this (largest) one?

Higher

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Listen again as I play all three of them in size order (Do it a few times) Now, close your eyes, and listen as I play the three triangles in some order. I want you to listen, and then tell me what size order I played them in (i.e. middle, large, small) Notice that you could tell me what the size of the triangle was just by listening to it without having to see it! The size of the triangle affects how it sounds. In general, large things produce lower musical tones than small things. A Chihuahua dog has a higher pitched bark than a St. Bernard.

Next, I will show you how attaching something to the triangle changes the way it sounds. Here is the small triangle again, and here is another small triangle just like this one except I have attached a small clip to it. Here's the sound of the triangle without anything attached. (Strike the small triangle without the clip) Now, here's the sound with the clip attached. (strike the triangle with the clip attached)

How did the two sound different?

The one with the clip attached sounds "dull" or "muffled" compared to the "bright" ringing tone of the unclamped triangle.

The sound has changed because a lot of the tones made by the unclamped triangle have been removed by the clamp. Close your eyes and tell me if I have struck the clamped or the unclamped triangle. Notice that you could tell me if something extra was attached to the triangle just by listening to it.

Finally, I will show you that a spinning triangle sounds different from one that is standing still. Here's the sound of a triangle standing still. (Ring the middle triangle) Now I am going to wind this rubber band up and spin the triangle after I hit it. (Do it but PRACTICE BEFORE THE LESSON!)

What do you notice that is different about the sound?

The spinning triangle will produce a wavering tone whose loudness seems to go up and down.

The change in pitch of a moving object is called the **Doppler Effect**.

The sound is different because if something makes a sound while it is moving, it changes the tone of the note heard by someone standing still. You may have noticed that the pitch of a police siren changes as the police car passes you. It's the same thing. Close your eyes and tell me if I am spinning the triangle. Moving things sound different than when they are standing still.

At this point you can play some computer generated sound files of solar music. You can't really dance to it, but it tells us a lot about the inside of the Sun.

You can download the files here: http://soi.stanford.edu/results/sounds.html

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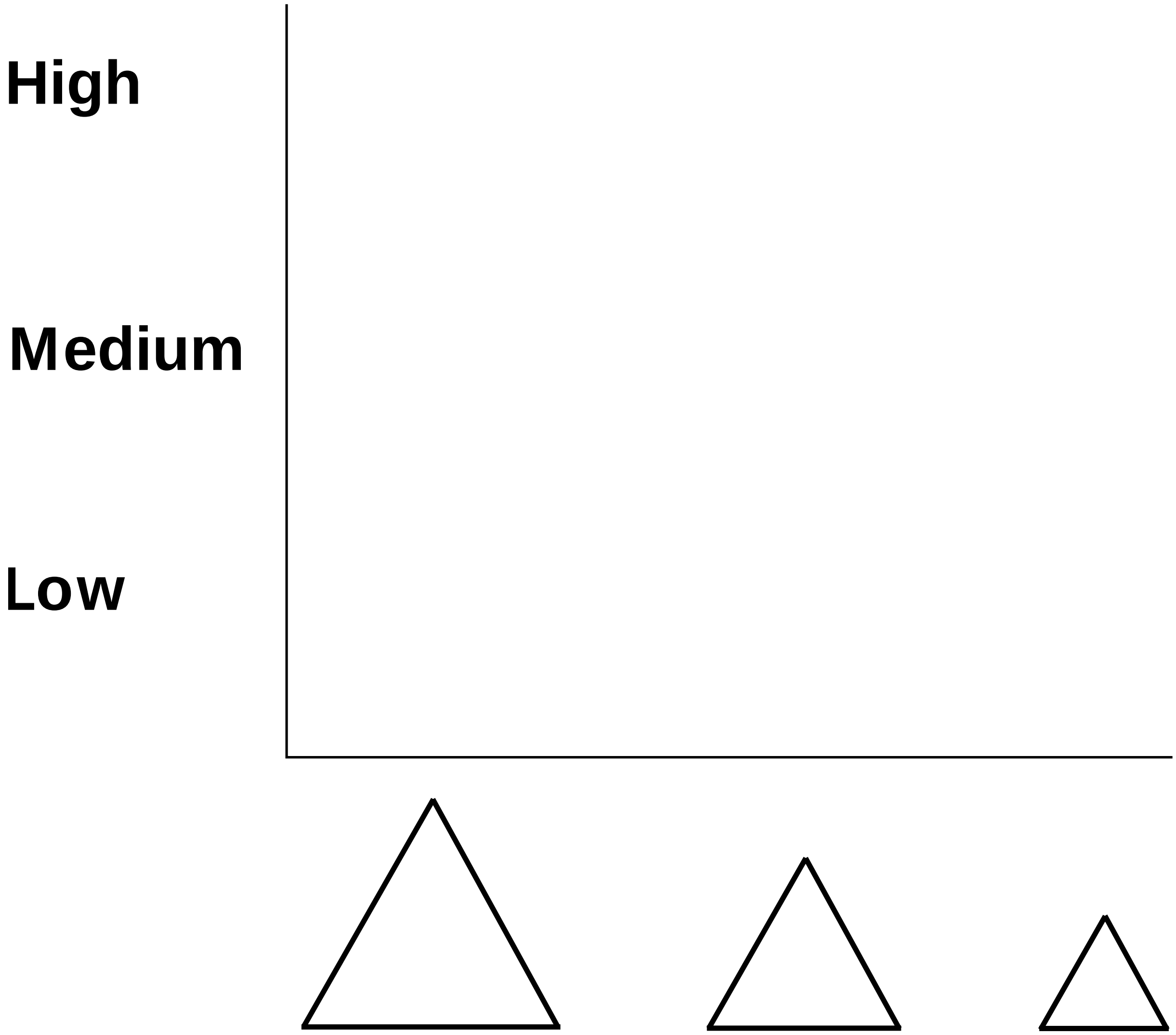
Size versus Pitch



If your students are familiar with basic graphing concepts they can fill in the graph above. If not, you could draw this simple graph on a chalk/whiteboard for them and relate it to Slide #5 as follows:

After listening to the different sized triangles, place an X at the appropriate spot on the graph for each triangle. For example, if the middle sized triangle sounds the highest to you, place an X across from the word High and above the middle sized triangle. Draw a line connecting the three Xs.

The line that you drew should be similar to the curved, colored lines you see in Slide #5. If the triangles emitted several tones (like harmonics), and your ears were able to accurately detect them, then you might get multiple Xs for each triangle. Connecting those Xs with a line should result in a graph that is very similar to what you see in Slide #5.

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Follow-up Activities

Materials For follow-up Activities

- Shoe boxes of similar size
- Various balls (ping pong, rubber, etc.)
- Beans
- Rice
- Sand
- Wooden blocks
- Copies of the grid (see procedure)

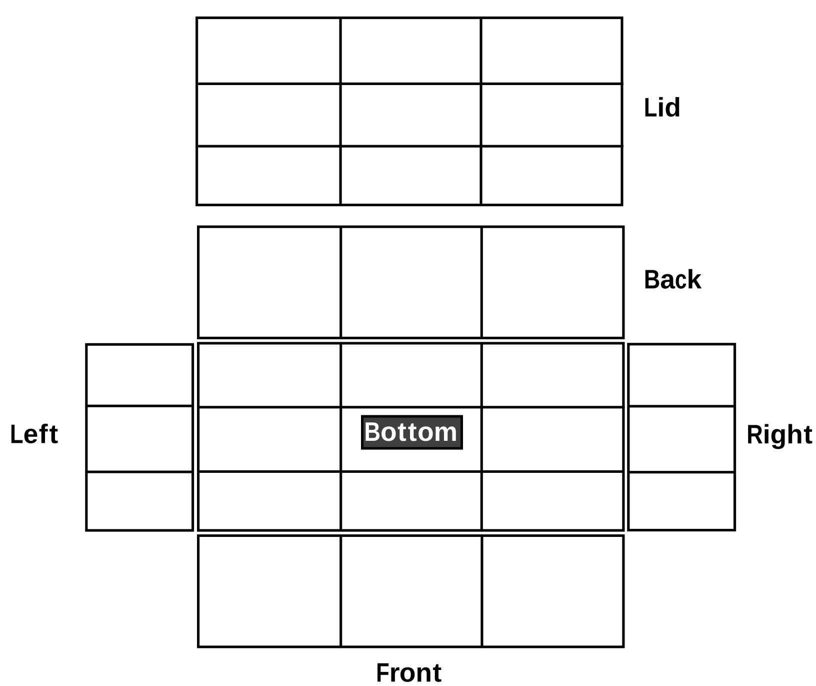
For younger students:

Obtain a number of similar boxes and place different objects inside them. Then seal the boxes. Students will tip, tilt, and shake the boxes to try to figure out what is inside them based on the sounds they hear. See materials list to the left for suggestions.

For older students:

Obtain several shoe boxes that are the same size. Make a grid on the inside surfaces of the boxes (see illustration) and glue several (5-10) blocks onto the surfaces of the box. Seal a ball inside each box. Label the outside of the boxes Top, Bottom, Front, Back Left and Right. Label each box A, B, C, etc. Be sure to mark a grid for each box to serve as a key. Or you could open up the boxes so students can see how well they were able to visualize where the blocks were in the boxes.

Have students tip, tilt and shake the boxes to map the locations of the blocks on a grid like the one below.



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Related Activities

It is assumed that this lesson will take place in the context of a larger unit on the Sun. It is recommended that the class do some activities to set the stage for this lesson. Suggestions include:

Motion of the Sun in the sky

Use the plastic Sun Tracking Hemisphere Kit (available from Learning Technologies at http://www.starlab.com/pspl.html) to track the apparent motion of the Sun in the sky.

Do shadow measurements at several times during the day to track the Sun's apparent motion.

Make Sundials

Surface of the Sun

Use a SunSpotter (also available from Learning Technologies at http://www.starlab.com/ltiss.html) to view the surface of the Sun.

View the current H-alpha image of the Sun on the web at http://www.Sunspot.noao.edu/DSTWWW/Sunpic.html

View recent solar images from the National Solar Observatory on the web at http://www.nso.noao.edu/diglib/recent.html

Acknowledgements

This activity was developed by Mark Newhouse with support from NASA grant #S-92698-F. Based on an activity developed by NSO Astronomer Frank Hill.

References

For further reading you may begin with the following sources:

- Browne MW. "Deep solar rumblings may offer key to Sun's inner structure." The New York Times, B5, 24-Oct-95.
- Leibacher JW, Noyes RW, Toomre J and Ulrich RK. "Helioseismology." Scientific American 253(3):48-57, 1985.
- GONG Helioseismology http://helios.tuc.noao.edu/helioseismology.html
- The Singing Sun http://solar-center.stanford.edu/singing/singing.html
- Helioseismology Introduction http://soi.stanford.edu/results/heliowhat.html
- SOLAR MUSIC - HELIOSEISMOLOGY http://www.noao.edu/education/ighelio/solar_music.html
- Surface Waves and Helioseismology http://science.msfc.nasa.gov/ssl/pad/solar/p_modes.htm
- Sound waves in the solar interior http://bigcat.ifa.au.dk/helio_outreach/english/engrays.html
- Solar oscillations http://bigcat.ifa.au.dk/helio_outreach/english/engHA4.html
- Oscillations on the solar surface http://bigcat.ifa.au.dk/helio_outreach/english/engkuglefkt.html