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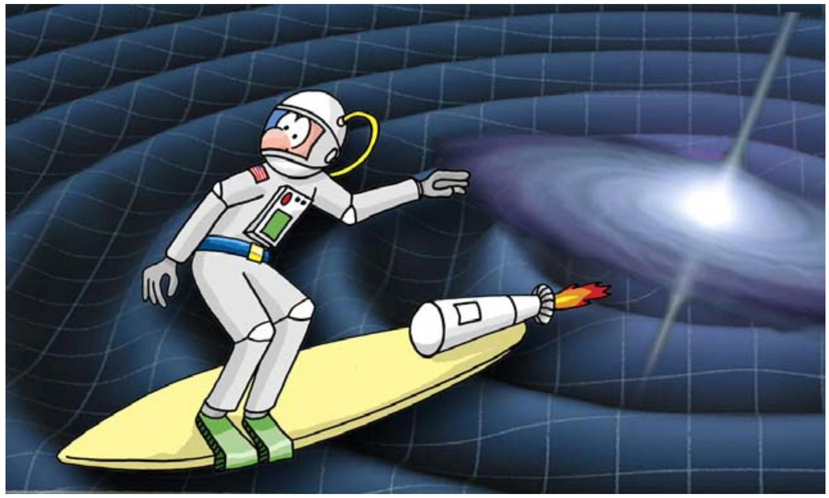
Catch a Gravitational Wave, Dude!

If you're a surfer, you're amped when you spot a dune coming into shore. Rain or shine, you can't wait to catch a pumping bump and drop in late. But while you're getting aerial, stuffed, or wiped out you probably aren't thinking about where those waves are coming from. You just don't want a gnarley wave to get you clucked.

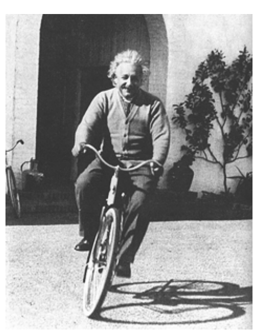


Well, whether gnarley or shore-dump, waves are created by ocean disturbances far out at sea. Storms or other atmospheric conditions disturb the fluid mound of water that flows over our planet. These large disturbances ripple through the ocean currents, carrying waves—large and small—to far away shores. But did you know that there are disturbances in space that cause waves? Yes, there are waves in space itself!

The type of space-travelling waves we now know most about are electromagnetic waves (radio waves, x-rays, gamma rays, visible light, and more). But, there is another type of space waves we don't know much about—gravitational waves. In fact we haven't detected one yet. We didn't know anything about gravitational waves until Albert Einstein predicted their existence in 1916.

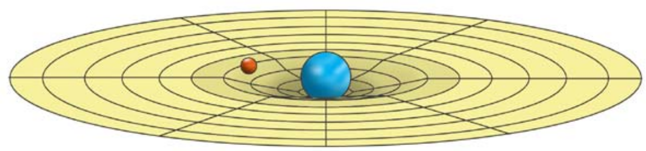
Albert's Warped Ideas

Albert Einstein was a great scientist who figured out many new things about the Universe. One of his ideas was that objects cause the space around them to be warped or curved. Picture a bowling ball sitting on a soft mattress. The heavy ball would cause the mattress to sag. A marble placed on this bowling-ball-laden mattress might roll right into the ball.



Einstein rides his bike in Santa Barbara.

In Einstein's picture of the Universe, the mattress is three-dimensional space. The space around a large object or mass, like a planet or the Sun, is so curved that other objects passing nearby follow the curvature and end up in orbit around the planet or the Sun.



And this is what gravity is all about! Gravity is the warping of space around a mass. The part of space that is warped around the mass is its gravitational field. Other objects inside this field, such as your body on Earth's surface, or the moon in orbit around Earth, or Earth in orbit around the Sun, influence and are influenced by this gravitational field. The more massive the object, the more it warps space, and the more gravitational influence it has on anything near it.

If not for gravity, we would go zinging off into space.

Let's follow Einstein's idea a bit further. Because of how masses warp whatever space is around them, when they move they cause disturbances, or ripples, in space. Think how disturbing the calm surface of a pond causes ripples. From a single point, the ripples move outward in bigger and bigger circles. And, just as violent atmospheric (weather) disturbances (hurricanes or typhoons) cause huge waves on Earth's oceans, cosmic disturbances cause the biggest gravitational waves in space.

It's Cosmic, Dude

But, what is considered a cosmic disturbance? Well, it might be a supernova explosion.

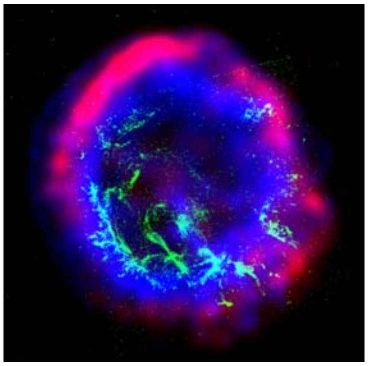
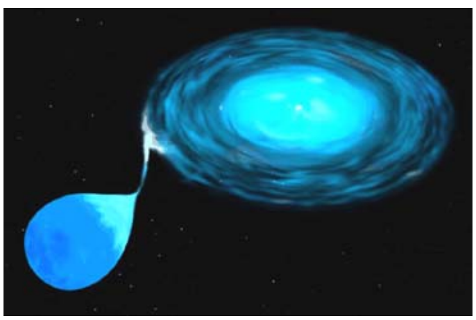


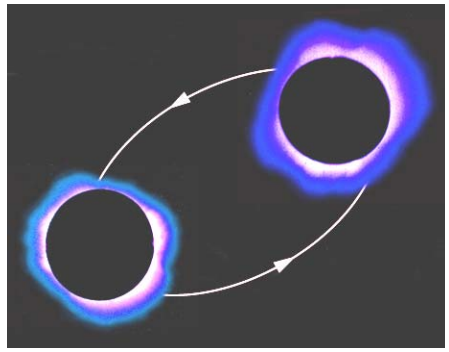
Image of a supernova in the Small Magellanic Cloud galaxy, made from data captured by the Australia Telescope Compact Array.

It might be two very large stars orbiting each other in what is called a binary system. It might be a massive star orbiting a black hole or two black holes orbiting each other. Just as a huge boulder causes bigger ripples than does a pebble when dropped onto the surface of a calm lake, these kinds of cosmic events produce the strongest gravitational waves.



Artist's painting of galactic binaries

The strength of the gravitational wave created by a binary star system depends upon the size of the two stars and the period of time it takes for them to orbit each other. As the gravitational waves carry energy away, the stars in a binary system gradually move closer together. As they get closer, the amount of time for each orbit gets shorter. While this is happening, the amount of energy they lose increases, meaning that the gravitational waves are getting stronger. The very strongest of waves is created just before the two massive objects collide.



Artist's painting of two black holes orbiting each other. We wouldn't really see them.

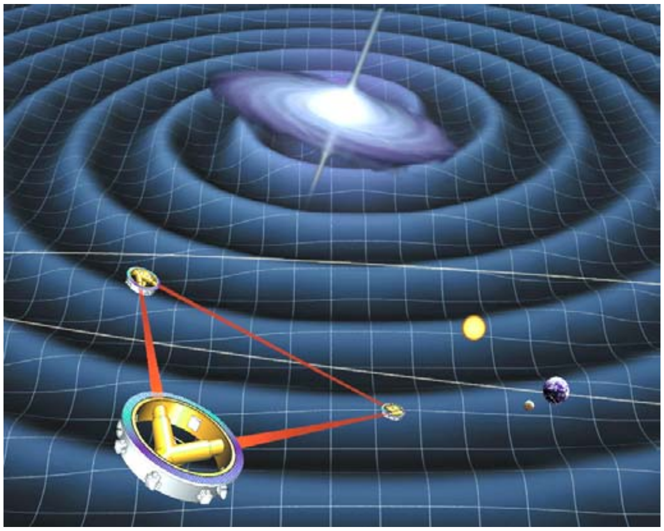
And when objects come near a black hole, its strong gravitational field sucks them in. Nothing escapes the extremely dense matter of a black hole, not even light!

But if no one has ever detected a black hole, how do we know they exist? Well, scientists have observed the motion of massive orbiting objects and their gravitational fields. Many scientists believe that every galaxy has a massive black hole at its center. (The Milky Way isn't the only galaxy in the Universe—it's just the one we live in). The motion of a black hole and another huge object orbiting each other cause strong gravitational waves that we, even as far away as we are, might be able to detect. Their gravitational waves may even be detectable several years before the two objects collide!

Let LISA Do It

Scientists want to know more about these gravitational waves and their sources because they could us help us understand more about the Universe. How? Well, we think that gravitational waves don't break up and scatter like electromagnetic light waves. We think that although they get weaker as they travel across space, gravitational waves aren't changed when they pass through matter. So, the signals they carry will be unchanged across time and space. This means we may be able to learn how the Universe began.

The Laser Interferometer (in-ter-fear-AH-muh-ter) Space Antenna (LISA) is a space mission that NASA hopes will be able to find some of these gravitational waves. LISA will have three spacecraft flying in the shape of an equilateral triangle (a triangle with three equal sides) five million kilometers (3 million miles) apart. LISA will look for gravitational waves in our galaxy, the Milky Way, and in other galaxies. If approved by NASA, LISA will bring us a new vision of the cosmos.



Artist's painting of the LISA mission detecting gravitational waves.

Learn more about LISA at the LISA mission website (http://lisa.jpl.nasa.gov/) and do an interactive crossword about LISA at The space Place website (http://spaceplace.nasa.gov/lisa_fact2.htm).

Activity - Gravitational Wave Game

Note to Teachers

This game tests your students' knowledge of gravitational waves and their sources in a team format. It reinforces the subject matter, following a period of study and discussion of the information in this article and in the LISA Amazing Fact hosted on The Space Place at:

http://spaceplace.jpl.nasa.gov/lisa_fact2.htm

Supplemental information for teachers is available on the LISA web site at http://lisa.jpl.nasa.gov.

This game is played in a manner similar to college science bowls where teams compete against each other in a timed war of knowledge. In a fun-fast-and-furious round-robin setting, students compete in panels of four against four AND against the clock!

What you will need:

1. a timer (an egg timer works well)
2. two bells
3. two erasable slate boards and chalk or whiteboards and markers
4. two panel settings: two tables with four chairs each, or just the chairs

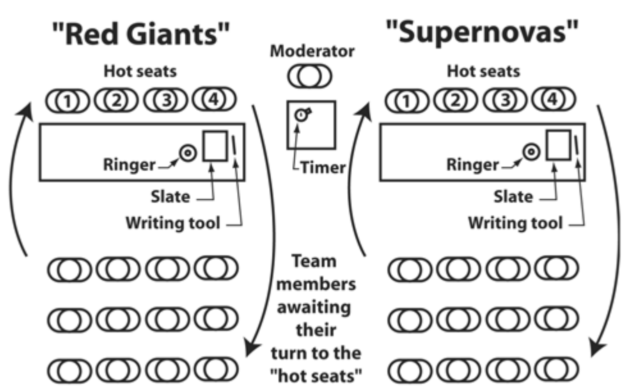
Here's how to play:

First divide the entire class into two teams, evenly if possible. Name each team something relevant to the subject. For example, one team may be called the "Red Giants," while the other team is called the "Supernovas."

Select four initial panelists from each team. Each group of four will sit in "hot seats" in front of the class (perhaps around a table or in a circle for ease of conferring with one another). Each of the two groups of hot seats is labeled 1 through four, left to right. On each team, panelist number four is designated the answer writer and bell ringer. (See diagram at top, right).

Post all the game answers in plain view (perhaps in large letters on the classroom black or white board). The answer list is provided on the following page. Game questions and their corresponding answers (in parentheses) begin on the following page. Some incorrect answers, such as "astrology," have been thrown into the mix for fun.

Select a moderator, generally a teacher, to present the questions. Randomly select questions from the list provided here. Each question and answer is a round. In keeping with the subject matter, we suggest calling each round a "wave."



For each wave the moderator poses a question from the list to both panels simultaneously. The panelists on each team collaborate to come up with an answer based on the material they have studied. To keep the game fun-fast-and-furious, each wave should be timed. We recommend one minute per question. It is a race against time and the other team.

When either team, as a group, decides upon an answer from the listed answers, panelist number four writes it on the erasable board and then rings the bell, signaling they are ready. Whichever team rings its bell first gets to answer. If neither team rings its bell before the time limit is reached, the moderator calls time and moves on to the next question. The unanswered question is saved for another wave or another game.

Each group of panelists is playing for points for their entire team (these points are redeemable in a manner designated by the teacher). Correct first answers win some amount of points—we recommend 10 per question. Incorrect answers cause the loss of points, or negative points, such as five points per error. If the panel answering first comes up with an incorrect answer, they lose points for their team. The question then goes to the other panel. If they have the correct answer written on their slate, they win the points for that wave. However, if they too give an incorrect answer, no points are lost, since they did not choose to risk any points by being first to answer (possibly incorrectly). Not being first with the answer loses no points.

A way to engage all team members is to have them do the "stadium wave" (standing with arms extended overhead and sitting, in quick sequence) when their panelists are first to answer a question correctly. Doing this may depend upon class size and, in general, class temperament.

Following a suggested minimum of four waves (four questions and answers), all four panelists in the hot seats on each team return to the larger team group. A new group of four panelists from each team moves to the hot seats. The moderator then poses the question for the next set of waves.

After each team member has had an opportunity to sit on the panel in the hot seats and answer the determined minimum set of questions as suggested above, the moderator may call the game "over." The team with the most points wins and all players on the team get to redeem game points in a manner determined by the teacher. For example, they might win extra credit, an amount of free time, etc.

Gravitational Wave Game

Answer List

Gravitational Waves
Star
Sun
Andromeda
Binary System
Black Hole
Chandra
Supernova
Einstein
Light
Milky Way
Red Giant
Astronomy
Electromagnetic Spectrum
Gravitational Field
Galaxy
LISA
Equilateral Triangle
Spacecraft
Cassini
Electromagnetic
Isaac Newton
Energy
Hubble Space Telescope
Orbit
Astrology
Curvature
LISA Spacecraft

Place these in plain view of the panelists on each team (perhaps write in large letters on the black or white board). Other answers (and questions) may be added to this list from the supplemental source material available on the LISA web site.

Gravitational Wave Game Questions and (Answers)

These questions have been developed from the information available in the preceding ITEA article, The Space Place, and the LISA web site. You may formulate additional questions and answers from these sources.

1. To learn about stars you might study this. (Astronomy)
2. A gravitational wave causes a ripple in this. (Space)

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3. Shining stars dancing around each other in space could be this. (Binary System)
4. This is a spacecraft formation good for detecting gravitational waves. (Equilateral Triangle)
5. These carry signals unchanged across space and time. (Gravitational Waves)
6. This kind of super star explodes in a big way. (Supernova)
7. This scientist thought about warps and curves. (Einstein)
8. Cosmic events in space cause these. (Gravitational Waves)
9. Binary star systems lose this as they orbit closer together. (Energy)
10. All of space and everything in it is called this. (Universe)
11. This is the name of our galaxy. (Milky Way)
12. These kinds of space waves do not change when they pass through matter. (Gravitational Waves)
13. The LISA mission will fly in this shape. (Equilateral Triangle)
14. LISA will look for gravitational waves in this galaxy. (Milky Way)
15. This kind of space wave hasn't been detected yet. (Gravitational Wave)
16. Many scientists think this is at the center of each galaxy. (Black Hole)
17. Not even light can escape this. (Black Hole)
18. This is the warping of space around masses. (Gravity)
19. Moving masses cause disturbances in this. (Space)
20. Gravitational waves carry this away. (Energy)
21. The motion of objects in space causes this. (Gravitational Waves)
22. X-ray, visible light, and radio are some types of energy in this. (Electromagnetic Spectrum)
23. If we study gravitational waves we may be able to learn how this began. (Universe)
24. These get weaker as they travel across space. (Gravitational Waves)
25. As stars in a binary system get closer, the amount of time for each of these gets shorter. (Orbit)
26. Cosmic disturbances in space cause the biggest of these. (Gravitational Waves)
27. As gravitational waves carry energy away, the stars in this move closer together. (Binary System)
28. We know these exist because of the motion of orbiting objects. (Black Holes)
29. In addition to gravitational waves there is this type of space wave. (Electromagnetic)
30. This NASA mission will study black holes. (LISA)
31. When objects collide, the very strongest of these are created. (Gravitational Waves)
32. The more massive an object, the more it warps this. (Space)
33. This scientist predicted gravitational waves. (Einstein)
34. Among the LISA spacecraft, these are like a spider web made of light. (Laser Beams)
35. Using different telescopes, we have observed different wavelengths of this. (Electromagnetic Spectrum)
36. This is the most mysterious force in the Universe. (Gravity)
37. Most of his ideas have been proven correct. (Einstein)
38. These are usually very weak by the time they reach us. (Gravitational Waves)
39. These have never been measured. (Gravitational Waves)
40. These will be 3 million miles apart. (LISA Spacecraft)
41. Very large masses moving quickly create ripples in this. (Space)
42. These will be five million kilometers apart in space. (LISA Spacecraft)
43. The Milky Way is one of these. (Galaxy)
44. Many scientists think this is at the center of each galaxy. (Black Hole)
45. Earth orbits this. (Sun)

This article was written by Sandi Beck, Space Place Team science and technology writer, and Diane Fisher, science and technology writer and developer of The Space Place website. It is provided through the courtesy of the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Illustrations are by Alex Novati.