

SAMPLE LESSION

Title: Gravitational Waves and Dance

Student Ages: Middle - high school

Essential question: how can the concepts of gravitational waves be incorporated into a movement study

Objectives: 1. Introducing and explaining scientific principles of gravitational waves and black holes. 2. Insight into the creative process by showing how the scientific principles can be explored through movement. 3. Introduce vocabulary for basic dance concepts. 4. Develop an appreciation for dance by analyzing, interpreting and judging according to aesthetic principles of dance.

Science concepts: Gravitational waves are ripples in spacetime caused by accelerating masses such as colliding black holes, exploding stars and even the birth of the universe itself. These ripples travel at the speed of light through the Universe, carrying with them information about their origins.

When two compact objects orbit each other, they radiate gravitational waves. This carries away energy thereby decreasing the orbital distance and increasing the orbital speed.

Vocabulary: These words relate to basic dance concepts:

1. Space 2. Energy 3. Shape 4. Time 5. Choreograph 6. Theme

Materials Needed: None

Activities:

1. Introduce the concept of gravitational waves. What are the general characteristics that relate to the dance vocabulary above. Write down 4 characteristics
 - A. Space - expansion/contraction
 - B. Time - acceleration, frequency
 - C. Shape - distortion
 - D. Energy- waves
2. Individually explore each of the above characteristics.
 - A. Space - stretch your body in different ways. Reach your elbow as high as you can and your foot as low as you can, stretching each body part as far away from each other as possible. Explore stretch other body parts stretching away from each other.

Contract - curl your body into a tight ball as possible. Alternate between stretching and contracting your body, using different body parts and your entire body

B. Time - Vary the timing in expand/contract. Expand as slowly as you can, then contract quickly. Do the opposite. Now try varying the time using slow motion, quick, moderate speeds moving seamlessly from one to the other

C. Shape - pick 4 different shapes. Experiment with ways that you can distort or change each shape. Then move from one shape to the other with your distortions. Try different levels for your shape

D. Energy - movement qualities. Explore different movement qualities - shake, percussive, smooth, tense, loose (like a noodle), wavy. Walk around changing movement qualities

E. Create a short movement study using all of the elements you've explore above

3. Group activity - related to this concept:

When two black holes spiral towards each other, the orbital frequency increases as the orbital separation between the two objects decreases

A. Form into pairs. Slowly begin to orbit one another. As the two dancers come closer to each other their frequency increases until they merge.

B. Group activity: (show diagram) [plus polarization](#), [cross polarization](#). Form a circle. Pulse the circle by moving in and out, closer and further away, each time you move away the circle becomes an oval shape that moves from vertical to horizontal orientation in the space

C. If time: create a group dance choosing the elements you've explore above. There can be individual sections, pairs, coming together as a group.

Assessment of Learning: Students will also be asked to reflect on what they saw and to answer a series of short questions such as:

1. What was your favorite part of this activity, and why?
2. What part did you have the most difficulty understanding, and why?
3. Are you interested in learning more about gravitational waves?
4. Can you think of other scientific topics that could be explored through movement?

Further resources:

1. LIGO, [www://ligo.caltech.edu](http://www.ligo.caltech.edu). Extensive information about gravitational waves with diagrams, teacher resources. Particularly <https://www.ligo.caltech.edu/page/educational-resources>

- Popular science articles that explain gravitational waves. The first two talk about LIGO, the second two discuss pulsar timing arrays, and the last article describes trying to use star "wobbles" to detect gravitational waves.

- "[Gravitational waves, Einstein's ripples in spacetime, spotted for first time](#)", *Science*

- "[The Gravitational-Wave 'Revolution' Is Underway](#)", *Scientific American*

- "[Pulsar timing arrays are poised to reveal gravitational waves](#)", *Physics Today*

- "[Galaxy-Size Gravitational-Wave Detector Hints at Exotic Physics](#)", *Scientific American*

- "[Using Gaia as a Gravitational-Wave Detector](#)", *Astrobit*

- [Video that shows how LIGO works](#). In general, that LIGO website has a lot of great videos and resources.

- [Video that compares the "chirps" from two different black hole mergers that LIGO detected](#)

- This is a [music album based on gravitational waves](#), and [this is the technical paper they wrote explaining how they generated the music](#). There's also [an associated website](#) with the project.

Video link to DS&D dance, *Gravitational Waves*: <https://vimeo.com/838175648/6976f0b5ce>