Educational Resources

Video Introductions to LIGO

TED-Ed: "What are gravitational waves?" [5:24] - Includes lesson materials. **Level:** Middle school and older

Minute Physics: "Gravitational Waves Explained Using Stick Figures" [3:20] **Level:** Middle school and older

Piled Higher and Deeper: "Gravitational Waves Explained" [3:19] **Level:** Middle school and older

LIGO: "Journey of a Gravitational Wave" [2:56] **Level:** Middle school and older

Cardiff Univ.: "Gravitational Waves (Part 1)" [6:17], "Gravitational Waves (Part 2)" [6:00] **Level:** High school and older

Online Activities

Gravitational Wave Open Science Center (GWOSC) Learning Paths

Web-based learning activities great for in person and remote learning!

- Waveform Fitter
  Determine the mass and distance of the black holes involved in the first detection of gravitational waves by using slider bars to change the parameters until you have achieved your best fit. Compare your mass and distance to the published parameters.
  Estimate: 5 minutes
  Level: middle school and older
- Wave Physics with LIGO Data
  Learn about wave properties with sound and light, then extend those themes to gravitational waves.
  Estimate: 50 minutes
  Level: middle school and older
- Signal Processing Tutorial
  Learn the basics of signal processing in the time-domain and the frequency-domain without any coding! Work through the examples by adjusting slider bars.
  Estimate: 30 minutes
  Level: high school and older
- Gravitational Wave Data Quickview App
  Application which allows students to see multiple visualizations of gravitational wave events. Use the slider bars to adjust the signal processing that is applied to each event. See how the processing affects the ability to see the event.
  Estimate: 15 minutes
  Level: high school and older

Black Hole Hunter
Online game to find black hole signals
Estimate: 10 minutes

Sounds of Spacetime
Thoughtful website giving introduction to gravitational wave sources and signals. Emphasis on audio files and videos with gravitational wave simulations.
Estimate: 30 minutes to browse materials

LIGO/Virgo Audio Files
Listen to both real and simulated gravitational wave signals. Includes link to example code to make your own audio files.
Estimate: 10 minutes to browse materials

Gravity Spy
Help scientists classify glitches in real LIGO data
Estimate: 15 minutes to get started, with many hours of online material

Classroom Activities

Cardiff University Classroom Activities
Pencil and paper activity that can be completed remotely or in the classroom. Aimed at students aged 14-16 (Intermediate) and 16-18 (Advanced). Includes small-group work, to estimate black hole properties and positions based on gravitational wave data, culminating in an estimate of the Hubble Constant. Includes 10 minutes of high-quality explanation videos.
Estimate: 1-2 hours of instruction time
Level: high school
There is also a workshop with experimental hands-on activities that can be run in the classroom.

Continued on next page ☞

Classroom Activities (cont'd)

Penn State Classroom Activities
Hands on activity finding signals in noisy data, using only paper, pencils, and rulers.
Estimate: 1 hour of instruction time for each of 2 activities

- Searching for Signal in the Noise: a Gravitational wave Icebreaker Activity
  Level: middle school and older
- Hands-On Gravitational Wave Astronomy: Extracting Astrophysical Information from Simulated Signals
  Level: high school and introductory college physics courses.

Gravitational Wave Detection in the Introductory Lab
Activity to link GW data with orbital physics
Estimate: 1 hour of instruction time
Level: undergraduate students

LIGO Educator's Guide
Pamphlet with introduction to LIGO and describing classroom hands-on activities.
Estimate: 2 hours of instruction time
Level: middle school through high school

Online Courses in Gravitational Waves from Sonoma State
Two complete courses in gravitational wave physics and detection!
Estimate: Up to 80 hours of reading, videos, and homework problems

- LIGO: Detecting Gravitational Waves
  Level: undergraduate students and teachers (professional development)
- LIGO: Waves and Gravity
  Level: undergraduate students and teachers (professional development)

Computer Programming

LIGO Astrophysics Jupyter Notebooks
Python code to measure astrophysics using LIGO data. Uses python Jupyter notebooks that will run in your browser. Best for college level students.
Estimate: 2 hours of instruction time

- Extracting Astrophysics from Gravitational Waves: GW170817 Case Study
  Extract properties of the source of GW170817 to see this was a merger of two neutron stars.
  Level: advanced undergraduate
- The Complementarity of Multi-wavelength and Multi-messenger Observations
  Determine the Hubble constant using gravitational waves.
  Level: advanced undergraduate

GWOSC Tutorials
Learn to download, plot, and analyze LIGO/Virgo data using python examples and online courses.
Estimate: Start with Quickview tutorial for a 10-minute introduction. Up to several hours of additional material.
Level: advanced undergraduate and graduate students

Gravitational Wave Open Data Workshops
Write code to find gravitational wave signals! Open Data Workshops are a complete course in LIGO data analysis, including video lectures, software tutorials, and data challenges.
Estimate: 30 hours of materials. Pick and choose tutorials for limited times.
Level: advanced undergraduate and graduate students

This document was provided as supplemental material for the talk, "Can You Surf a Gravitational Wave?: Explaining LIGO Science," presented by Amber Stuver (Villanova University) at the 2021 AAPT Summer Meeting. If you have questions or comments, please feel free to contact here at amber.stuver@villanova.edu.

These educational materials have been made by fellow educators, many of them members of the LIGO Scientific Collaboration. This collection was curated by Amber Stuver (Villanova University), Jonah Kanner (Caltech), and Christopher North (Cardiff University).