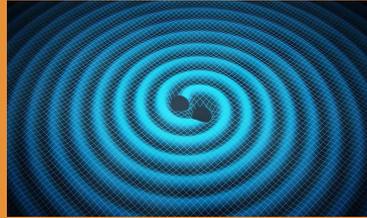# Topic: Gravitational Wave Astronomy

Title: Extraction and analysis of astrophysical data from coalescing black holes.

Lesson Objectives

- Students will describe the changes that occur in gravitational waves emitted from a compact binary system as the system moves towards coalescence.
- Students will analyse data from gravitational wave measurements and use relevant equations to calculate the chirp masses and astronomical distances of binary systems.
- Students will describe the process that scientists would use to extract information about astrophysical sources from gravitational wave data.
- Students will demonstrate the manual skill that is required to build a precision device
- Students will explain light interference using the basic model of wave behavior
- Students will describe the relationship between the movement of an interferometer mirror and the resulting movement of the pattern of fringes
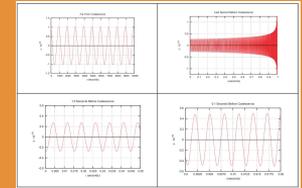
Integrated STEM

Science:
- Waves behaviour
- Circular motion
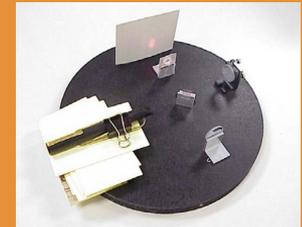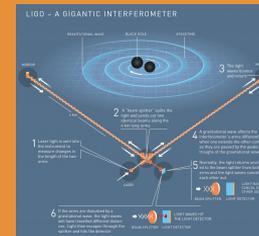- Black holes

Mathematics:
- Analysing graphical data
- Use gravitational wave mathematics

$$A(t) = \frac{2(G\mathcal{M})^{5/3}}{c^4 r}\left(\frac{\pi}{P_{gw}(t)}\right)^{2/3}$$

Engineering:
- Design and build a Michelson Interferometer to model LIGO.

Summary: 5E Lesson Plan

ENGAGE

Prompt - Your body has been stretched and squeezed without you realizing it!

Students then read the article A Wave of Discovery and watch Einstein's Messengers. Students then discuss the prompt.

EXPLORE

Part 1: Examining the data
Part 2: Using Gravitational Wave Mathematics
Part 3: Design and build a Michelson Interferometer

$$A(t) = \frac{2(G\mathcal{M})^{5/3}}{c^4 r}\left(\frac{\pi}{P_{gw}(t)}\right)^{2/3}$$
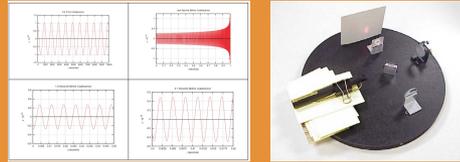
EXPLAIN

Students complete questions related to data processing and building the interferometer to explain their understanding.

Q&A

ELABORATE

Students dig deep into the physics (interference) behind the laser interferometer.
They will have access to a Phet simulation and a self study resource from the Physics classroom.
Further evidence will be provided by answering probing questions.

PhET INTERACTIVE SIMULATIONS

Q&A
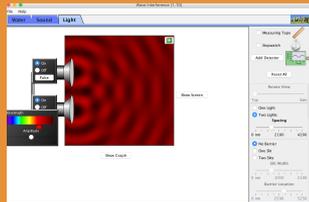
EVALUATE

Students will peer assess each others draft work before final submission. Students will be assessed against the objectives and their collaboration in the design task

Rubric - Gravitational Wave Astronomy   Name:_____

1 = standard not met; 2 = standard partially met; 3 = standard met; 4 = exceeds expectations

Gravitational Wave Astronomy					
Assessment Criteria	1	2	3	4	Feedback
Describe the changes that occur in gravitational waves emitted from a compact binary system as the system moves towards coalescence.					
Analyse data from gravitational wave measurements and use relevant equations to calculate the chirp masses and astronomical distances of binary systems.					
Describe the process that scientists would use to extract information about astrophysical sources from gravitational wave data.					
Demonstrate the manual skill that is required to build a precision device					
Explain light interference using the basic model of wave behavior					
Describe the relationship between the movement of an interferometer mirror and the resulting movement of the pattern of fringes					
Level: 19=L7; 18=L6; 16=L5; 14=L4; 12=L3; 8=L2; 6=L1	Total -				Overall level-

COLLABORATION RUBRIC
(for secondary and upper elementary grades)

	Below Standard	Approaching Standard	At Standard	Above Standard
Responsibility for Oneself	◆ is not prepared and ready to work with the team ◆ does not do project tasks ◆ does not complete tasks on time ◆ does not use feedback from others to improve his/her work	◆ is sometimes prepared and ready to work with the team ◆ does some project tasks, but needs to be reminded ◆ completes some tasks on time ◆ sometimes uses feedback from others	◆ is prepared and ready to work with the team; is available for meetings and uses the team's communication system ◆ does what he or she is supposed to do without having to be reminded ◆ completes tasks on time ◆ uses feedback from others to improve his or her work	In addition to At Standard criteria ◆ does more than what he or she has to do ◆ asks for additional feedback to improve his or her work, beyond what everyone has been given
Helping the Team	◆ does not help the team solve problems; may cause problems ◆ does not share ideas with other team members ◆ does not give useful feedback to others ◆ does not offer to help others	◆ cooperates with the team but does not actively help it ◆ makes some effort to share ideas with the team ◆ sometimes gives useful feedback to others ◆ sometimes offers to help others	◆ helps the team solve problems, manage conflicts, and stay focused and organized ◆ shares ideas that help the team improve its work ◆ gives useful feedback (specific and supportive) to others so they can improve their work ◆ offers to help others do their work if they need it	In addition to At Standard criteria ◆ steps in to help the team when another member is absent ◆ encourages others to share ideas; makes clear, and connects them to the team's work ◆ notices if a team member does not understand something and takes action to help
Respect for Others	◆ does not pay attention to what teammates are talking about ◆ does not show respect for teammates (may interrupt, ignore ideas, hurt feelings)	◆ usually listens to teammates, but not always ◆ is polite and kind to teammates most of the time, but not always	◆ listens carefully to teammates ◆ is polite and kind to teammates	In addition to At Standard criteria ◆ encourages the team to be respectful to each other ◆ recognizes everyone's strengths and encourages the team to use them