Shift Happens

Unit:	Utah SEEd Standard / NGSS Performance Expectation:	Time:
Space Science	**Standard ESS.1.2** **Construct an explanation** of the Big Bang theory based on astronomical evidence of electromagnetic radiation, motion of distant galaxies, and composition of matter in the universe. Emphasize redshift of electromagnetic radiation, cosmic microwave background radiation, and the observed composition and distribution of matter in the universe. (PS4.B, ESS1.A)	1 Class Hour: 70 minutes

Unit scope and sequence
Prior lessons in the unit that will provide necessary student understanding:

- Matter vs Energy
- Electromagnetic Spectrum: wave properties, light as a wave, order including visible and non-visible wavelength, etc.
- Star cycle: sequence, color, HR diagram, temperature, magnitude, luminosity, gravity, etc.
- Spectroscopy: spectrum, emission, and composition

Post lesson:

- Hubble's Law shows the expansion velocity increasing.
- Other evidence that supports the Big Bang.

Access to all material for this lesson: Lesson Folder

Anchor Phenomenon	The Doppler effect as it relates to sound and light waves. Use sound waves as a hook and relate it to how light waves change according to the source.
Driving Question(s)	What happens to waves emitted by a moving object? How can scientists use star spectra to determine a star's position and velocity?
Performance Task	Phenomenon-Doppler Effect Expansion of Waves activity Redshift and Distance pattern finding Redshift and Velocity pattern finding

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Lesson Summary:			
	Time	**Guiding Question / Learning Objective**	**How are students answering the guiding question or meeting the learning objective?** (Highlight the SEPs, DCIs, and CCCs in the corresponding color.)
Engage		What happens to sound and light waves when the source of a wave is moving? How are emitted spectra altered if a celestial body is moving away from Earth?	Students watch several videos demonstrating the Doppler effect, making observations about what patterns they notice related to sound in relation to movement.
Explore		Where do we find evidence? What does that evidence tell us? How is it linked to Red Shift?	-A slinky demonstration allows students to view what happens to wavelength as an object moves away from the observer. -Skyserver data cards evaluated.
Explain		Claim, Evidence, Reasoning Discussion. We want the students to make the connection between the data they are finding and claims made.	-Class discussion -Extensions show what scientists have been able to determine or discover from red shift evidence.
Evaluate		No formal evaluation/assessment for this lesson.	Teacher will use student work to evaluate student understanding. Adding quality questions about redshift to a summative assessment would be appropriate.

Three Dimensions Focused on in This Lesson

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Disciplinary Core Idea:	Science and Engineering Practices:	Crosscutting Concept:
NGSS Appendix E **ESS1.A The Universe and the Stars** The study of stars' light spectra data (redshift and blueshift) and brightness is used to identify their movements, and their distances from Earth.	**NGSS Appendix F** **Analyzing and Interpreting Data:** Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.	**NGSS Appendix G** **Patterns:** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

Learning Objectives

1. I can explain that all waves behave in the same way regardless of the speed of the wave.
2. I can explain how wavelength is affected when the source of the wave is moving.
3. I can use a Star's Spectra pattern to determine its distance and velocity.

Related Knowledge and Skills from Prior Grades

Disciplinary Core Idea:	Science and Engineering Practices:	Crosscutting Concept:
NGSS Appendix E	NGSS Appendix F	NGSS Appendix G

Connections to Mathematics and ELA/Literacy Standards

ELA/Literacy Standards:

- **RST.11-12.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- **WHST.9-12.1** Write arguments focused on discipline - specific content.
- **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
- **SL.11-12.4** Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics Standards:

- **MP.2** Reason abstractly and quantitatively.
- **MP.4** Model with mathematics.
- **HSN-Q.A.**1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- **HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling.
- **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

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Materials		
Handouts	**Lab Supplies**	**Other Resources**
Student Handout (digital has accompanying links) Student handout (Word version) Slides (GoogleSlides) Slides (PowerPoint) Earth and Star Signs (to print)	Slinky Ruler/Meter Stick (optional) Wavelength Cards (to print) SkyServer Data Card Skyserver Data Card (word version)	Skyserver

ENGAGE

Use Slides as the presentation resource along with the student handout.

Student Handout Section A

1. Ask the students to look for answers to question 1 while the videos play on slide 2. After answering individually, they will do a think-pair-share while focusing on the patterns they see in the videos.
2. Have students read questions 2-3 and listen for the answers when they watch the video 3, writing nothing until after the video.
3. Watch the first 1:47 of the video describing the Doppler effect and how it relates to sound waves.
4. Give students 1-2 minutes to discuss questions 2-3 with a partner or small group, emphasizing patterns they notice.
5. Change to Slide 4 and call on a couple of students to give their answers to each question and discuss. End the discussion by asking: Do you think the Doppler Effect can be seen with other types of waves?

Optional: Slide 5 includes a couple more videos showing examples of the Doppler effect.

Student Handout Section B

6. Slide 6 – transition from sound to light waves. Review the statements on the slide. Show the EM spectrum and remind the students of the portion that is visible light.
   Possible questions to ask students: Are there things that can see other forms of light outside of visible light (UV and Infrared)? Outside of visible light (UV and Infrared)? Which side of the visible spectrum is the longer wavelength? Shorter wavelength? What color would be associated with a shorter wavelength? Longer wavelength? What color would be associated with a shorter wavelength? Longer wavelength? Now, end with a rhetorical question - “What happens when a light source is moving?”
7. Show the video on slide 7
8. Have students answer questions 4-5. Discuss that both sound and light travel in waves and that the principles of the Doppler effect will be the same with light waves.
   Possible questions: How does light travel? How does sound travel? Are there similarities in how light and sound travel? What patterns do you observe with how light travels and how sound travels? If you have a light source in space, what does that look like to us (the observer)? What happens to the wavelength if the source moves away from the observer or toward the observer?

Teacher Tips

Find a video that may relate better to your students. We used trains and race cars as they are familiar to our students.

Ask students where they have heard of the phenomenon before using other examples.

Remind students that an emission spectrum can be used to understand the composition of the light source.

When the class discusses answers to question 1, notice and lead the conversation toward a change of pitch as described in the video rather than a change in volume.

Help students recognize the patterns that exist when comparing the Doppler effect between light and sound waves.

Slide 6- Have students show what they already know about the EM spectrum before clicking the transition showing the EM spectrum.

Also, ask the students what patterns they see with the EM spectrum and others they have seen before.

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EXPLORE

Student Handout Section C: Teacher Demonstration

9. Get two student volunteers and attach the Earth printout to one and the star printout to the other. Give each one the end of a slinky.
10. Have both students stretch the slinky by slowly walking in opposite directions.
11. Students should see that the new wavelength (slinky peaks) is longer and has become redshifted, lowering the apparent energy.
12. Students should answer questions 6-8 for section C.

Student Handout Section D- Small group work (2-4 students)

13. Have students answer questions 9-10. Walk around and check students' answers to questions.
14. Discuss answers they got for questions 2 and 3.
15. Have students pull out the five printed spectral shift cards from their supplies (Wavelength cards) Students should try to put the 4 stars in order according to their distance from Earth by comparing them against the reference spectra, which is done by seeing how much redshift is happening: the more redshift, the further away the star.
16. Have students answer question 11 and discuss their answers with their groups.

Student Handout Section E- Small group work (2-4 students)

17. Students will need to click on the SkyServer link to access the data. (This specific link has good spectral data).
18. Let the students explore for a few minutes. Possible questions for the teacher related to what they are seeing: Are these stars? What else do you see? Can you describe any patterns? Do you think we have data for all these objects we are seeing? What colors do you see?
19. Show the students how to find the correct data they need for each of the 10 celestial objects they choose.
20. Students will move around the room, viewing data cards from 10 of the 20 objects (depending on time) from the SkyServe Data Cards to collect data for their data table.
21. Have them plot their data on the graph.
22. Have them answer questions 12-15. Be a resource as the students have questions. Encourage them to answer written questions on their own.
23. Once students finish the questions, bring everyone together for a discussion on question 15—further emphasis on redshift as evidence that the universe is expanding and how that tells us.

Teacher Tips

Section C: Having the students move in opposite directions can be an opportunity to show students that the Earth is not the center of the universe or a fixed point in space. As part of the Milky Way Galaxy, Earth is also moving in space.

Section D can be done as group work, which should take the students about 5 minutes to complete.

Cut the spectral image as close to the image edge as possible when printing off the cards. It is recommended to have sets glued to different colored cardstock to prevent cards from separate sets from getting mixed up.

After arranging the cards, you could briefly discuss what patterns the student may see if there were other cards showing further redshift or even blueshift.

Important items to discuss as a class:

- The color of an object in the sky does not indicate redshift.
- Spectral emission deals with composition, temperature, and size.
- Most stars are main sequence stars and will mainly be red/orange.

Extra support for students could include requiring them to gather less data or pair with another student.

When discussing question 14, help students recognize that even if they were somewhere else in the universe, they would still see the same patterns of expansion.

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EXPLAIN	
Lead a class discussion on the following: (Slide 13) Using Claim, Evidence, Reasoning, explain what redshift tells us about the universe. Possible Claims: -As an object moves away from an observer the wavelength increases. -As distance increases, redshift increases. -As velocity increases, redshift increases.	**Teacher Tips** Have students see if they can find evidence to each of the claims. Discuss as a class the reasoning behind them.

EVALUATE	
The last question on the student worksheet is filling in a claim, evidence, and reasoning table. Students could do this on their own as a way to test their knowledge. It is our intention that teachers will use student work and class discussion to evaluate student understanding. Additionally, adding content from this lesson to whatever summative assessment would be appropriate	**Teacher Tips**

POSSIBLE EXTENSION / ALTERNATIVE ADAPTATIONS

- Have students brainstorm and record their own examples of the Doppler effect and submit it to the teacher.
- Slides 14-18 provide optional extension activities, examples, and discussions
- Students may want to explore the Skyserver website, looking for examples of redshift and blueshift or looking at other data

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