

Origin of the Universe 5E

How many solar systems and galaxies are out there? Were they formed in the same way?

Performance Expectations
HS-ESS1-2

Investigative Phenomenon
There are more stars in the universe than there are grains of sand on Earth and scientists predict each one of those stars hosts several planets.

Time
6-7 days

In this 5E instructional sequence, students are investigating the questions that surfaced during the Driving Question Board launch about how many galaxies and solar systems are in the universe and whether other solar systems and galaxies are similar to ours. Students investigate electromagnetic wave behavior and use what they learn to infer that all the matter in the universe must have been tightly compacted in the beginning and then expanded. Students then use the crosscutting concept of conservation of energy to predict what evidence of a small, dense, hot universe we should be able to observe today (cosmic background radiation) and are introduced to that evidence. Students bring all this evidence together to develop an explanatory model for the origin of the universe (the big bang). Students will then connect their model of the origin of the universe to the formation of solar systems and galaxies, including our own, and use it to make claims about whether it is probable that life exists on other planets.

Engage	Engage: Where did everything in the universe come from? Has the universe always been the same?	Students work in groups to develop an initial claim of how the universe came into existence and how that led to the formation of all the stars and planets.
Explore	Investigating light from stars in other galaxies	Students use a simulator to track the flow of sound and light energy waves between a source and an observer in order to gather data that can help them explain differences in absorption lines in spectra of light from other galaxies .
Explain	Explaining redshift and making inferences about the universe in the past	Students use their understanding of the flow of sound and light energy waves between a source and an observer to develop an explanation for the redshift noticed when observing the spectra of other galaxies . Students then develop a model of the early universe by making inferences based on the fact that it has been expanding.
Elaborate	Exploring additional evidence for the Big Bang theory and constructing an explanation for the origin of the universe	Students hypothesize and read a text about what the temperature and pressure of the early universe must have been like and learn about the law of conservation of mass and energy . Students use what they learn about the early universe and conservation of mass and energy to articulate why cosmic background microwave radiation and Hydrogen and Helium ratios in the universe serve as additional evidence for their final explanatory models .
Evaluate	Is it probable that there is life elsewhere in the universe?	Students use models for how the origin of the universe led to the formation of solar systems to make predictions about whether life exists on other planets.

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Engage

Engage: *Where did everything in the universe come from? Has the universe always been the same?*

Students work in groups to **develop an initial claim** of **how the universe came into existence** and how that led to the formation of all the stars and planets.

Preparation

Student Grouping

None

Routines

☐ Rumors

Literacy Strategies

None

Materials

Handouts

☐ How did the universe form?

Lab Supplies

None

Other Resources

☐ Sticky notes
☐ [How Many Stars?](#)

Launch

1. Remind students that during the Driving Question Board launch, two categories of questions they had that were related to the probability of life elsewhere in the universe, were: *How many stars and planets are there in the universe?* and *Are other galaxies and solar systems similar to ours?*
2. Use these questions to transition to this 5E investigation. Tell students that you are going to show a video that will help them answer their questions about the number of stars and planets in the universe. Show the video, [How Many Stars?](#) (0-2:51 only).
3. After the video, have several students share what they took away from the video and / or reactions. Then share with students that scientists predict that each star has several planets that orbit around it.

4. Let them know that one way scientists approach investigating questions about whether stars and planets in the universe are similar to those in our solar system and galaxy, is by trying to understand how the universe formed. In other words, how the universe began and evolved into what it is today.

Surfacing Student Ideas

1. Distribute the handout, *How did the universe form?*. Tell students that you would like to hear what their ideas are about how all the matter in the universe came into existence and how that led to the formation of all the stars and planets. Have students individually respond to the following prompt:
 - a. How did all the stars and planets in the universe come into existence?
2. Have students work independently to brainstorm ideas. After students have time to independently brainstorm, ask them to choose the idea they feel most confident in and write it on a post-it.

Implementation Tip



This is the first time the routine **Rumors** appears in this unit. The goal of the **Rumors** routine is to have students exchange ideas while listening for similarities and differences in thinking. It's meant to be low stakes, so it is frequently used to surface initial student ideas about phenomena during an Engage phase. Please read the Earth & Space Science Course Guide for detailed steps about this routine.

3. Use the group learning routine **Rumors** to surface students' ideas. Students may have a range of ideas, including ideas grounded in religious beliefs. Be sure to acknowledge and honor all these ideas.
4. Let students know that for the purposes of this science course, they will have an opportunity to look at the evidence scientists have gathered to answer questions about the formation of the universe to develop an explanation from a scientific perspective. Convey to students that a scientific explanation about the formation of the universe is not necessarily in contradiction with religious or philosophical beliefs, and that in fact, many scientists are also religious and often see their scientific and religious ideas about the universe as different ideas that can coexist.

Explore

Investigating light from stars in other galaxies

Students **use a simulator** to **track the flow of** sound and light **energy waves between a source and an observer** in order to gather data that can help them explain **differences in absorption lines in spectra of light from other galaxies**.

Preparation

Student Grouping

☐ Pairs

Routines

☐ Rumors

Literacy Strategies

None

Materials

Handouts

☐ Investigating Light Spectra from Other Galaxies

Lab Supplies

None

Other Resources

- ☐ Sticky notes
- ☐ [Model 1: Doppler Effect](#)
- ☐ [Model 2: Piano](#)
- ☐ [Model 3: Doppler Effect](#)
- ☐ [Model 4: Electromagnetic Spectrum](#)
- ☐ [Siren Doppler Effect](#)

Launch

1. Begin by asking students to remind us what we are trying to figure out (the origin of the universe and the formation of all its stars and planets). Tell students that so far, they have a lot of ideas about where the universe came from; point to Rumors patterns if still visible in the classroom. Let them know that for the purposes of this unit's investigation, they will explore the evidence that the scientists have discovered and used to develop a theory for the origin of the universe that is widely accepted in the scientific community. Their job is to draw their own conclusions about what exactly the evidence tells

Classroom Supports

us.

2. Share with students that the first piece of evidence that led to the origin of the universe theory was the discovery of other galaxies in the universe. Explain that their light absorption spectra is like the spectra from stars within our galaxy that they analyzed and interpreted during the investigation of the sun and other stars during unit 1, but it comes from the light of stars in other galaxies.



Document student questions about the spectra somewhere in the class that is visible to all, so that these questions can be revisited as students conduct the investigation that follows.

Differentiation Point

-  Though students have engaged with star spectra before, they may struggle to understand how
-  light spectra form and are detected. If your classroom has access to spectroscopes, use this
-  opportunity to explore how different colors of light result in different light spectra when viewed through the spectroscopes.

3. Distribute the handout, *Investigating Light Spectra from Other Galaxies*. Have students complete the first page of the handout and facilitate a class discussion to surface student observations.

Look & Listen For



Students may generate ideas such as:

- Like stars within our galaxy, the absorption lines from other galaxies have the same absorption pattern as hydrogen and helium gas, except they are shifted to the right / red side of the spectrum.
- There seems to be a relationship between the distance to the galaxy and the amount the absorption lines are shifted to the right / red side of the spectrum.

4. Validate these observations and ask students the following questions:
 - If the stars and galaxies are so far away, how is it possible that their light arrived here on Earth?
 - What do you think might explain the relationship between the degree to which the absorption lines are shifted right and the distance of the galaxy?

Look & Listen For



Students may generate ideas such as:

- The light travels through space from stars and galaxies.
- Something might be happening to the light when it travels here and it happens more to light from more distant galaxies because that light travels farther.

5. Ask students what they think the class should investigate in order to explain the relationship between the degree to which the absorption lines are shifted right and the distance of the galaxy. Listen for students to say that the class should study how waves travel.
6. Let them know that they will start with some scenarios here on Earth that are related, the first scenario is related to sound waves, which behave very similarly to light waves.

Investigation: Sound and Light Energy Wave Travel

1. Launch students into conducting an investigation of how sound and energy waves move between the source they are emitted from and an observer using models 1 and 2, which model the movement and properties of sound waves between a source and an observer.

Conferring Prompts



Confer with students as they work in collaborative groups to collect data and complete the See-Think-Wonder chart.

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

Model 1

- When making observations from Model 1 what do you notice about the sound?
- What else do you notice in Model 1 that might explain the changes in the sound?
- Do you notice any differences between the sound waves as they reach the microphone when the source is moving toward the microphone and the sound waves as they reach the microphone when the source is moving away from the microphone? Why do you think this is happening?
- How does this relate to the siren sound you heard during the engage phase?

Model 2

- How do the wave characteristics change as the pitch gets higher?

Routine



The **Domino Discover** group learning routine is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Unit 1 Teacher Guide for support with this routine.

Integrating Three Dimensions



Throughout this phase, students are engaging with **CCC #5 - Energy and Matter**. It is important that students

- How do the wave characteristics change as the pitch gets lower?
- How does this relate to the siren sound you heard during the engage phase?

observe that light and other forms of energy are not destroyed, but change as they move between places, objects, or systems.

2. Have students work in lab groups to record their ideas about the data they collected from models 1 and 2 in the **See-Think-Wonder** chart.
3. Elicit student ideas through the group learning routine **Domino Discover**. Record the ideas coming up in the class on a chart paper, or on the board.

Look & Listen For



These are ideas that students need to surface from the data in order to be successful with the Explain phase:

Model 1

- The sound changes as the source moves
- The sound is heard more frequently when the source is moving toward the microphone (observer)
- The sound is heard less frequently when the source is moving away from the microphone (observer)
- The sound waves are closer together in the direction that the drum is moving
- The sound waves are further apart behind the source as it moves
- I think that the microphone is picking up the sound more frequently when the source is moving toward it because the waves are bunched up and reaching it more frequently
- I think that the microphone is picking up the sound less frequently when the source is moving away from it because the waves are more spread apart and reaching it less frequently
- I think this is what was happening when the siren was moving toward and away from the observer

Model 2

- Playing different keyboard notes produces sounds with different pitches
- High frequency (low wavelength) is associated with high pitch sounds and low frequency (high wavelength) is associated with low pitch sounds
- As the wavelength of sound waves increases, the frequency decreases

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.
5. Launch students into working with Models 3 and 4, and answering the corresponding questions.

Conferring Prompts



Confer with students as they work in collaborative groups to collect data and complete the See-Think-Wonder chart.

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

Model 3

- How do the light waves change depending on the movement of the galaxy in the model?
- How do your observations of lightwaves relate to what you learned about sound waves?
- What colors does the model associate with the changes in wavelength of the light waves?

Model 4

- What is the relationship between frequency of light waves and the color an observer perceives?
- How does that relationship relate to the changes in color seen in Model 3?

6. Have students work in lab groups to record their ideas about the data in the **See-Think-Wonder** chart.
7. Elicit student ideas through the group learning routine **Domino Discover**. Record the ideas coming up in the class on a chart paper, or on the board.

Look & Listen For



These are ideas that students need to surface from the data in order to be successful with the Explain phase:

Models 3 and 4

- When the source of light and the observer are moving away from each other the light waves are perceived as having a lower frequency (longer wavelength). The observer perceives a change of light wave color toward the red side of the visible light spectrum
- When the source of light and the observer are moving toward each other the light waves are perceived as having a higher frequency (shorter wavelength). The observer perceives a change of light wave color toward the blue side of the visible light spectrum

8. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Explain

Explaining redshift and making inferences about the universe in the past

Students use their understanding of the **flow of** sound and light **energy waves between a source and an observer** to **develop an explanation** for the **redshift** noticed when observing the **spectra of other galaxies**. Students then **develop a model** of the early universe by making inferences based on the fact that it has been expanding.

Preparation

Student Grouping

☐ Table Groups

Routines

☐ Read-Generate-Sort-Solve

Literacy Strategies

None

Materials

Handouts

- ☐ What does the light spectra of galaxies tell us?
- ☐ Summary Task

Lab Supplies

None

Other Resources

Constructing an Explanation for Red Shift in Galaxy Light Spectra Data

1. Remind students that as part of their investigation to understand the scientific theory about the origin of the formation of the universe (big bang theory) they are trying to understand and explain the first piece of evidence that led scientists to their theory, the light spectra from other galaxies.
2. Distribute the handout, *What does the light spectra of galaxies tell us?*. Have students use what they learned from the Explore phase to complete predictions about what changes in light waves would be perceived as a result of different observer and source scenarios.

Implementation Tip



Many students need support to build a habit of generating many ideas before selecting the best one. The **Read-Generate-Sort-Solve** routine supports students in articulating their thinking and making it transparent, before considering solutions. Please read the Earth & Space Science Course Guide for detailed steps about this routine.

3. Facilitate student collaboration in constructing an explanation for the galaxy light spectra data, using the Group Learning Routine, Read-Generate-Sort-Solve.
4. Confer with students as they develop their explanation.

Look & Listen For



While students are engaged in Read-Generate-Sort-Solve, circulate and listen for these ideas:

- The galaxy light spectra data appears to have the absorption signature of hydrogen and helium, but shifted to the red side of the spectrum
- The galaxy light spectra data shows that the further a galaxy is the more the absorption signature of hydrogen and helium is shifted to the red side of the spectrum
- Based on our observations from model 3 from the Explore phase, I think this means the universe is expanding, causing galaxies to move further away from us.

Class Consensus Discussion

1. Orient the class to the purpose and the format of the group learning routine **Class Consensus**

Discussion. You may say something like this:

"We have a lot of different ideas circulating in the room right now, and they are in the form of different scientific explanations. It is really important for us to get to some agreement on how we represent what we know about why there is a shift in the light spectra data of other galaxies when compared to the spectra of stars in our galaxy, so that we have a shared understanding to build upon as we move ahead. In order to do this we are going to do something called a **Class Consensus Discussion**. First I will select a few different groups to share their ideas. Then, we will let each group share their claim and discuss what we can agree to as a class." You may decide to walk students through the entire poster, or take them through the steps as you facilitate it.

2. Select two or three groups' claims to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. It provides an opportunity for groups to share out around their sensemaking and for other groups to list, summarize, and ask questions after each share.

how the Sun releases energy. The decision about which claims to share with the class should be based on both the ideas circulating in the classroom *and* the goals of this part of the 5E sequence. Look ahead to the “Take Time for these Key Points” below to help you determine which groups you want to share out, so that those key points are surfaced.

3. Ask the first group to share their claim. You can do this by:
 - Projecting using a document camera; OR
 - Copying the claims to be shared and passing them out to the class; OR
 - Taking a picture of each model and projecting them as slides.

Class Consensus Discussion Steps

- we select a few different groups' ideas.
- The first group shares out their work.
- One person repeats or reiterates what the first group shared.
- Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

- Everyone confers in table groups.
- Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

4. Proceed through the steps in the Consensus Discussion Steps.
5. Before table groups confer, prompt them to consider the role of models in figuring out which claim is best supported. These prompts connect to high school elements of CCC #4 - Systems and Systems Models and SEP #2 - Developing and Using Models. Some prompts you might provide are:
 - a. What did we observe in the models 1 and 3 that was helpful in explaining the shift in spectra from different galaxies? Why?
 - b. How did the models serve as evidence to support your explanation?
 - c. Was the energy in the models ever destroyed? What happened to it?
 - d. Where do you think the energy in the models came from?
 - e. Why was it useful to use four different models during this investigation? What was most useful about each? What limitations did they each have?

This is the first time doing such a discussion in this unit, so focus more on the *steps* and the process. In future parts of this unit, you will use this format to do more in-depth discussions and consensus building. For now, it's just about establishing a common understanding of the format.

Classroom Supports



Post the steps to the Class Consensus Discussion in the room, as a reference you can return to in future lessons.

Integrating Three Dimensions



The prompts in the Class Consensus Discussion are in support of students' consideration of the foregrounded SEP and CCC. The first two questions is meant to surface the idea that models can be used as evidence, an important high school element of **SEP #6 - Constructing Explanations and Designing Solutions**. The next set of prompts surfaces the idea that these models are showing the movement of energy, and that they demonstrate that energy is never destroyed, an important

Implementation Tip



We recommend you do NOT just let students read their claims aloud. Some classmates will need to see/read the claim to be able to follow up. A discussion with no visual component can leave out a number of students.

6. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following **key points**:

- The galaxy light spectra data appears to have the absorption signature of hydrogen and helium, but shifted to the red side of the spectrum
- The galaxy light spectra data shows that the further a galaxy is the more the absorption signature of hydrogen and helium is shifted to the red side of the spectrum
- In the simulations waves (sound or light) are perceived as longer by an observer when the waves are moving away, and perceived as shorter by an observer when the waves are moving toward the observer.
- Longer wavelengths are seen in the absorption lines of galaxies appearing further on the red side of the spectra as we look at galaxies further and further away, this means these galaxies must be moving away from us - the universe is expanding.
- The redshift observed in the spectra of galaxies is explained by the expansion of the universe.

Note: The class has not yet explained the origin of the universe, but that is coming up!

7. Display the categories of ideas about how all the matter in the universe came into existence that students generated during the Engage phase. Ask students if there are ideas on the class list that can be:
 - a. eliminated based on our investigation of galaxy spectra data;
 - b. changed based on our investigation of galaxy spectra data;
 - c. added based on our investigation of galaxy spectra data.
8. Modify the list of student ideas about the red shift in galaxy light spectra data based on student responses.

part of CCC #5 - Energy and Matter.

Access for Multilingual Learners



Rather than assigning a list of vocabulary words—a technique that rarely works for learning new vocabulary—this activity allows language learners to learn vocabulary from context, which may be particularly helpful for **transitioning** language learners, who already have some mastery of language.

9. Return to student questions from the start of the 5E (the Engage), in order to bring up lingering issues not yet resolved, and new issues that have come up, such as:
 - Where did all the matter in the universe come from?
 - Has the universe always been the same? What was it like in the past?
 - Is it probable that there is life elsewhere in the universe?
10. Point out that so far the class has only made an evidence-based claim that the universe has been expanding. Let students know that they will have the opportunity to analyze additional evidence about the origin of the universe generated by models.

Summary

1. Students individually complete *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to circle back to the ideas in this text in the coming parts of the 5E lesson.

Implementation Tip



This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas:

1) understanding how they are **using the three dimensions to make sense of a phenomenon**; 2) ideas about how they and their peers are **building knowledge together**; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Elaborate

Exploring additional evidence for the Big Bang theory and constructing an explanation for the origin of the universe

Students hypothesize and read a text about what the **temperature and pressure** of the **early universe** must have been like and learn about the **law of conservation of mass and energy**. Students use what they learn about the early universe and **conservation of mass and energy** to articulate why **cosmic background microwave radiation** and **Hydrogen and Helium ratios** in the universe **serve as additional evidence for their final explanatory models**.

Preparation

Student Grouping

☐ Pairs

Routines

None

Literacy Strategies

None

Materials

Handouts

☐ How did it all start?

Lab Supplies

None

Other Resources

- ☐ Balloons
- ☐ Permanent markers
- ☐ [Murmur of a Bang](#)
- ☐ [Origins of the Universe 101](#)

If the universe is expanding, what did it look like in the past?

1. Pose the guiding question:
If the universe is expanding, what can we conclude about what it was like over 13 billion years ago?
2. Have students carry out the balloon modeling activity in Part 1 of *Could there be other Earth-like planets?* to make inferences about what the universe must have been like in the past. Use probing questions to support students in arriving at the conclusion that if the universe is expanding, then it must have been much smaller and dense early in its history.

Look & Listen For



While students are engaged in modeling activity circulate and listen for these ideas:

- If the universe is expanding, then it must have been smaller in the past and the galaxies must have been closer together
- The further you go back in time, the smaller the universe was, meaning the galaxies were closer together
- At the beginning of time, the universe must have been clumped together

How can we test our claim of a small, dense, and hot early universe?

1. Direct students to begin Part 2 of their handout to extrapolate what the early universe would have looked like and how it might have changed as it expanded.
2. After students have done questions 1-3, engage the class in a discussion of their conclusions. Once the class has come to consensus around the idea that the universe was likely very hot, bright, and dense, let students know that these are the same claims that many scientists made based on galaxy light spectra data, and they called this theory, the Big Bang theory.
3. Have students turn back to finish reading the text in Part 2 of their handouts.
4. For added context, show students the video: [Origins of the Universe 101](#) , up to 1:10
5. Share with students that scientists kept testing the Big Bang theory by thinking about the conditions of a compact early universe and what evidence of those conditions they should be able to find today. Let them know that they will explore this further in the next activity, and that it will be important to consider what they have learned about the behavior of energy within a system as they continue to investigate.
6. As a class, read the beginning of Part 3, in which students are introduced to the way scientists use computational models to predict what the universe used to look like and how that would impact the observed universe today.
7. Tell students that, in order to understand how conditions of the universe changed over time, we need to understand some fundamental properties of the universe relating to the light that we already learned about.

8. Ask students to think about the light and sound waves from the Light Spectra of Other Galaxies Investigation. Was the energy in those models ever destroyed?
9. Ask students to think about energy sources they have learned about before. Prompt them to think about where the energy comes from in their cell phones or other battery-powered devices; and to think about the energy emitted from stars in Unit 1. Ask them to decide if they think new energy can be created.
10. Ask students to recall what they learned during unit 1 in the Star Life Cycle 5E about conservation of matter. When students have surfaced the idea that matter is not created or destroyed, build upon that by sharing with students that scientists have also proven over and over that this is also true about energy within all systems.

Look & Listen For



Pause the discussion and ask for clarification, particularly of the following **key points**:

- Energy cannot be created or destroyed, but it can move and change
- Matter cannot be created or destroyed, but it can move and change

11. Tell students that they are now going to do what scientists do and test their claim about where all the stars and planets in the universe came from by making predictions about what the universe should look like if the big bang theory is correct and then comparing their predictions to observed data from the universe today. Have students work in pairs to respond to steps 1-6 in Part 3 of their handouts in order to form predictions. Students will use a balloon to support them in visualizing the changes that will occur as the balloon universe expands. For New York State teachers, the spectrum diagram in this section comes from page 3 of the ESSRT.
12. When students are finished with Part 3, have pairs turn to Part 4, comparing their predictions to observations of the Universe today.
13. Confer with students as they respond to the prompts and carry out the modeling activity.
14. Have students independently link evidence we find today to the claim of the Big Bang by completing the *Bringing all the evidence together* section of the student handout.

Class Consensus Discussion

1. Orient the class to the purpose and the format of the group learning routine **Class Consensus**

Discussion. You may say something like this:

"We have a lot of different ideas circulating in the room right now, and they are in the form of different scientific explanations. It is really important for us to get to some agreement on how we represent what we know about why there is a shift in the light spectra data of other galaxies when compared to the spectra of stars in our galaxy, so that we have a shared understanding to build upon as we move ahead. In order to do this we are going to do something called a **Class Consensus Discussion**. First I will select a few different groups to share their ideas. Then, we will let each group share their claim and discuss what we can agree to as a class."

You may decide to walk students through the entire poster, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

- we select a few different groups' ideas.
- The first group shares out their work.
- One person repeats or reiterates what the first group shared.
- Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

- Everyone confers in table groups.
- Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

Classroom Supports



Post the steps to the Class Consensus Discussion in the room, as a reference you can return to in future lessons.

Integrating Three Dimensions



The prompt about the law of conservation of energy and matter in the Class Consensus Discussion is in support of students' consideration of the foregrounded CCC. Here students have an opportunity to think about how knowing that all energy and matter in the universe is conserved is useful when making sense of a phenomena, including the formation of the universe. This relates to the idea that **energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems**, an important element of **CCC #5 Energy and Matter** at the high school level.

2. Select two or three groups' claims to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of how the evidence available to us supports the Big Bang Hypothesis. The decision about which claims to share with the class should be based on both the ideas circulating in the classroom *and* the goals of this part of the 5E sequence. Look ahead to the "Take Time for these Key Points" below to help you determine which groups you want to share out, so that those key points are surfaced.
3. Ask the first group to share their claim. You can do this by:
 - Projecting using a document camera; OR
 - Copying the claims to be shared and passing them out to the class; OR
 - Taking a picture of each model and projecting them as slides.
4. Proceed through the steps in the Consensus Discussion Steps.

5. Before table groups confer, prompt them to consider the role of the law of conservation of energy and matter in figuring out which claim is best supported. Some prompts you might provide are:
 - a. How was considering the law of conservation of energy and matter helpful in connecting the different pieces of evidence to the claims?
6. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following **key points**:

- The law of conservation of matter and energy tells us that the hydrogen, helium and energy that existed soon after the universe began should still be around today, but perhaps in a different form
- The balloon model tells us that nothing would happen to the hydrogen:helium ratio as a result of universe expansion
- The balloon model tells us that the visible light energy waves would elongate, and therefore be a longer wavelength, as a result of universe expansion

7. Display the categories of ideas about how the Sun works that students generated during the Engage phase. Ask students if there are ideas on the class list that can be:
 - a. eliminated based on our investigation of the origin of the universe;
 - b. changed based on our investigation of the origin of the universe;
 - c. added based on our investigation of the origin of the universe.
8. Return to student questions from the start of the 5E (the Engage), in order to bring up lingering issues not yet resolved, and new issues that have come up, such as:
 - Is it probable that there is life elsewhere in the universe?
9. Use this question to transition to the Evaluate phase where students will use models to make predictions about whether life exists elsewhere in the universe.

Evaluate

Is it probable that there is life elsewhere in the universe?

Students **use models** for **how the origin of the universe led to the formation of solar systems** to **make predictions** about whether life exists on other planets.

Preparation

Student Grouping

- ☐ Pairs
- ☐ Individual
- ☐ Small groups of 3-4 students

Routines

None

Literacy Strategies

None

Materials

Handouts

- ☐ Could there be other Earth-like planets?
- ☐ Revisiting the Performance Task: Origin of the Universe 5E

Lab Supplies

None

Other Resources

- ☐ Chart paper
- ☐ Sticky notes
- ☐ Markers
- ☐ [How Many Stars?](#)

Revisit the Performance Task

1. Remind students that we are hoping to come up with an answer to the question about if there is likely life on other planets, and that part of that answer would come from knowledge of if there are other planets like ours in the universe.
2. Remind students of the video [How Many Stars?](#)
3. Provide students with the handout *Could there be other Earth-like planets?*, and have students work in

pairs to answer the prompts

4. Then, have students independently respond to the prompts in the handout *Revisiting the Performance Task: Origin of the Universe 5E*. Confer with students while they are working.

Conferring Prompts



Confer with students as they work to develop their models. Prompt students to return to the class wide scientific argument characteristics, posted in the room.

Suggested conferring questions:

- What evidence did you generate in this 5E sequence?
- Where did the evidence come from?
- How well does that evidence support the claim?
- What ideas or contradictory evidence weaken the claim?

5. Ask students to work in table groups to collaboratively develop a group model. These should go onto new pieces of chart paper.
6. Facilitate student critique of one another's models through the Group Learning Routine **Idea Carousel**. Have students annotate other groups' models using post-its. Each post it should have a symbol and comment from each of the following categories:
 - a. ✓ Write a check on sticky notes with comments about ideas represented in the model that resonate.
 - b. + Write a plus symbol on sticky notes with comments about ideas that should be added to the model.
 - c. ? Write a question mark on sticky notes with comments about ideas that you don't think are relevant to the model.
 - d. Δ Write a delta symbol on sticky notes with comments about suggestions for how to clarify an idea or represent it more clearly.

Look & Listen For



While students are engaged in the Idea Carousel, listen for the following ideas. Where needed, discuss with groups what is coming up in their models, to ensure these points emerge in the classroom.

- The universe started as all one incredibly hot and small mass, then suddenly expanded in all directions.

- The processes that formed our galaxy and the solar systems within it, were taking place everywhere in the universe, so all those galaxies and solar systems must have many characteristics that are similar to the characteristics of our galaxy and solar system.
- The universe is bigger than we can even imagine.
- The number of chances there are for life to appear / exist across our universe are extremely high which makes it seem probable that life exists elsewhere.

7. At the end of the Idea Carousel, it may be the case that some specific ideas have surfaced in some groups but not others. If that is the case, prompt those groups to share with the class. A share-out from every group, however, is not needed at this point.
8. Allow groups to use peer feedback and ideas shared by other groups to go back and revise their model.

Revisit the Driving Question Board

1. Use the **Driving Question Board Routine** to discuss which of the class's questions have been answered.
2. Have students identify which categories or questions they have not figured out yet. Prompt students to share out these questions, and document new questions that arise based on what they have been learning.
3. Add new questions to the Driving Question Board.
4. Ask students if they think that it is likely that there are other Earth-like planets on which intelligent life could have evolved. Ask them if they think extinction events could have impacted intelligent societies that may have existed in the past. Ask them if they think our own society could go extinct before we make contact with other societies.
5. Use these questions to transition to the next investigation about the stability of the solar system

Standards in Origin of the Universe 5E

Performance Expectations

HS-ESS1-2

Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).

Assessment Boundary: None

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Using Mathematics and Computational Thinking

- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. SEP5(2)

Constructing Explanations and Designing Solutions

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. SEP6(2)
- Apply scientific reasoning, theory, and/or models to link evidence to the claims to

ESS1.A The Universe and Its Stars

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. ESS1.A(2)
- The big bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. ESS1.A(3)
- Other than the hydrogen and helium formed at the time of the big bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy.

Energy and Matter

- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. CCC5(3)

Science and Engineering Practices**Disciplinary Core Ideas****Crosscutting Concepts**

assess the extent to which the reasoning and data support the explanation or conclusion. SEP6(4)

Heavier elements are produced when certain massive stars achieve a supernova stage and explode. ESS1.A(4)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Using Mathematics and Computational Thinking		<i>Investigating Light Spectra from Other Galaxies</i>	<i>Summary Task</i>		
Constructing Explanations and Designing Solutions			<i>What does the light spectra of galaxies tell us?</i>	<i>How did it all start?</i>	<i>Revisiting the Performance Task: Origin of the Universe 5E</i>
ESS1.A The Universe and Its Stars	<i>How did the universe form?</i>	<i>Investigating Light Spectra from Other Galaxies</i>	<i>What does the light spectra of galaxies tell us?</i>	<i>How did it all start?</i>	<i>Revisiting the Performance Task: Origin of the Universe 5E</i>
Energy and Matter		<i>Investigating Light Spectra from Other Galaxies</i>	<i>What does the light spectra of galaxies tell us?</i> <i>Summary Task</i>	<i>How did it all start?</i>	<i>Revisiting the Performance Task: Origin of the Universe 5E</i>

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP1 MP2	MP2	MP2	MP1 MP2

	Engage	Explore	Explain	Elaborate	Evaluate
		MP4			
ELA/Literacy		RST.9-10.3 RST.9-10.5 SL.9-10.1 SL.9-10.4	RST.9-10.1 WHST.9-10.2 SL.9-10.1 SL.9-10.4	RST.9-10.1 RST.9-10.2 WHST.9-10.8	RST.9-10.1 WHST.9-10.2 WHST.9-10.4 WHST.9-10.10 SL.9-10.4