LESSON 15: What is beyond the stars?

PREVIOUS LESSON *We worked in small groups to Obtain, Evaluate, and Communicate Information about exoplanets from multiple sources. We created podcasts to share with the class that described the exoplanet, where this planet is compared to Earth, how the planet was discovered, and created an argument about if this planet could potentially support life.*

THIS LESSON

INVESTIGATION

2 days

We make noticings and wonderings from a photo taken by the Hubble telescope of the space between stars, showing what we think might be more stars or maybe something else entirely. We learn that these are galaxies, islands of stars much like the ones we see in the sky. We watch the movie Powers of Ten to visualize how scientists model the universe at various scales. We notice that the universe appears to be organized into systems held together by gravity, separated by vast emptiness.

NEXT LESSON *We will make a classroom consensus model at various scales of how gravity organizes the universe and use this model to help quantify the number of civilizations that might be out there, ready to communicate with us. We will return to the DQB to take stock of how far we have come in this unit and then reflect on the unit and Earth's place in the universe.*

BUILDING TOWARD NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

WHAT STUDENTS WILL DO

15.A Obtain and synthesize information across multiple sources about the organization of space systems in our universe from the human scale to the galactic scale.

15.B Develop a model of the universe that shows how gravity forces bound space systems at multiple scales.

15.C Compare and critique two arguments emphasizing the same evidence (images of galaxies) about the organization of systems in space.

WHAT STUDENTS WILL FIGURE OUT

- Earth orbits the Sun, making the Sun and Earth part of our solar system, along with other planets, asteroids, comets, and so forth.
- Moons orbit planets, creating subsystems of the solar system.
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.
- Gravity appears to determine this organization because in the places where there is stuff, that stuff is held together by gravity.

Lesson 15 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**LOOKING BEYOND THE STARS** Recall that we wanted to see what was beyond the stars with a telescope. Notice and wonder about the Hubble Deep Field photo.	A-B	*Hubble ultra-deep field*
2	10 min	**THE GREAT DEBATE IN ASTRONOMY** Introduce the Shapley-Curtis Great Debate in astronomy about whether galaxies are clouds of dust and gas or islands of stars.	C-D	*The Great Debate*
3	15 min	**WATCH POWERS OF TEN** Watch the movie *Powers of Ten* and respond to a series of Turn and Talk prompts.	E-H	*Powers of Ten Part 1 Transcript*, https://www.youtube.com/watch?v=0fKBhvDjuy0
4	15 min	**BUILDING UNDERSTANDINGS DISCUSSION** Hold a Building Understandings Discussion to develop the idea that Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.	I-J	*The Great Debate*, chart paper, markers
				End of day 1
5	10 min	**MODELING THE UNIVERSE IN GROUPS** Organize all the different systems and subsystems where we might find life so that we can figure out what we know in order to make our estimate.	K-L	*Powers of Ten Part 1 Transcript*, chart paper, markers, Objects that Interact through Gravity poster
6	13 min	**NAVIGATION** Consider how this new perspective affects the possibility of extraterrestrial life.	P-Q	
				End of day 2

Lesson 15 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Hubble ultra-deep field* • *The Great Debate* • *Powers of Ten Part 1 Transcript* • optional: https://tinyurl.com/massiveblackholes	• chart paper • markers	• https://www.youtube.com/watch?v=0fKBhvDjuy0 • chart paper • markers • Objects that Interact through Gravity poster • chart paper titled "Classroom Consensus Model for the Universe"

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test https://www.youtube.com/watch?v=0fKBhvDjuy0 . Make sure you can hear the audio.

Prepare chart paper for posters. The posters you will make in this lesson are as follows:

- Objects that Interact through Gravity
- Classroom Consensus Model for the Universe

Be sure you have materials ready to add the following words to the Word Wall and/or a personal glossary: *galaxy* and *universe*. Do not post these words on the wall until after your class has developed a shared understanding of their meaning.

Lesson 15 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will develop the last element of the DCIs associated with MS-ESS1-2: Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

Where We Are NOT Going

The existence of galaxy clusters held together by gravity is as far as students will go into cosmology in middle school. We will not develop ideas about the large-scale structure of the universe, the cosmic microwave background, the Big Bang, or nucleogenesis.

LEARNING PLAN for LESSON 15

1 · LOOKING BEYOND THE STARS

5 min

MATERIALS: science notebook, *Hubble ultra-deep field*

Briefly orient students to where we are. Project **slide A**. Ask, *What were we wondering about at the end of the previous lesson? Look back in your notebook.* Look for students to suggest that we were wondering what was beyond the stars.

Notice and wonder about the blobs in Hubble Deep Field. Say, *We were wondering if we could use a telescope to look beyond the stars. Scientists have wondered the same thing and have kept designing more powerful telescopes to try to find out what else is beyond them. I found one source of photos taken using one of the most powerful telescopes, the Hubble Space Telescope. The photo you will see on the next slide was what they saw when they pointed the telescope at a space in between the stars, a tiny patch of the sky that looks to us to be about the size of the head of a pin held at arm's length. And they zoomed in and took a photo.*

Display **slide B**, which shows the Hubble Deep Field. You could also hand out *Hubble ultra-deep field* if you can print in high-resolution color.

Briefly elicit student noticings and wonderings about the photo. Look for students to suggest that the images are stars or star systems. Some students might suggest that they are galaxies. Ask those students, *What do you mean by "galaxy"? Can you explain that further?*

2 · THE GREAT DEBATE IN ASTRONOMY

10 min

MATERIALS: *The Great Debate*

Introduce the Great Debate. Say, *We have a couple of ideas about what these blobs in the photo might be. Scientists have argued over what was beyond the stars for a long time as well. Some scientists thought that what we saw in the sky was everything in the universe, like an island made of stars in a vast sea of nothingness. Other scientists thought that if we live inside an island of stars, there must be other islands of stars out there.*

Project **slide C** and pass out *The Great Debate*.

Give students three minutes to read on their own and then ask one or two students to read aloud the text on the handout. Then elicit student ideas about the prompts at the bottom of the handout:

1. How did Shapley's model for the universe explain the evidence he had at the time? How did Curtis's model for the universe explain that same evidence?
2. What would you do to resolve this debate? What kind of data would you collect, and how?

ASSESSMENT OPPORTUNITY

Building Towards: 15.C Compare and critique two arguments emphasizing the same evidence (images of galaxies) about the organization of systems in space.

What to look/listen for: Look for students to notice that both models explain the evidence in different ways. Also look for students to seek out data related to how far away things are in space.
What to do: Highlight student ideas about using telescopes to look more closely or measuring the distance to stars or blobs somehow.

Project **slide D**. Say, *In the 1920s, scientists used telescopes to confirm that there are islands of stars out there. They named the islands of stars galaxies. This allowed them to build a model for the known universe. I have a visual representation of that model here. It's a movie called* Powers of Ten.

ALTERNATE ACTIVITY	**Extension Opportunity** If you have students who are interested in citizen science and finding out more about galaxies, you can suggest that they become involved in Galaxy Zoo, which is a crowdsourced astronomy project that invites people to assist in the classification of large numbers of galaxies. https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/

3 · WATCH POWERS OF TEN

15 min

MATERIALS: *Powers of Ten Part 1 Transcript*, https://www.youtube.com/watch?v=0fKBhvDjuy0

Review the mathematical concept of powers of ten. Present **slide E**. Say, *The movie we are about to watch uses a math idea to help zoom out and zoom in to different scales by referring to something called powers of ten. Powers of ten are numbers that can be formed by multiplying the number ten times itself. The powers of ten are often represented by the number ten with an exponent. The exponent tells you how many times the ten is multiplied by itself to create the power of ten.*

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH	In the CCMS students should have already had prior experience in grade 5 with using whole-number exponents to denote powers of 10 [CCSS.MATH.CONTENT.5.NBT.A.2]. If students don't readily recall those experiences you could explain patterns in the number of zeros of the product when multiplying a number by powers of 10 and explain patterns in the placement of the decimal point when a number is multiplied or divided by a power of 10. If you feel like your students need more explanation, consider the following kinesthetic activity: use a hula hoop to represent a meter and then form a circle of students ten meters across around the hula hoop to demonstrate one power of ten.

Organize students for the Turn and Talk activity. Organize students in groups of 4 to watch the movie. Assign each student in the group a number. For each Turn and Talk during the movie, use the combinations in the following table to partner students so that they don't talk with the same person each time.

Watch *Powers of Ten*. Pass out *Powers of Ten Part 1 Transcript*. Begin playing https://www.youtube.com/watch?v=0fKBhvDjuy0 . You will watch only the first five minutes in this unit. Pause at the following places to give students a chance to discuss the prompts with their partner. Give 1.5 minutes to discuss each question.

Time stamp	Slide	Turn and talk prompt	Partner pairs
3:00	**Slide F**	*The narrator points out that the cloud of comets we call the Oort Cloud "completes the solar system." Why do you think scientists choose to make these comets the boundary of our solar system? Why not end the solar system at Neptune or extend it out to include other stars?*	1 & 2; 3 & 4
4:15	**Slide G**	*We have just zoomed out enough to see the Milky Way galaxy. Does the shape of the galaxy remind you of any other systems that we have studied so far? If so, how? What do you think that means about how the parts of the Milky Way system interact?*	1 & 4; 2 & 3
4:38	**Slide H**	*The narrator said that "glowing points are no longer single stars but whole galaxies of stars seen as one." What does this mean, and how can this help us understand the Hubble Deep Field photo?*	1 & 3; 2 & 4

4 · BUILDING UNDERSTANDINGS DISCUSSION

15 min

MATERIALS: *The Great Debate*, chart paper, markers

Discuss each of the Turn and Talk prompts as a class. Project **slide I**, which lists all the prompts.

Suggested prompt	Sample student response
The narrator points out that the cloud of comets we call the Oort Cloud "completes the solar system." Why do you think scientists choose to make these comets the boundary of our solar system? Why not end the solar system at Neptune or extend it out to include other stars?	*All of the things in the solar system interact with each other because of gravity.*
We have just zoomed out enough to see the Milky Way galaxy. Does the shape of the galaxy remind you of any other systems that we have studied so far? If so, how? What do you think that means about how the parts of the Milky Way system interact?	*The galaxy is a flat disk, like our solar system. Maybe the parts are also orbiting something at the center of the galaxy.*
The narrator said that "glowing points are no longer single stars but whole galaxies of stars seen as one." What does this mean, and how can this help us understand the Hubble Deep Field photo?	*We are so far away that the stars in the galaxy look like one point of light. The splotches in the Hubble Deep Field are probably galaxies full of stars.*

ASSESSMENT OPPORTUNITY

Building Towards: 15.A Obtain and synthesize information across multiple sources about the organization of space systems in our universe from the human scale to the galactic scale.

What look/listen for: Use this discussion as an opportunity to formatively assess students' ideas and respond in the moment to push student thinking.

What to do: Use probing questions to clarify student ideas and encourage students to use gestures and drawings to express themselves. Here are some examples:

- I heard you say that gravity makes things go down, is that accurate?
- What do you mean when you say the galaxy is a circle? Can you show me with your hands or sketch a picture on the board?
- I heard you say that the stars are very far away. How does that affect what we see when we look at a galaxy?

Agree on a definition for *galaxy*. Say, *We decided that each of the objects in the Hubble Deep Field photo were galaxies. How should we define the word* galaxy*?* Accept all student ideas. Highlight ideas about galaxies having a lot of stars and about gravity. If gravity does not come up naturally, ask students what they think keeps all the stars together instead of flying into space.

Summarize by saying, *A galaxy is a large collection of stars held together by gravity. Just like how the planets orbit around our Sun, defining the boundaries of our solar system, all the stars in the Milky Way galaxy orbit around its center, defining the boundaries of the galaxy.*

Agree on a definition for *universe*. Then say, *I have also heard a couple of people use the word* universe *over the past few weeks. What do we mean when we say* universe*?* Look for students to say that "universe" describes everything we know about in space. Some students might mention the possibility of other universes.

Summarize by saying, *The universe is all of space, all of the matter and all the energy in it. This includes the parts we can see and the parts we can't.*

Take the time to add these words (*galaxy* and *universe*) to the Word Wall or have students add it to their personal glossaries.

Connect back to the Shapley-Curtis debate. Present **slide J** and direct students' attention back to *The Great Debate*.

Suggested prompt	Sample student response
Who had the correct model, Shapley or Curtis?	*Curtis! There are many galaxies.*
Was Curtis totally right? Or was there something Shapley had right in his model?	*We are not in the center of the Milky Way, we are on the edge, like in Shapley's model.*
Both Shapley and Curtis included gravity in their models. Why is gravity important for explaining the structure of the universe?	*Because it keeps the systems together and determines how everything moves in orbits.*
How does gravity keep systems together? I thought gravity was a force between two objects. What are the objects that are interacting through gravity?	*The Moon and Earth* *Earth and the Sun* *The Sun and the Milky Way galaxy* *The Milky Way and a cluster of galaxies*

Make a public record of these ideas. Write down students' ideas about objects that are interacting through gravity on chart paper titled "Objects that Interact through Gravity".

KEY IDEAS

Purpose of the discussion: To establish the important parts and interactions in a dynamic model of the universe that matches recent data.

Listen for these ideas:

- Earth orbits the Sun, making the Sun and Earth part of our solar system, along with other planets, asteroids, comets, and so forth.
- Moons orbit planets, creating subsystems of the solar system.
- The entire solar system orbits the center of the Milky Way, which is a galaxy.
- Gravity appears to determine this organization because orbits are caused by interactions between two objects due to gravity force pairs.

End of day 1

5 · MODELING THE UNIVERSE IN GROUPS

10 min

MATERIALS: *Powers of Ten Part 1 Transcript*, chart paper, markers, Objects that Interact through Gravity poster

Motivate the modeling. Present **slide K**. Read the prompt on the slide: *At the end of the movie we watched last time, the narrator says that "This lonely scene, the galaxies like dust, is what most of space looks like. This emptiness is normal. The richness of our own neighbourhood is the exception." We now know that other stars have rich systems as well, with planets and probably moons and other objects, but that there is a lot of empty space in between all these parts and systems. Why is it that we find things in space clumped together, with so much emptiness in between, instead of spread out evenly? Can we make a model of the universe that shows and explains this structure?*

Create final models of the universe. Present **slide L**. Remind students that they have for reference *Powers of Ten Part 1 Transcript* with photos from https://www.youtube.com/watch?v=0fKBhvDjuy0 and the Objects that Interact through Gravity poster.

Break students into groups of 3-4 and have each group develop a model at multiple scales for the universe and draw their representation on chart paper to create their poster. Move around the room to make sure that students are using zooming to model multiple scales, including a scale where we can see multiple galaxies. Ask students to hang their posters along the walls when they are finished.

ASSESSMENT OPPORTUNITY

Building towards: 15.B Develop a model of the universe that shows how gravity forces bound space systems at multiple scales.

What to look/listen for: Look for students to include multiple scales and to be able to articulate the reasons why their model looks like that:

1. Students could say, "The space between each scale is enormous and empty, so we model only the interesting bits."
2. Gravity dictates this organization. Students may represent gravity forces on their models, but if not, use probing questions to get them thinking about gravity in their models.

What to do: Use probing questions to focus student attention on the interactions that each scale has in common.

- *It seems like we have different parts in focus at different scales, but are the interactions different?*
- *Why do all the parts of the solar system stay in the solar system? Why don't they fly out into the galaxy, filling up the space between star systems?*
- *Why don't the stars, which we also know are moving, stay in the galaxy? Why don't they fly out, filling up the space between the galaxies?*

Hold a brief gallery walk. Present **slide M**. Send groups on a gallery walk to look at other posters and notice similarities and differences across models. You can rotate groups through all posters if there is time, or you can ask groups to visit 3-4 models and to choose models to visit that have few or no students at them already. Do not spend more than 5 minutes on this. Make sure to leave plenty of time to build a classroom consensus model.

Alternative callout: If there is not enough time for a gallery walk, you can have students hang their posters and then move on to the Consensus Discussion, referencing the posters during the Scientists Circle. If you choose to do this, make sure to probe students as they make suggestions for the consensus model, for example,

- *Do you see any examples of that on the posters around the room?*
- *When you look around at the posters, does it look like that was how most people represented that?*

Gather in a Scientists Circle to develop a classroom consensus model. Present **slide N**. In a Scientists Circle, draw students' attention to a piece of chart paper titled "Classroom Consensus Model for the Universe."

Ask, *What objects did you notice at different scales on the posters that you think we should include in our model?* Look for students to suggest the following:

- galaxies (or clusters of galaxies) are the largest objects
- stars or star systems (or inside the Milky Way or the Milky Way)
- our solar system
- the Earth-Moon system (optional)

Establish the role of gravity in the model.

Suggested prompt	Sample student response
Why is it that we find objects at these different scales in space clumped together with so much emptiness in between instead of spread out evenly?	*Stuff is orbiting something.* *Gravity is holding each system together.* *Gravity forces are stronger when objects are close together, so exoplanets orbiting other stars will be pulled toward those stars, not toward our Sun. Stars are really far apart, so they are not interacting with each other.*
Why do the stars in the Milky Way orbit around the center of the galaxy if they are very far away from it?	*Maybe it's really massive?* *(Accept all responses.)*
Is distance the only thing that makes gravity forces stronger? Look back in your notebook at Lesson 5.	*Gravity is also dependent on mass.*
What does this tell us about whatever is at the center of the Milky Way galaxy?	*Something very massive must be at the center of the galaxy. (Students might not get here, but if they do, there is an optional home learning about supermassive black holes found at https://tinyurl.com/massive blackholes .)*

ALTERNATE ACTIVITY

Extension Opportunity
For an extension opportunity, if your students are interested in black holes, assign https://tinyurl.com/massiveblackholes as home learning. Ask students to consider as they read our question about what could be at the center of the Milky Way that is creating such strong gravitational force pairs to keep stars in orbit.

ASSESSMENT OPPORTUNITY

Building towards: 15.B Develop a model of the universe that shows how gravity forces bound space systems at multiple scales.

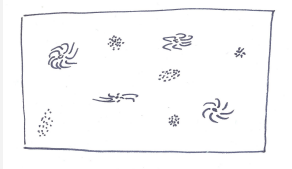
What to look/listen for: Look for students to articulate the role of gravity in bounding space systems by keeping things in orbit around more massive things.

What to do: If students included gravitational interactions in their models, this may come naturally. If not, use probing questions to focus student attention on the interactions that each scale has in common. Such as:

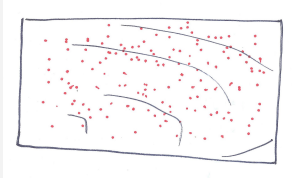
- *It seems like we have different parts in focus at different scales, but are the interactions different?*
- *Why do all the parts of the solar system stay in the solar system? Why don't they fly out into the galaxy, filling up the space between star systems?*

Model each scale as a class, zooming backward toward Earth.

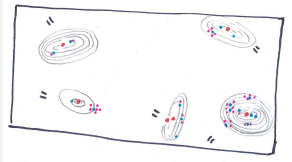
Say, *Let's start with the largest scale and zoom in. What did you notice on most or all of the posters that we should include at the largest scale?* Look for students to suggest galaxies. Note that students are not expected to know anything about the structure of galaxies, so accept however they choose to represent galaxies as a class, whether as spirals, circles, large clusters of stars, or some combination of shapes. Ask, *Where did you see gravity forces modeled in this system?*



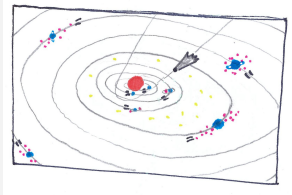
Ask, *What should we zoom in on here to model next?* Look for students to suggest zooming in on one of the galaxies. Students may suggest zooming in on a couple of star systems or zooming in on a larger swath of the Milky Way. Either is fine. Draw a box around where students want to zoom and then a line pointing to a new diagram. In the new diagram, draw another model with the parts and interactions students agree on. Ask, *Where did you see gravity forces modeled in this system?*



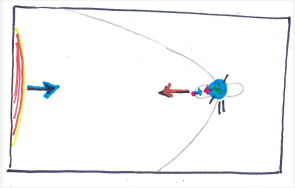
Again, ask, *What should we zoom in on here to model next?* Again, indicate zooming in and diagram students' ideas. At a stellar scale, make sure that students include some indication that other stars have planetary systems. Ask, *Where did you see gravity forces modeled in this system?*



Repeat this until students have zoomed in on our solar system. At this scale, look for students to suggest planets and the Sun. They may also suggest moons, asteroids, and/or comets. Do your best to include all the solar system objects that students suggest, but do not fish for more beyond planets and the Sun. Ask, *Where did you see gravity forces modeled in this system?*



Students may or may not decide to zoom in further to show some of the details of the Earth-Moon system or how gravity force pairs cause orbits in more detail.

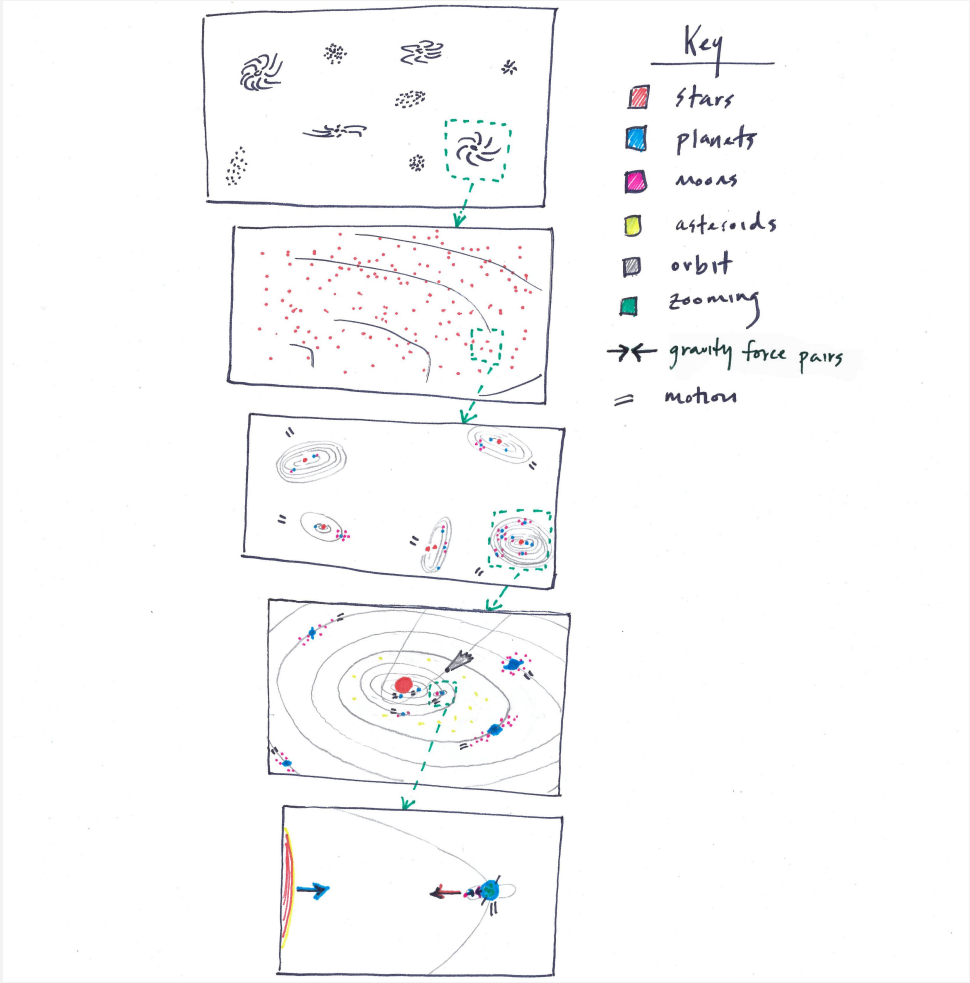


Record in a key the conventions you decide on as a class.

Present **slide O**. Ask students to record the final model into their Progress Tracker and label it “Consensus” to indicate that the class developed it together. Elicit ideas about the sources of evidence that the class used to construct each part of the model and have students record this in their Progress Tracker as well. Your final model may look something like the image in the sample Progress Tracker. It may have fewer scales represented or different conventions for orbits or zooming. Use the organization and conventions that the class has agreed on as long as at least three scales are represented and the representations are accurate.

Question / Lesson #	Source(s) of evidence
What is our place in the universe? (Lesson 15)	• Hubble ultra deep field image • Light curves • *Powers of Ten video*

What I figured out in words/pictures



6 · NAVIGATION

13 min

MATERIALS: None

Connect these ideas back to our questions about life. Present **slide P** and read the following quote from Neil DeGrasse Tyson, astrophysicist and head of the American Museum of Natural History:

> "Saying there is no life in the universe because we haven't found any evidence is like going to the beach and scooping up a glass full of water, and saying 'there are no whales in this ocean.'"

Ask, *What do you think Dr. Tyson means by this?* Have students turn and talk about this analogy before sharing out. Look for students to point to how many more stars there are that could possibly have the things we are looking for and where life might exist. Now we have expanded the possibilities to not just our solar system and other star systems in our galaxy but to other galaxies as well, each with billions of star systems.

Read the quote on the slide from Philip Morrison, professor of physics at MIT:

> "The probability of success is difficult to estimate, but if we never search, the chance of success is zero."

Ask, *What do you think Professor Morrison means by this?* Have students turn and talk about this quote before sharing out. Look for students to say that if we don't look for aliens, we won't find them.

Say, *We cannot possibly search the whole universe for extraterrestrial life; it is incredibly vast. But astronomers are starting to search some of it at least, because if we do not look, there is zero chance of finding anything. And if we do look, the probability is higher. How high? Professor Morrison says it's difficult to estimate.*

Say, *I'm wondering though, Professor Morrison said this in 1959, and we have discovered so much since then, including the existence of planets around other stars! Maybe we could estimate this probability now a little bit better.*

Brainstorm what we need to figure out the probability of life. Lead a brief brainstorm about what we need to quantify in our model to estimate the probability of finding life. Present **slide Q**.

Suggested prompt	Sample student response
Where in our model do we see places where we might find life?	*The planets and moons in our solar system and the planets and moons in other solar systems.*

Say, *This model is qualitative. That means that it describes the parts and interactions, like planets orbiting around stars or galaxies clustering together. It also tells us about why we see these systems--because gravity forces pull things together. But it doesn't tell us how many of anything there is, like how many planets might have life. For that we need to quantify our model.*

Suggested prompt	Sample student response
What do we need to know to make an estimate about how many planets and moons are out there that could support life?	*We need to know how many are in our galaxy, and then we need to know how many galaxies there are.*
How could we tell how many are in our whole galaxy when we can't even detect all the planets in the closest stars near us?	*Maybe we could see how many planets there are on average in a system and then count how many stars there are?*
What else do we need to know to make a guess about how many of those planets and moons actually have life?	*We need to know on average how many planets and moons have the conditions for life, like water and other chemicals needed for life.*
What else do we need to know to make an estimate about how many of those planets develop life that we could actually communicate with?	*(Accept all responses.)*

ADDITIONAL GUIDANCE	Do not spend a lot of time looking for the right answers here. Think of this as an opportunity to get students thinking about what it means to make a quantitative prediction based on very limited evidence. As students describe space systems (i.e., galaxies, star systems), point them out (or ask students to point them out) on the classroom consensus model.

Say, *we can keep working on this next time.*