Science & Literacy Activity

GRADES 3-5

OVERVIEW

This activity, which is aligned to the Common Core State Standards (CCSS) for English Language Arts, introduces students to scientific knowledge and language related to astronomy. Students will read content-rich texts, view the *Dark Universe* space show, and use what they have learned to complete a CCSS-aligned writing task, creating an illustrated text about how technology helps us see stars or other objects in the universe that are too far away to see with our eyes.

Materials in this packet include:

- Teacher instructions for:
  - o Pre-visit student reading
  - o Visit to *Dark Universe* and student worksheet
  - o Post-visit writing task
- Text for student reading: "Looking Into the Universe"
- Student Worksheet for *Dark Universe* visit
- Student Writing Guidelines
- Teacher rubric for writing assessment

Common Core State Standards:
W.3-5.2, W.3-5.8, W.3-5.9
RI.3-5.1, RI.3-5.2, RI.3-5.7, RI.3-5.10

New York State Science Core Curriculum:
PS 1.1b

Next Generation Science Standards:
PE 4-PS4-2
DCI ESS1.A: The Universe and its Stars
The Sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.
DCI PS4.B: Electromagnetic Radiation
An object can be seen when light reflected from its surface enters the eyes.

SUPPORTS FOR DIVERSE LEARNERS: An Overview
This resource has been designed to engage all learners with the principles of Universal Design for Learning in mind. It represents information in multiple ways and offers multiple ways for your students to engage with content as they read about, discuss, view, and write about scientific concepts. Different parts of the experience (e.g. reading texts) may challenge individual students. However, the arc of learning is designed to offer varied opportunities to learn. We suggest that all learners experience each activity, even if challenging. We have provided ways to adapt each step of the activities for students with different skill-levels. If any students have an Individualized Education Program (IEP), consult it for additional accommodations or modifications.

1. BEFORE YOUR VISIT

This part of the activity engages students in reading a non-fiction text about how the distance of stars and other objects in the universe determines how they appear to us and how we can use technology, like telescopes, to help us see them more clearly. The reading will prepare students for their visit by introducing them to the topic and framing their investigation.

Student Reading
Have students read "Looking into the Universe." Have them write notes in the large right-hand margin. For example, they could underline key passages, paraphrase important information, or write down questions that they have.

Discussion Quesions:

Ask:

- The Sun and the tiny points of light that we see in the night sky are all stars; why does the Sun look so much larger and brighter than the stars in the night sky? *(A: The Sun is much closer to us than other stars, that makes the Sun look larger and brighter than the stars we see in the night sky.)*
- Whether we are looking with our eyes or with instruments like telescopes, what do the Moon, stars, comets, and other objects in the sky have in common so we can see them? *(A: They all give off light; we see them because our eyes or the instruments collect the light that they give off.)*
- Why did using a large telescope help Edwin Hubble see a galaxy that was not visible with the naked eye? *(A: Telescopes can collect more light than our eyes can. That is why we can use them to see things that we would not otherwise be able to see because they are farther away.)*

They can work in pairs, small groups, or as a class. During discussion, remind students to use evidence from the text to explain their thinking.

SUPPORTS FOR DIVERSE LEARNERS: Student Reading
- "Chunking" the reading can help keep them from becoming overwhelmed by the length of the text. Present them with only a few sentences or a single paragraph to read and discuss before moving on to the next "chunk."
- Provide "wait-time" for students after you ask a question. This will allow time for students to search for textual evidence or to more clearly formulate their thinking before they speak.

After the reading, show students the following supplementary material.
- To help them visualize star distances: Build the Big Dipper — amnh.org/ology/features/stufftodo_astro/dipper.php
- To help them understand how telescopes help us see objects that would otherwise be too dim to see with the naked eye: Gathering Light — amnh.org/explore/curriculum-collections/discovering-the-universe/gathering-light

2. DURING YOUR VISIT

This part of the activity engages students in exploring the *Dark Universe* space show.

Museum Visit & Student Worksheet
It is important to review the worksheets with the students prior to their visit so that they know what information to look for when they are viewing the space show. Let students know that they will be using the Student Worksheets to gather information about four kinds of technology used to see the universe. Explain to students that they will be viewing the space show in the Hayden Planetarium, and that when the show ends, the group will gather in a quiet location to discuss what they saw and share ideas. Back in the classroom they will refer to these notes when completing the writing assignment.

SUPPORTS FOR DIVERSE LEARNERS: Museum Visit
- Review the Student Worksheet with students, clarifying what information they should collect during the visit.
- Have students work in pairs, with each student completing their own Student Worksheet.

3. BACK IN THE CLASSROOM

This part of the activity engages students in an informational writing task that draws on the pre-visit reading and on observations made at the Museum.

Writing Task:
Distribute the Student Writing Guidelines handout, which includes the following prompt for the writing task:

> Explain why using technology like telescopes helps us see stars or other objects in the universe that are too far away to see with our eyes.
>
> Be sure to:
> - name three kinds of technology used to see the universe
> - describe what we were able to learn from each
> - include an labeled illustration for each
>
> Support your discussion with evidence from the reading and *Dark Universe*.

Go over the handout with students. Tell them that they will use it while writing, and afterwards, to evaluate and revise their essays.

Before they begin to write, have students use the prompt and guidelines to frame a discussion around the information that they gathered from viewing *Dark Universe* and compare their findings. They can work in pairs, small groups, or as a class. Referring to the writing prompt, have students underline or highlight all relevant passages and information from the reading and discussion questions, and their notes from the space show that can be used in their response to the prompt. Instruct each student to take notes on useful information that their peers gathered as they compare findings. Students should write their essays individually.

SUPPORTS FOR DIVERSE LEARNERS: Writing Task

- Re-read the "Before Your Visit" assignment with students. Ask what they saw in the show that helps them understand why using technology such as telescopes helps us see stars or other objects in the universe that are too far away to see with our eyes.
- Allow time for students to read their essay drafts to a peer and receive feedback based on the Student Writing Guidelines.

Student Reading
Looking into the Universe

When you look up into the night sky, what can you see without a telescope? On most nights, you'll see the Moon and maybe a few planets. You might even glimpse a meteor's bright streak or a comet's glowing tail. These objects are very close.

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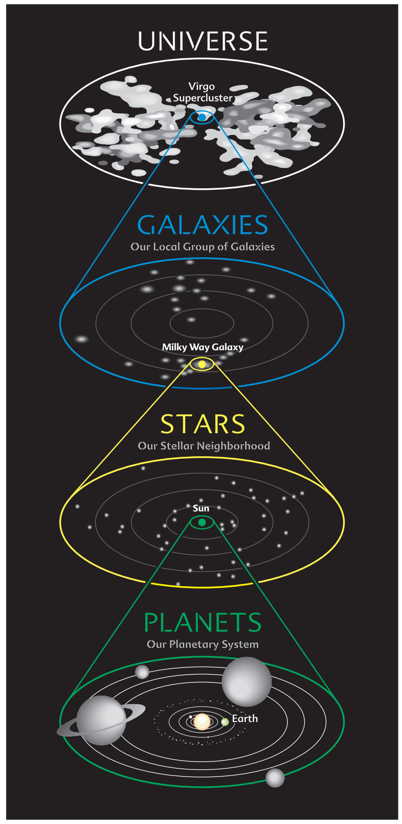

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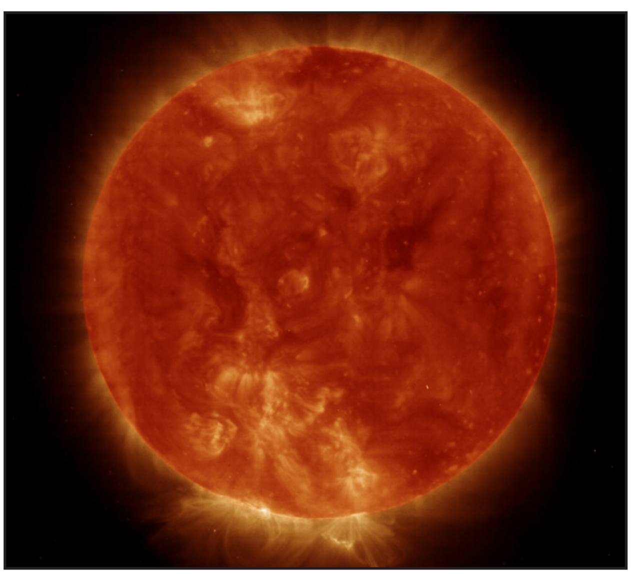
Earth is just one planet orbiting the Sun in our solar system. Our Sun is one of billions of stars in the Milky Way galaxy. Zoom out even further and you'd find that the Milky Way is one of millions of galaxies in the Virgo Supercluster. And as you probably guessed, millions of superclusters are spread out across the universe.

Beyond these objects, you can see thousands of stars. They might look like little dots of light, but they're really huge, burning balls of gas — just like our star, the Sun. Some are even bigger than our Sun. They just look tiny because they're so far away.



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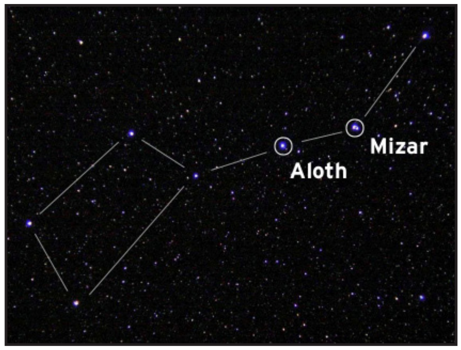
our star, the Sun

On a starry night, you can also make out constellations like the Big Dipper. Stars in a constellation may look close together, but they're really light-years apart — vast distances compared to our solar system. And, the stars in a constellation look like they're the same distance away, as if they're points on a distant "connect the dot" background. In fact, if you could travel through space to view the constellation from different angles, you'd see they're all different distances away. Some stars are billions of miles farther from Earth than others.



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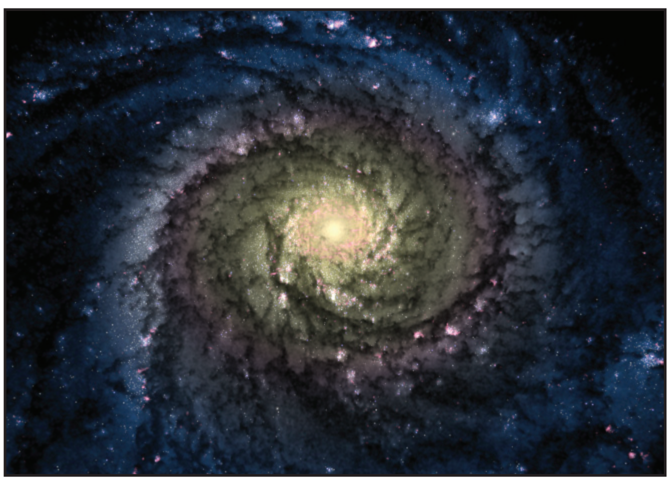
This is what the Big Dipper looks like from Earth. The stars of this constellation may all look the same distance away, but it's an illusion. The star Mizar is 88 light years from Earth, while Alioth is 631 light years away!

With so many stars, so far away, it might seem like you're peering across the universe. But every star you see with your naked eye is in the Milky Way Galaxy, so you're seeing only a tiny fraction of the entire universe. When you look at a star, your eyes are capturing light that traveled all the way from the star to your eye. Astronomers learn about stars, galaxies, and other faraway phenomena by collecting light from them with specialized instruments that can collect much more light than the human eye.



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The Milky Way is a spiral galaxy.

To see farther into the universe, we use scientific instruments like telescopes. Telescopes allow us to view objects that are too far away, and too faint, to see with just our eyes. In 1923, the astronomer Edwin Hubble discovered that other galaxies existed. He used a large telescope to detect a galaxy beyond the Milky Way for the first time. Since then, scientists have found millions more.

Today, telescopes are larger and more powerful. We even put telescopes into space. Orbiting Earth high above the blurring effects of our atmosphere, they provide razor-sharp views of objects too faint or far away to ever have been seen before. We also have telescopes that can "see" different forms of light that are otherwise invisible to the human eye: gamma rays, X-rays, ultraviolet rays, infrared waves, microwaves, and radio waves.

© STS-82 Crew, STScI, NASA

Named after astronomer Edwin Hubble, the Hubble Space Telescope was launched in 1990 and is the first major optical telescope to orbit Earth.

While we probably won't be traveling to other stars or galaxies anytime soon, new technology is letting us see farther than ever before. What might we discover next?

Student Worksheet

Instructions: Draw each one and write what it helped us discover or see about the universe.

Mount Wilson Observatory Telescope

What did it help us discover or see?

Bell Horn Radio Antenna

What did it help us discover or see?

Planck Satellite

What did it help us discover or see?

Galileo Probe

What did it help us discover or see?

ANSWER KEY

Student Worksheet

Instructions: Draw each one and write what it helped us discover or see about the universe.

Mount Wilson Observatory Telescope

What did it help us discover or see?
(Answer: saw the first galaxy other than the Milky way, Andromeda)

Bell Horn Radio Antenna

What did it help us discover or see?
(Answer: discovered energy coming evenly from all directions in the sky)

Planck Satellite

What did it help us discover or see?
(Answer: collected information about the early universe)

Galileo Probe

What did it help us discover or see?
(Answer: explored Jupiter's atmosphere)

Student Writing Guidelines

Writing Prompt:

Explain why using technology such as telescopes helps us see stars or other objects in the universe that are too far away to see with our eyes.

Be sure to:
• name three kinds of technology used to see the universe
• describe what we were able to learn from each
• include an labeled illustration for each

Support your discussion with evidence from the reading and *Dark Universe*.

Use this checklist to ensure that you have included all of the required elements in your essay.

- [ ] I included an introduction.
- [ ] I clearly explained why using technology such as telescopes helps us see stars or other objects in the universe that are too far away to see with our eyes.
- [ ] I included a labeled illustration of three kinds of technology used to see the universe and described what we were able to learn from each.
- [ ] All of the information I presented is relevant to technologies used to see the universe.
- [ ] I used information from "Looking into the Universe" to explain why using technology like telescopes helps us see stars or other objects in the universe that are too far away to see with our eyes.
- [ ] I used information from the *Dark Universe* space show to explain why using technology like telescopes helps us see stars or other objects in the universe that are too far away to see with our eyes.
- [ ] I included a conclusion at the end.
- [ ] I proofread my essay for grammar and spelling errors.

Assessment Rubric

	Scoring Elements	1 Below Expectations	2 Approaches Expectations	3 Meets Expectations	4 Exceeds Expectations
RESEARCH	**Reading**	Attempts to include text using examples, quotes, or other references.	Presents some information from reading materials but may lack accuracy or relevance.	Accurately presents information from reading materials relevant to the purpose of the prompt to inform or explain.	Accurately and effectively presents important information from reading materials to inform or explain.
	AMNH Exhibit	Attempts to include Museum exhibit content using examples, quotes, or other references.	Presents some information from Museum exhibit but may lack accuracy or relevance.	Accurately presents information from Museum exhibit relevant to the purpose of the prompt to inform or explain.	Accurately and effectively presents important information from Museum exhibit to inform or explain.
WRITING	**Focus**	Attempts to address the prompt, but is off-task.	Addresses the prompt, but focus is uneven.	Addresses the prompt with an adequately detailed response; stays on task.	Addresses key aspects of prompt in a detailed response; stays on task.
	Development	Attempts to inform or explain but lacks details.	Informs or explains by presenting some details.	Informs or explains using appropriate details.	Informs or explains by providing detailed and relevant information.
	Conventions	Lacks cohesion and control of grammar, usage, and mechanics appropriate to grade level	Demonstrates an uneven command of standard English conventions appropriate to grade level.	Demonstrates a command of standard English conventions, with few errors as appropriate to grade level.	Maintains a well-developed command of standard English conventions, with few errors. Response includes language and tone appropriate to the purpose and specific requirements of the prompt.
SCIENCE	**Content Understanding**	Content is irrelevant, inappropriate, or inaccurate.	Shows uneven understanding of disciplinary content related to the prompt	Presents generally accurate disciplinary content related to the prompt.	Presents accurate and relevant disciplinary content to enhance understanding of the topic.

Science & Literacy Activity

GRADES 6-8

OVERVIEW

This activity, which is aligned to the Common Core State Standards (CCSS) for English Language Arts, introduces students to scientific knowledge and language related to astronomy and the study of the universe. Students will read content-rich texts, view the *Dark Universe* space show, and use what they have learned to complete a CCSS-aligned writing task, creating an illustrated text about astronomy.

Common Core State Standards:
WST.6-8.2, WST.6-8.8, WST.6-8.9
RST.6-8.1, RST.6-8.2, RST.6-8.7, RST.6-8.10

New York State Science Core Curriculum:
PS 1.1b

Next Generation Science Standards:
PE MS-ESS1-2
DCI ESS1.A: The Universe and Its Stars
Patterns of the apparent motion of the Sun, the Moon, and stars in the sky can be observed, described, predicted, and explained with models. Earth and its solar system are part of the Milky Way Galaxy, which is one of many galaxies in the universe.

Materials in this activity include:

- Teacher instructions for:
    - o Pre-visit student reading
    - o Visit to *Dark Universe*
    - o Post-visit writing task
- Text for student reading: "Discovering the Universe"
- Student Writing Guidelines
- Teacher rubric for writing assessment

SUPPORTS FOR DIVERSE LEARNERS: An Overview
This resource has been designed to engage all learners with the principles of Universal Design for Learning in mind. It represents information in multiple ways and offers multiple ways for your students to engage with content as they read about, discuss, view, and write about scientific concepts. Different parts of the experience (e.g. reading texts, or locating information in the exhibit) may challenge individual students. However, the arc of learning is designed to offer varied opportunities to learn. We suggest that all learners experience each activity, even if challenging. We have provided ways to adapt each step of the activities for students with different skill-levels. If any students have an Individualized Education Program (IEP), consult it for additional accommodations or modifications.

1. BEFORE YOUR VISIT

This part of the activity engages students in reading a non-fiction text about astronomy. The reading will prepare students for their visit by introducing them to the topic and framing their investigation.

Student Reading
Have students read "Discovering the Universe." Have them write notes in the large right-hand margin. For example, they could underline key passages, paraphrase important information, or write down questions that they have. They may also use this space for drawings or diagrams that show how scientific understanding of the universe has changed over time.

Ask:

- What kinds of instruments do astronomers use to study the universe? *(A: Astronomers use telescopes to gather light, and collect the information contained within this light.)*
- Describe the discovery made by Edwin Hubble. Why was this discovery so revolutionary? *(A: Hubble discovered that objects once thought to be parts of our galaxy, are in fact distant galaxies. Not only this, but he also discovered that these galaxies are moving away from ours at great speed. This means that the universe is much larger than initially thought, and that it is expanding. This was revolutionary because scientists at the time, even famous scientists like Einstein, presumed that the universe was "static" which means not changing in size.)*

- How has our understanding of the universe changed as a result of the three discoveries covered in this reading? Include specific examples. *(A: Hubble discovered that the universe was much larger than scientists expected, and that it was expanding; growing larger all the time. This implies that the universe was once much smaller and hotter at some point in the past. Penzias and Wilson discovered the cosmic microwave background, the light from a much earlier time in the history of the universe when it was much smaller and hotter. This confirmed the expansion of the universe, and further supported the big bang theory as the most likely explanation for observations. The High-z Supernova Team discovered that rather than slowing down, the expansion rate of the universe was actually increasing, despite gravity that would naturally attempt to pull everything together. This represents the discovery of a totally new phenomenon: dark energy. We now know that the universe will accelerate forever, and expand forever becoming vastly larger than it is today.)*

They can work in pairs, small groups, or as a class. During discussion, remind students to use evidence from the text to explain their thinking, and to use specific examples, such as important discoveries made during the past century.

SUPPORTS FOR DIVERSE LEARNERS: Student Reading

- "Chunking" the reading can help keep them from becoming overwhelmed by the length of the text. Present them with only a few sentences or a single paragraph to read and discuss before moving on to the next "chunk."
- Provide "wait-time" for students after you ask a question. This will allow time for students to search for textual evidence or to more clearly formulate their thinking before they speak.

2. DURING YOUR VISIT

This part of the activity engages students in viewing the space show.

Museum Visit

Explain to students that they will be viewing a space show in the Hayden Planetarium called *Dark Universe*. Back in the classroom they will use this experience to help complete the writing assignment. As soon as possible after the show, have students discuss and take notes on the important discoveries that they learned about. Tell them that back in the classroom they will refer to these notes when completing the writing assignment.

SUPPORTS FOR DIVERSE LEARNERS: Museum Visit

- Review the assignment with students, clarifying what information they should collect during the visit.
- Have students discuss the show in pairs, with each student taking their own notes.

3. BACK IN THE CLASSROOM

This part of the activity engages students in an informational writing task that draws on the pre-visit reading and on observations made at the Museum.

Writing Task

Distribute the Student Writing Guidelines handout, which includes the following prompt for the writing task:

> Based on your reading, your viewing of the *Dark Universe* space show, and your discussions, write an essay in which you describe how astronomers have used powerful telescopes to make important discoveries in astronomy, and how these discoveries have changed our understanding of the universe.
>
> Be sure to include:
> - at least two important discoveries
> - an explanation of how these discoveries have changed our understanding of the universe
> - examples of the instruments, such as telescopes, used to make these discoveries
>
> Support your discussion with evidence from the reading and *Dark Universe*.

Go over the handout with students. Tell them that they will use it while writing, and afterwards, to evaluate and revise their essays.

Before they begin to write, have students use the prompt and guidelines to frame a discussion around the information that they gathered from *Dark Universe*, and compare their findings. They can work in pairs, small groups, or as a class. Referring to the writing prompt, have students underline or highlight all relevant passages and information from the reading that can be used in their response to the prompt. Instruct each student to take notes on useful information that their peers gathered as they compare findings. Students should write their essays individually.

SUPPORTS FOR DIVERSE LEARNERS: Writing Task

• Re-read the "Before Your Visit" assignment with students. Ask what they saw in the show that helps them understand astronomy.

• Allow time for students to read their essay drafts to a peer and receive feedback based on the Student Writing Guidelines.

Student Reading

Discovering the Universe

When you look up at the night sky, the farthest stars you can see without a telescope are thousands of light-years away. But compared to the size of the universe, that distance is tiny — like looking at a nearby sand grain on a giant beach. In fact, scientists estimate the farthest galaxies are billion of light-years away — and moving farther away all the time. Scientists have also determined that the universe was born in a fiery instant nearly 14 billion years ago.

How do scientists learn about the size and age of the universe? They begin by asking questions about things they observe (and many things they can't). Then they use scientific tools to collect data. Telescopes allow astronomers to observe objects far past our own galaxy — even some that don't give off visible light. With the data they collect using these tools, scientists develop or revise theories about the universe. Sometimes they raise new questions based on the evidence.

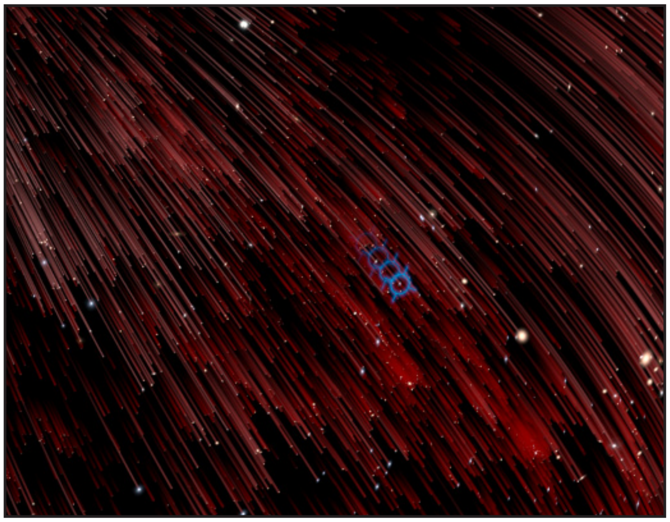
Let's take a look at three of the most important discoveries of the past century and see how each one changed our understanding of the universe.

Almost all our information about the universe comes from light emitted, absorbed, or reflected by the objects in it. Light from distant galaxies has taken hundreds of millions or even billions of years to reach us.

Hubble and the Expanding Universe

In the 1920s, many scientists, including Albert Einstein, believed the size of the universe was constant — neither collapsing nor expanding. Then in 1929, astronomer Edwin Hubble made an amazing discovery that would change everything. Hubble's instrument was the Hooker telescope, the largest optical telescope in the world at the time.

With its 100-inch mirror, the reflecting telescope could collect more light than smaller telescopes. After all, the purpose of a telescope mirror is to gather as much light as possible. The larger a telescope's mirror, the more light it collects, and the more information it gathers from objects in space. The Hooker telescope gave scientists a clearer view into the universe, letting them study distant objects in detail that were once too faint to see.



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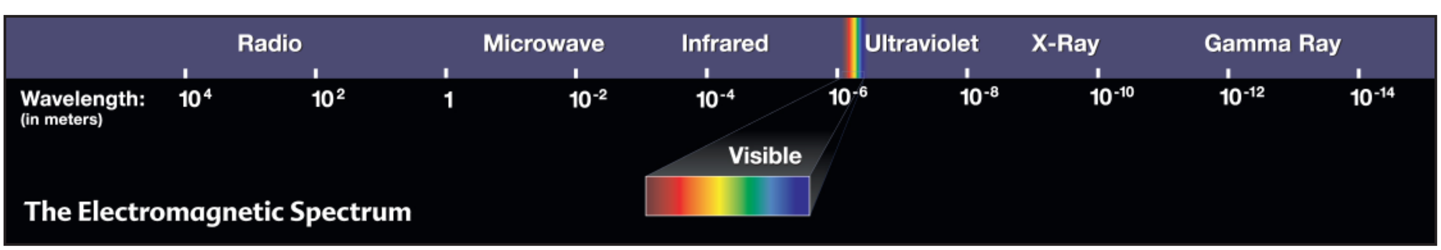
Because our universe is expanding, distant galaxies appear to be moving away from Earth. The farther away an astronomical object is, the faster that motion is. This motion elongates the wavelengths of light — called "red shifting" — making distant galaxies appear redder than they should be.

Using this new instrument, Hubble identified galaxies beyond the Milky Way. His discovery revealed that ours was just one of many galaxies in the universe. He also observed that other galaxies — in all directions — were moving away from us. He figured this out by studying the light from distant galaxies. Hubble observed that the light coming from these galaxies were redder than expected. This unexpected "redshift," an increase in wavelength, led him to conclude that the galaxy must be moving away. Every other galaxy he observed in every direction also exhibited redshift, and thus was also moving away. This new evidence showed the universe was expanding. And scientists concluded that if the universe was expanding, it must have once been much smaller than it is today.

Penzias and Wilson and the Cosmic Microwave Background

After Hubble's discovery, scientists proposed different theories for the expansion of the universe. One idea was that the universe started in a fiery explosion or "big bang." The early universe would have been small, dense, and extremely hot. So hot, it would give off light the way a star does. Some thought we might be able to detect light from the early universe. We wouldn't be able to see this light because — like the light of a receding galaxy — the light waves that reach us would be stretched out (redshifted) beyond the visible spectrum. Only a radio telescope could pick up these longer wavelengths.



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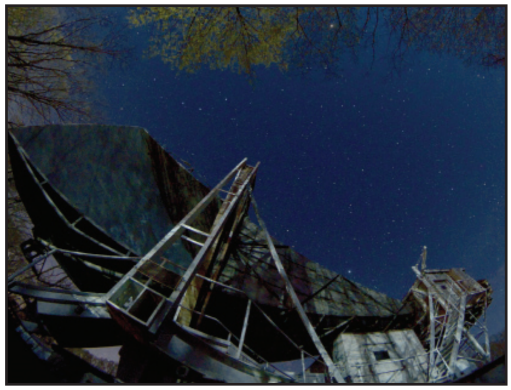
The theory had many skeptics. Then, in 1965, two astronomers, Arno Penzias and Robert Wilson, encountered something unexpected. Arno Penzias and Robert Wilson detected unusual background "static" as they were mapping radio signals from the Milky Way. The static turned out to be microwave radiation coming from all directions. At first, the mysterious radiation was a nuisance. After ruling out different possibilities, even bird droppings inside the horn-shaped radio telescope, they realized what it was: the afterglow of the young universe. This light — the oldest light ever seen — became known as the "cosmic microwave background." It was evidence that the early universe was very hot — hot enough to glow brightly the way a star does. It was also evidence that confirmed the big bang theory.



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Astronomers testing a radio antenna at New Jersey's Bell Labs accidentally recorded low-level light coming from all directions: the cosmic microwave background.

High-z Supernova Search Team and Dark Energy

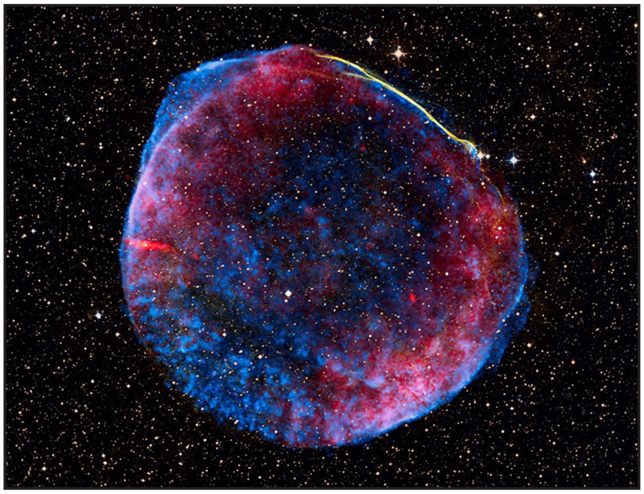
By the 1990s, evidence from Hubble, Penzias, Wilson and other astronomers supported two important ideas: First, the universe is not infinite in age; it was formed about 14 billion years ago. Second, the universe was expanding. Many scientists predicted that gravity — the same force that holds together stars, solar systems, and galaxies — would slow down this expansion. After all, gravity is the force that attracts matter to other matter — so wouldn't gravity attract all the matter in the universe? Some thought the force of gravity might act as a break to some day stop, or even reverse the expansion of the universe. Think of what happens when you push a skateboard against the force of gravity, for example up a shallow hill. You'd expect the skateboard to slow down, eventually stop, and maybe even roll back down. But what if, instead of slowing down, the skateboard actually started rolling faster uphill? That would be surprising, right? Your response might describe how an international team of astronomers felt in 1998.

The High-z Supernova Search Team was studying the expansion of the universe — specifically, how fast it has expanded at different times in its history. To measure expansion very early in the history of the universe they needed to look at objects as far away as possible. To do this, they used a series of telescopes, including two enormous optical telescopes with mirrors 10 meters (almost 33 feet) across. By collecting huge amounts of light, these telescopes let astronomers observe objects at extremely remote distances.

With these powerful telescopes, the team searched for distant supernovae — bright, exploding stars. By focusing on one type of supernova, they could determine each one's distance by its brightness, like car headlights on a highway. They also measured the supernova's redshift to determine how fast it was moving away from us. By analyzing the data from many supernovae, they could begin to see how the universe's rate of expansion has changed over time.

They were not surprised to find that the expansion slowed down during the first eight billion years. But after that the rate increased — it started expanding faster. And it's expanding faster all the time.

What was propelling this acceleration? On the cosmic scale of the universe, an invisible pressure seems to be working in opposition to gravity — pushing matter apart. Scientists called this mysterious pressure "dark energy." They still don't know what dark energy is, but they know it exists. Scientists estimate that dark energy makes up about 70% of the total mass-energy of the universe.



By investigating exploding stars, called supernovas (pictured), scientists have found that space itself, once thought to be mere nothingness, holds more energy than all the stars. They call this mysterious pressure "dark energy."

New Tools, New Discoveries

Less than a century ago, Edwin Hubble peered through the world's largest telescope and changed what we knew about the universe. His discovery revealed the universe was expanding. Decades later, Penzias and Wilson used a large radio telescope to pick up the remnant light from the early universe, evidence that the universe began with a sudden explosion. By the 1990s, telescopes four times larger than Hubble's gave scientists their deepest view into the universe and led to the discovery of dark energy. What discoveries lie ahead to explain dark energy? What else is out there yet to be discovered?

As scientists keep asking questions about the universe, they'll rely on larger and more powerful instruments to look for evidence. Today, there are plans for optical telescopes with mirrors up to thirty meters across, and radio telescopes hundreds of meters across. These tools will let scientists observe new and more distant parts of the universe. They will likely lead to fascinating discoveries, new theories, and a better understanding of our cosmos.

Student Writing Guidelines

Based on your reading, your viewing of the *Dark Universe* space show, and your discussions, write an essay in which you describe how astronomers have used powerful telescopes to make important discoveries in astronomy, and how these discoveries have changed our understanding of the universe.

Be sure to include:
- at least two important discoveries
- an explanation of how these discoveries have changed our understanding of the universe
- examples of the instruments, such as telescopes, used to make these discoveries

Support your discussion with evidence from the reading and *Dark Universe*.

Use this checklist to ensure that you have included all of the required elements in your essay.

- [ ] I introduced at least two important discoveries made by astronomers and explained how these discoveries changed our understanding of the universe.
- [ ] I clearly named telescopes and described how these telescopes help astronomers study the universe.
- [ ] I only included relevant information about discoveries in astronomy have changed our understanding of the universe.
- [ ] I used information from "Discovering the Universe" to explain at least two major discoveries in astronomy in detail.
- [ ] I used information from the *Dark Universe* space show to explain at least two major discoveries in astronomy in detail.
- [ ] I used academic, non-conversational tone and language.
- [ ] I included a conclusion at the end.
- [ ] I proofread my essay for grammar and spelling errors.

Assessment Rubric

	Scoring Elements	1 Below Expectations	2 Approaches Expectations	3 Meets Expectations	4 Exceeds Expectations
RESEARCH	**Reading**	Attempts to present information in response to the prompt, but lacks connections to the texts or relevance to the purpose of the prompt.	Presents information from the text relevant to the purpose of the prompt with minor lapses in accuracy or completeness.	Presents information from the text relevant to the prompt with accuracy and sufficient detail.	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the text.
	AMNH Exhibit	Attempts to present information in response to the prompt, but lacks connections to the Museum exhibit content or relevance to the purpose of the prompt.	Presents information from the Museum exhibit relevant to the purpose of the prompt with minor lapses in accuracy or completeness.	Presents information from the Museum exhibit relevant to the prompt with accuracy and sufficient detail.	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the Museum exhibit.
WRITING	**Focus**	Attempts to address the prompt, but lacks focus or is off-task.	Addresses the prompt appropriately, but with a weak or uneven focus.	Addresses the prompt appropriately and maintains a clear, steady focus.	Addresses all aspects of the prompt appropriately and maintains a strongly developed focus.
	Development	Attempts to provide details in response to the prompt, including retelling, but lacks sufficient development or relevancy.	Presents appropriate details to support the focus and controlling idea.	Presents appropriate and sufficient details to support the focus and controlling idea.	Presents thorough and detailed information to strongly support the focus and controlling idea.
	Conventions	Attempts to demonstrate standard English conventions, but lacks cohesion and control of grammar, usage, and mechanics.	Demonstrates an uneven command of standard English conventions and cohesion. Uses language and tone with some inaccurate, inappropriate, or uneven features.	Demonstrates a command of standard English conventions and cohesion, with few errors. Response includes language and tone appropriate to the purpose and specific requirements of the prompt.	Demonstrates and maintains a well-developed command of standard English conventions and cohesion, with few errors. Response includes language and tone consistently appropriate to the purpose and specific requirements of the prompt.
SCIENCE	**Content Understanding**	Attempts to include science content in explanations, but understanding of the topic is weak; content is irrelevant, inappropriate, or inaccurate.	Briefly notes science content relevant to the prompt; shows basic or uneven understanding of the topic; minor errors in explanation.	Accurately presents science content relevant to the prompt with sufficient explanations that demonstrate understanding of the topic.	Integrates relevant and accurate science content with thorough explanations that demonstrate in-depth understanding of the topic.

Science & Literacy Activity

GRADES 9-12

Common Core State Standards:
WHST.9-12.2, WHST.9-12.8, WHST.9-12.9, RST.9-12.1, RST.9-12.2, RST.9-12.4, RST.9-12.7, RST.9-12.10

New York State Science Core Curriculum:
PS 1.2a

Next Generation Science Standards:
PE HS-ESS1-2
DCI ESS1.A: The Universe and Its Stars
The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.

OVERVIEW

This activity, which is aligned to the Common Core State Standards (CCSS) for English Language Arts, introduces students to scientific knowledge and language related to the study of cosmology. Students will read content-rich texts, view the *Dark Universe* space show, and use what they have learned to complete a CCSS-aligned writing task, creating an illustrated text about how scientists study the history of the universe.

Materials in this activity include:

- Teacher instructions for:
  - o Pre-visit student reading
  - o Viewing the *Dark Universe* space show
  - o Post-visit writing task
- Text for student reading: "Case Study: The Cosmic Microwave Background "
- Student Writing Guidelines
- Teacher rubric for writing assessment

SUPPORTS FOR DIVERSE LEARNERS: An Overview
This resource has been designed to engage all learners with the principles of Universal Design for Learning in mind. It represents information in multiple ways and offers multiple ways for your students to engage with content as they read about, discuss, view, and write about scientific concepts. Different parts of the experience (e.g. reading texts) may challenge individual students. However, the arc of learning is designed to offer varied opportunities to learn. We suggest that all learners experience each activity, even if challenging. We have provided ways to adapt each step of the activities for students with different skill-levels. If any students have an Individualized Education Program (IEP), consult it for additional accommodations or modifications.

1. BEFORE YOUR VISIT

This part of the activity engages students in reading a non-fiction text about the discovery of the cosmic microwave background. The reading will prepare students for their visit by introducing them to the topic and framing their investigation.

Student Reading
Before reading, introduce students to the following vocabulary words; you can discuss the words to with them elicit their prior understanding, or simply have them write the definitions down for reference while reading.

Cosmology: the study of the origin and history of the universe

Theory: an explanation of process or phenomenon, based on observation and evidence, that has been tested and that can be used to make predictions about future events and ongoing processes

Model: a representation of an object or process that shows or explains how it looks or works

Have students read "Case Study: The Cosmic Microwave Background." Have them write notes in the large right-hand margin. For example, they could underline key passages, paraphrase important information, or write down questions that they have.

Ask:

- In the second paragraph of the article, it states that scientists "published an alternative cosmological theory." Based on the context of the article, what is a "cosmological theory?" *(A: A cosmological theory is a theory that explains how the universe was formed and/or has evolved.)*

- In the third paragraph of the article, it states that scientists "developed a detailed theoretical picture, or model, of the Big Bang." Based on the context of the article, what is a "theoretical model?" *(A: A theoretical model is a scientific explanation for how something happened that takes all known factors into account.)*
- What observation did scientists make that suggested that the universe was expanding? What two ideas did scientists come up with to explain this? *(A: Scientists observed that the light from distant galaxies is redshifted, suggesting that space itself is expanding. One idea proposed was that the universe is growing in size, starting with a "Big Bang." Another was that that matter is continually created, so that as the size of the universe increases, the average density remains constant.)*
- What did Alpher and Herman predict should exist if the Big Bang theory were true? What led them to this prediction? *(A: They predicted that there should be microwave energy coming from every direction. This would be the radiation produced in the Big Bang.)*
- Why did the scientists who predicted the CMB need to detect it? Why did the scientists who detected the CMB need to know about the prediction? What led them to this prediction? *(A: They needed to detect it to prove their theory. The scientists who detected the CMB needed the theory to explain what they were observing; without the prediction they didn't know where the radiation was coming from.)*

They can work in pairs, small groups, or as a class. During discussion, remind students to use evidence from the text to explain their thinking, and to use specific examples and scientific vocabulary in their explanations.

SUPPORTS FOR DIVERSE LEARNERS: Student Reading
- "Chunking" the reading can help keep them from becoming overwhelmed by the length of the text. Present them with only a few sentences or a single paragraph to read and discuss before moving on to the next "chunk."
- Provide "wait-time" for students after you ask a question. This will allow time for students to search for textual evidence or to more clearly formulate their thinking before they speak.
- For students who may benefit from watching a video about the CMB and some of the more recent observations of it, you may supplement (but not replace) the reading with this Science Bulletin: amnh.org/explore/science-bulletins/%28watch%29/astro/documentaries/cosmic-microwave-background-the-new-cosmology
- More information on cosmological discovery is available on the page 7 of the *Dark Universe* educator's guide entitled "A Century of Discoveries" (amnh.org/darkuniverse/educators). Have students read this text and note where theories and predictions were verified by observations, and vice versa.

2. DURING YOUR VISIT

This part of the activity engages students in viewing the *Dark Universe* space show.

Museum Visit

Before students watch the *Dark Universe* space show, instruct them to pay attention to when scientists make discoveries based on observations, and what they learn about the universe by creating and studying theoretical models. As soon as possible after viewing, have students discuss and take notes on the observations and discoveries they learned about. Tell them that back in the classroom they will refer to these notes when completing the writing assignment.

SUPPORTS FOR DIVERSE LEARNERS: Museum Visit
- Either before or after viewing, provide students with the show synopsis from pages 4 and 5 of the educator's guide (amnh.org/darkuniverse/educators) to help them remember what they saw.

3. BACK IN THE CLASSROOM

This part of the activity engages students in an informational writing task that draws on the pre-visit reading and on observations made at the Museum.

Writing Task

Distribute the Student Writing Guidelines handout, which includes the following prompt for the writing task:

> Based on your reading, your viewing of the *Dark Universe* space show and your discussions and notes, write an essay that explains how astronomers who make observations and astronomers who make theoretical models collaborate on cosmological theories.
>
> Be sure to:
> • define "cosmological theory" and "theoretical model"
> • include an example of an observation that raised a question about how the universe began and has evolved
> • include an example of a theoretical model that helps scientists understand previous observations
> • include further observations that support the theoretical model
>
> Support your discussion with evidence from the reading and *Dark Universe*.

Go over the handout with students. Tell them that they will use it while writing, and afterwards, to evaluate and revise their essays.

Before they begin to write, have students use the prompt and guidelines to frame a discussion around the information that they gleaned from the *Dark Universe* space show, and compare their findings. They can work in pairs, small groups, or as a class. Referring to the writing prompt, have students underline or highlight all relevant passages and information from the reading and their discussion notes that can be used in their response to the prompt. Instruct each student to take notes on useful information that their peers gathered as they compare findings. Students should write their essays individually.

SUPPORTS FOR DIVERSE LEARNERS: Writing Task

- Re-read the "Before Your Visit" assignment with students. Ask what they saw in the show that helps them understand the cosmic microwave background.
- Allow time for students to read their essay drafts to a peer and receive feedback based on the Student Writing Guidelines.

Student Reading

Case Study: The Cosmic Microwave Background

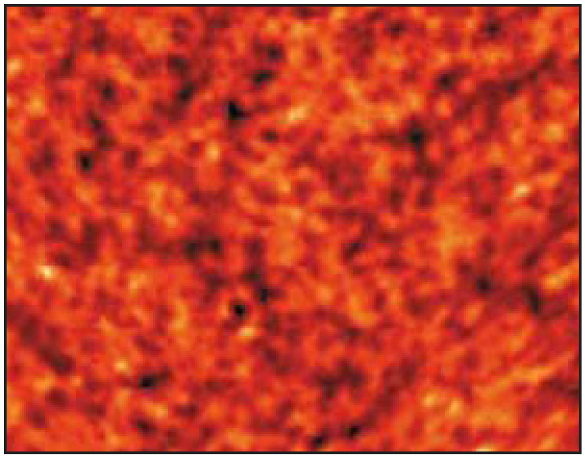


Photo courtesy of the BOOMERANG Project.

The cosmic microwave background radiation is the faint remnant glow of the big bang. This false color image, covering about 2.5 percent of the sky, shows fluctuations in the ionized gas that later condensed to make superclusters of galaxies.

In 1929, Edwin Hubble showed that the light from distant galaxies is shifted to longer wavelengths in proportion to their distances from the Milky Way. The modern interpretation is that space itself is expanding, carrying the galaxies along for the ride. In 1931, Georges Lemaître imagined running such an expansion backwards in time. At some remote point in the past, he reasoned, everything in the universe would have been packed together at enormous density. Lemaître suggested that all the matter and energy in the observable universe originated in an explosion of space, now called the Big Bang, which launched the expansion that continues to this day.

In 1948, Hermann Bondi, Thomas Gold, and Fred Hoyle published an alternative cosmological theory, which accounted for the observed expansion without invoking a beginning in time. They proposed that matter is continually created, to form new galaxies, so that the expanding universe maintains the same average density and appearance through infinite time. In this "steady state" theory, matter is created continuously. In the Big Bang theory, all the matter in the universe is created at once, at a definite point in the past.

In the same year, the physicists George Gamow, Ralph Alpher, and Robert Herman developed a detailed theoretical picture, or model, of the Big Bang. They realized that the universe immediately after the explosion would have been not only extremely dense but also extremely hot. At such high temperatures most of the contents of the universe would be in the form of intense light (radiation) rather than in the form of matter. This early period is now called the radiation era.

As the universe expanded, the total amount of light and matter had to fill a continually increasing volume of space, so the density of each had to decrease. But the expansion of space also stretched out the waves of the light traveling through it. And the longer the wavelength of light, the lower its energy. So the expansion of space caused the energy density of light to decrease even faster than the density of matter. Consequently, most of the energy of the universe was soon in the form of matter instead of radiation, and today we live in a matter-dominated universe.

The three scientists recognized that the radiant energy of the Big Bang must still exist in the universe today, although greatly reduced in intensity by the expansion of space. Alpher and Herman went on to calculate the present temperature corresponding to this energy. The answer they got was 5 K, which means 5 degrees above absolute zero on the Kelvin scale. (At absolute zero, the lowest possible temperature, molecular motion and thermal radiation come to a complete stop.) Radiant energy at a temperature of 5 K is mostly in the frequency band of microwaves.

Alpher and Herman in effect predicted that the universe today should be awash in a faint but uniform bath of microwave energy coming from every direction — the remnant glow from the Big Bang. But they made no attempt to search for it. As theoretical physicists, not observational astronomers, they perhaps assumed that the technology required for such an observation did not yet exist. Furthermore, radio astronomy was in its infancy in those days, and the handful of radio astronomers who might have known how to use the available technology to search for the microwave background radiation were unaware of the published theoretical prediction. So for several years the debate between the steady state and Big Bang theories continued, in the absence of any strong observational evidence in favor of one over the other.

In 1964, Arno A. Penzias and Robert W. Wilson at the Bell Telephone Laboratories in New Jersey began investigating the microwave radio emissions from the Milky Way and other natural sources. They had a very sensitive detector connected to a large horn-shaped antenna, previously used for satellite communication. When the two scientists tuned their equipment to the microwave portion of the spectrum, they discovered an annoying background static that wouldn't go away. No matter where they pointed the antenna, or when, the microwave static was the same. They spent months running down every possible cause for the static, including pigeon droppings inside the antenna, but they couldn't find a source or a solution.

At about the same time, Princeton physicist Robert H. Dicke had come to his own conclusion that residual radiation from the Big Bang must still be present in the universe. He did not know about the previously published work by Gamow, Alpher, and Herman. So Dicke independently calculated that the lingering radiation should have a temperature of about 10 K. He realized that it should be observable in the microwave portion of the spectrum. His research team was in the process of building an antenna to search for it when he learned that Penzias and Wilson had discovered a persistent microwave background noise. Dicke turned to his colleagues and said simply, "They've got it."

Penzias and Wilson had stumbled on the first observational evidence to support the Big Bang theory of the origin of the universe. For this discovery they shared the Nobel Prize for Physics in 1978. Subsequent observations of the microwave background at different wavelengths have refined the value of the radiation temperature of the universe to 2.73 K. This is about half the value calculated by Alpher and Herman in 1948, but their result is widely regarded as a successful prediction in view of the approximations required by the calculation. The discovery of the cosmic microwave background radiation led most astronomers to accept the Big Bang theory.

Student Writing Guidelines

Based on your reading, your viewing of the *Dark Universe* space show and your discussions and notes, write an essay that explains how astronomers who make observations and astronomers who make theoretical models collaborate on cosmological theories.

Be sure to:
- define "cosmological theory" and "theoretical model"
- include an example of an observation that raised a question about how the universe began and has evolved
- include an example of a theoretical model that helps scientists understand previous observations
- include further observations that support the theoretical model

Use this checklist to ensure that you have included all of the required elements in your essay.

- ☐ I introduced cosmological theory and theoretical model.
- ☐ I defined "cosmological theory" and "theoretical model."
- ☐ I only included relevant information about theoretical models and observations.
- ☐ I used information from "Case Study: The Cosmic Microwave Background" to explain theoretical models and observations in detail.
- ☐ I used information from the *Dark Universe* space show to explain theoretical models and observations in detail.
- ☐ I used academic, non-conversational tone and language.
- ☐ I included a conclusion at the end.
- ☐ I proofread my essay for grammar and spelling errors.

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