Science & Literacy Activity

GRADES 9-12

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

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.

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

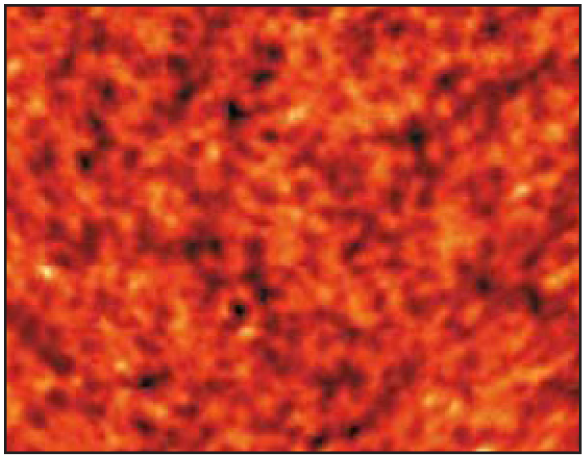

Photo courtesy of the BOOMERANG Project.

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.

This is an excerpt from *Cosmic Horizons: Astronomy at the Cutting Edge*, edited by Steven Soter and Neil deGrasse Tyson, a publication of the New Press.

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.

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.