The Cosmic Microwave Background

Suggested Grade Level(s): 9-12
Estimated class time: 30-45 minutes depending on class ability, assuming they have already read the Cosmic Times article

Summary

The purpose of this lesson is to further educate students to the nature of the cosmic microwave background. The lesson is aimed at explaining the surrounding nature of the background and the reason it exists as microwave radiation.

Objectives

- Students will be able to describe the reason the Big Bang theory yields the creation of a cosmic microwave background.
- Students will be able to describe why the cosmic microwave background is universal and surrounds us.
- Students will be able to compare and contrast changes in the portion of the electromagnetic spectrum in which the radiation resides.

National Science Standards

- NS.9-12.1 SCIENCE AS INQUIRY
  As a result of activities in grades 9-12, all students should develop
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- NS.9-12.2 PHYSICAL SCIENCE
  As a result of their activities in grades 9-12, all students should develop an understanding of
  - Motions and forces
  - Interactions of energy and matter
- NS.9-12.4 EARTH AND SPACE SCIENCE
  As a result of their activities in grades 9-12, all students should develop an understanding of
  - Origin and evolution of the earth system
- NS.9-12.7 HISTORY AND NATURE OF SCIENCE
  As a result of activities in grades 9-12, all students should develop understanding of
  - Science as a human endeavor
  - Nature of scientific knowledge
  - Historical perspectives

Knowledge Prerequisite

Students should be familiar with the electromagnetic spectrum, in particular the fact that all electromagnetic radiation is the same, just composed of different wavelengths and energy levels. They should also be familiar with knowledge that the universe is expanding.

Teacher Background

This lesson involves discussing the early universe and resulting expansion. Throughout the lesson notes are added with extra information to help you aid the students as necessary.

It is important to first survey students and to check with the school nurse to learn about any students who might have a latex allergy. If this is a possibility, latex-free balloons must be used in the Exploration section.

Materials

- Balloons (Enough for the class, see precaution in "Teacher Background" section above)
- Markers (One for each student in the class)
- 1965 Cosmic Times

Procedure:

I. Engagement

1. Have the students read the 1965 Cosmic Times article: "Murmur of a Bang." This can be done either the night before the lesson as homework or during the first part of class.

2. Begin a discussion first by talking about how the radiation was discovered. Then probe the class into a discussion about why the big bang would produce a uniform cosmic background. The main two ideas to be sure bring up are:

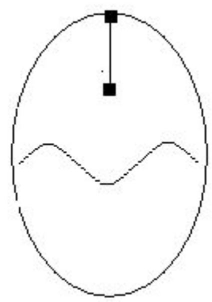
   a. Why is there radiation to begin with?
   b. Why would the radiation surround us and be isotropic? (Smooth, evenly distributed)

3. From here, tell the students that today they will make a model of the history of the universe. With their model they will explain two questions; "What is responsible for the background radiation, and why does it surround us and have the wavelength that it does?"

II. Exploration

1. Hand each student in the class a balloon and marker. Inform them that these will be the tools they will use to make their universe.

2. Have them mark their balloon in a manner similar to the image below. The picture needs to include a pair of points connected by a line and a wave going around the balloon.



3. Tell the students that this balloon simulates our universe. The wave they drew represents a beam of light and the dots connected by the line represent the distance between two points.

4. Tell them that the Big Bang theory that is supported by the noted recession of distant galaxies indicates that the universe is expanding. Be sure to tell them that this means that the galaxies are not moving away from each other but that the physical distance between them is growing.

5. Have them inflate their balloon. Then ask them the following questions:

   a. "What happened to the physical distance between two points on your balloon?" *They should indicate that they grew farther apart.* Ask them if the two points are actually moving away from each other or if the size of the balloon universe just got larger. *They should indicate that they are now farther apart because the balloon/universe got larger.*

   b. Ask them what happened to the wavelength of their light wave? *They should indicate that the wave increased in wavelength and coincidentally decreased in frequency.*

Teacher background: Please point out to your students, if they fail to realize, that the frequency changes also.

6. Now have them inflate their balloon further. Have the students conclude what happens to the distance between points and the wavelength of a wave that stretches

across the universe as the universe grows. They should conclude that the distance gets larger and waves grow in wavelength.

III. Explanation

7. Now talk about what would occur with the big bang. Talk about how scientists believe that by winding back the clock we would end up with a hot, small, and compact universe. Tell them that the discovered radiation is consistent with radiation emitted from a thermal source. Make a comparison to the heat given off from their bodies.

8. Continue to describe the early universe. Talk about how the big bang would have created a small, early universe filled with electromagnetic radiation. Describe how this early universe is similar to the conditions on the sun where there are no protons or electrons or neutrons. Everything is in a plasma state of motion.

9. Now reference their balloons. Point out that in the beginning they have a small universe that is hot. Make a reference to the electromagnetic spectrum, of which their body heat is a member. Point out that the early universe was composed of a uniform electromagnetic wave created by the big bang. This wave would be a part of the whole universe.

10. Now explain that over time the universe expands. Now reference their balloons again. What happens to the wavelengths of their balloons as the universe grows? Students should point out that the wavelength grows so the frequency drops and over time the wavelengths will shift to the radio range where the background radiation is found.

Teacher background: At this point it may be necessary to reference the electromagnetic spectrum. Point out that if thermal radiation increased in wavelength, it could end up in the microwave range.

11. Now ask the class, "If the origin of the background is the uniform thermal radiation of the big bang, then would the radiation produced evenly distribute around the small early universe?" *They should indicate yes; if not lead them to this idea.*

12. Now have them imagine the spot where the earth would eventually inhabit. Where would it be in this small universe? Does the radiation surround this spot in a uniform manner? *They should indicate yes.*

13. Now refer back to the balloon. If the radiation was everywhere in the early universe, and the universe got bigger (not just moved apart), would the radiation still surround us? *They should again indicate yes.*

Teacher background: Depending on your class composition and ability level, the previous can be conducted in two ways: Either a discussion, with note-taking occurring individually by the students themselves or in a notes presentation to the students. Just put the major points into bullets and deliver through some sort of visual manner.

14. As a summary of the discussion, students can now write a paragraph summarizing what they have learned. They may share it with a neighbor, group, or the class. Feel free to add your own assessment of the objectives for this lesson.