# Cosmic Chemistry: Cosmogony

# Cosmic Tug of War

## TEACHER GUIDE

## BACKGROUND INFORMATION

In the activities of this module, students had the opportunity to consider some of the evidence that supports the basic precepts of the standard cosmological model.

**Basic Precepts of the Standard Cosmological Model**

1. The physical laws adduced on Earth pertain throughout the observable universe.
2. The universe is expanding.
3. The universe is isotropic and homogeneous.
4. General relativity accurately describes the behavior of gravitation in the universe today.
5. The early universe was in a state of high density and high energy.
6. The universe is evolving.

As students completed these activities, they found that:

- The physical laws of thermodynamics and the properties of fundamental forces apply not only to the present universe, but can also be used to envision the history of the cosmos and to predict its future.
- The history of the quark model, based on these laws and mathematical calculations, showed how the cosmos might have evolved from an initial state of high density and high energy.
- Doppler shifts are used to study the direction and extent of cosmic expansion dynamics at the present time.
- Large luminous structures and voids form what may be an isotropic and homogeneous cosmos.
- Studies of galactic dynamics, influenced by gravitational force, indicate that there is more mass in the universe than luminous matter can account for.
- Determining the density of the present universe is a difficult problem because of the differences in mass of cosmic structures and voids and the indirect evidence for the presence of dark matter.

Note that all but one of the standard cosmological model precepts is written in the present tense; most of them pertain to the universe as it is today. Interestingly enough, two of those precepts—those describing gravity and expansion—involve forces that are in opposition to each other. In other words, there is a universal "tug of war" occurring between gravity and expansion. Emphasize to your students how these opposing forces make for a dynamic, rather than a static, universe.

Astronomers discuss expansion and gravity "tug of war" models in terms of values of **omega** ($\Omega$), the ratio of the **actual average mass density** of the universe to the **critical density**, where critical density is the density of mass required to halt the outward expansion of the universe. If $\Omega > 1$ the universe would be **closed**; if $\Omega < 1$; the universe would be **open;** and if $\Omega = 1$, the universe would be **flat**. All these models have one feature in common—that at some time in the past the distance between neighboring galaxies must have been zero. You may wish to use transparencies of the figures in the Student Text, "Cosmic Tug of War," as you discuss this terminology. Put the ratio in mathematical form on the overhead projector or chalkboard as you discuss the implications of the value of omega. Explain that omega can be considered to be a measure of how close the real density of the universe is compared to the critical density.

$\Omega$ = actual average mass density/critical density

In this assessment activity, students will decide which of three expansion models is the most credible. As they make their decisions students must again consider cosmic terminology from previous activities, including mass, density, light and dark matter. In addition, new terms, such as open universe, closed universe, finite, infinite, flat, and omega ($\Omega$) will be introduced. You may wish to spend some class time prior to their reading the Student Text, "Cosmic Tug of War," to focus on these terms and to help them make the necessary connections between the terms. You should also encourage them to review the student text and appendix materials from this module, before and during the completion of this assignment.

## NATIONAL SCIENCE STANDARDS ADDRESSED

**Grades 5-8**

*Science As Inquiry*
Understandings about scientific inquiry

*Science and Technology*
Understandings about science and technology

*Assessment B*
Achievement and opportunity to learn science must be assessed

*Assessment C*
Assessment tasks are authentic

**Grades 9-12**

*Science As Inquiry*
Understandings about scientific inquiry

*Earth and Space Science*
The origin and evolution of the universe

*Science and Technology*
Understandings about science and technology

*History and Nature of Science*
Nature of science and scientific knowledge

*Assessment B*
Achievement and opportunity to learn science must be assessed

*Assessment C*
Assessment tasks are authentic

*(View a full text of the National Science Education Standards.)*

## MATERIALS

For each student
- Copy of Student Activity, "Cosmic Tug of War"

## PROCEDURE

1. Make copies of the Student Activity, "Cosmic Tug of War," and any other student texts or appendices that you have not used in previous module activities.

2. Introduce the assessment activity by reviewing the conclusions reached in previous module activities that your students have completed. Be sure that you have included those outlined in the Background Information above. If you have not assigned all the activities, you will need to summarize the major concepts of those activities and hand out copies of student texts for background material.

3. You may make this activity either an individual or a group assignment. If you make it a group assignment, you will probably want to let the students form their own groups so that they are working with people who wish to defend the same position.

**Alternate Teaching Tip**

Begin this assessment as an individual assignment. Students should collect research information that helps support their answer. Midway through the activity, assemble groups of students to merge and defend their own data. This would bolster support for their answers.

4. Emphasize that students will employ the same (or similar) procedures used in the completion of previous activities of this module, since this is the assessment activity for the module. The difference is that answering the questions in this activity will probably require some outside research in addition to the information in the student text.

5. Post the timeline for this assignment on the chalkboard, the overhead projector, or in a handout, making sure that you have allowed ample time for further research and consideration of the three expansion models as you set deadlines. You should indicate:
   a) When the project is due.
   b) How much class time you have set aside for this assignment.
   c) What type of research sources you will accept (discourage the use of only encyclopedia sources).
   d) What form the completed project should take (oral, written, or poster presentations; outline and/or bibliography required, etc.).
   e) The method of evaluation for the assignment.

6. Note that in the student activity handout we included four basic questions for student consideration as they are forming their answers to **THE QUESTION**. These questions were included to direct their research and thinking, but they could also be made part of the assignment. Make sure that students know whether or not you want their answers to those questions included as a part of their answers to **THE QUESTION**.

7. The optional assignment is the construction of a physical model of the universe. If you wish students to make a physical model, allow extra time for the completion of the assignment.