The Evidence is "Clear"!

Suggested Grade Level(s): 9-12
Estimated class time: 1 class period plus time for a lesson summary

Summary

Students consider observations and inferences about the Steady State and Big Bang theories.

Objectives

- Distinguish between data collected from empirical observations and inference, which may or may not arise from data.
- Compare and contrast the Steady State and Big Bang theories for the origin of our universe.

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.9-12.4 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 universe
- NS.9-12.7 HISTORY AND NATURE OF SCIENCE

  As a result of activities in grades 9-12, all students should develop understanding of
  - Nature of scientific knowledge
  - Historical perspectives

Knowledge Prerequisite

Students should have read the Cosmic Times 1955 article *Origin of Everything: Hot Bang or Ageless Universe* and be familiar with the general ideas presented in both the Steady State and Big Bang Theories. Spectral Red Shift due to expansion and cosmic microwave background (CMB) are important terms in the study of cosmology. Use the Internet to find out more about them.

Important terms:

- Light year – the distance light travels in one year. The light we are viewing now from a distance of 500 light years took 500 years to get here. We are "seeing" the past!
- Interstellar reddening – Light traveling through space from very distant objects is scattered by clouds of dust in space. More blue light is scattered than red so objects will appear more reddish than they actually are. Many of the blue spectral lines disappear
- Red shift – Objects moving away from the viewer appear to be more reddish because all of the wavelengths of light coming from them are stretched. All of the spectral lines are shifted toward the red end, but none disappear. See http://www.classzone.com/books/earth_science/terc/content/visualizations/es2802/es2802page01.cfm

Teacher Background

Consult the sites listed here as well as k-12 student and college astronomy texts about cosmology.
http://map.gsfc.nasa.gov/m_uni/uni_101bb1.html
http://cosmology.berkeley.edu/Education/IUP/Big_Bang_Primer.html
http://www.damtp.cam.ac.uk/user/gr/public/bb_home.html
http://www.newtonphysics.on.ca/BIGBANG/Bigbang.html
http://curious.astro.cornell.edu/cosmology.php
http://www.answers.com/topic/cosmic-microwave-background-radiation?cat=technology
http://www.answers.com/topic/steady-state-theory

Materials

- One set of 34 Evidence cards per pair of students (included at the end of this lesson plan). Note: a shorter version of the activity may be done using 16 cards. See the Teacher Notes on page 5)
- Two large (about 40·80 cm) sheets of butcher paper for each pair of students

Procedure:

I. Engagement

Set up the following scenario for your students:

> You arrive at school one morning and observe a group of your friends clustered in the hall. They are laughing and seem to be passing something around among the group. Each person looks at it for a few seconds, then bursts out with new peals of mirth and releases it to someone else who eagerly grabs it away. Is it a picture; are they reading something; is it some object or toy? Then you remember that note of passionate love you were writing to your sweetheart and somehow lost yesterday.

When they see you, the group falls silent, still grinning, and quickly disperse in different directions at the sound of the morning bell.

What has happened? Did the group read your note? Perhaps their actions had nothing to do with you at all. What did you actually observe? What might you infer from those observations? How do you find out what was really happening? Believe it or not, this is exactly what science is all about!

II. Exploration

Explain to your students that science is the process of trying to find out what is happening. Scientists make careful quantitative observations of the world around them. Then they try to explain the meaning of those observations by making inferences that lead to the design of experiments that lead to new observations and new inferences. In the best scientific procedure, inferences are based on direct observation. As continued observations lead to similar inferences, scientists begin to construct a "model" which is an idea that we think represents how the real world works. As we collect more bits of information through observations, we decide whether they support or refute the model we have built. Sometimes our minds "jump to conclusions" and make inferences or even models before we have collected enough observations.

Tell students that in this activity they will be examining statements about two theories that try to explain our understanding of the nature of our universe and how it began.

Have students work in partners. Hand out a set of Evidence cards to each pair, and tell students to take turns drawing an Evidence card and deciding if the statement describes direct evidence as an observation/experiment or if it describes an inference or interpretation. Have them make two piles, one for observations, and one for inferences. If they disagree with their partner, tell them to set the card aside until later. There are two cards labeled "Model" in each set, have students set them aside until after they've made their two piles.

Next ask students to reread the *Origin of Everything* article in the 1955 Cosmic Times.

While they are rereading the article, hand out the butcher paper, two sheets to each pair of students. When they are finished reading, have the groups label one of the large sheets "Steady State Theory" and the other "Big Bang Theory". Ask them to chose the appropriate "Model" card for each theory, and place it under the theory it describes.

Next, have them make two columns down each sheet with one labeled OBSERVATION/experiment and the other labeled INFERENCE/interpretation.

Students should now go back through their stack of cards, beginning with the stack of "observation" Evidence cards, decide with their partner which theory the observation

supports. Place the card on the appropriate Theory sheet. Then they should do the same with their stack of "inference" Evidence cards.

When everyone is finished, have teams of students exchange places to examine the other team's placement of cards. If they disagree on any of the cards, they should discuss the matter among the four of them and try to come to a consensus. They should also try to resolve any cards they had set aside previously. Blank cards are available if students feel that any piece of evidence belongs in more than one place.

III. Explanation

Remind the students that the most reliable scientific explanations are based on observation and experiment. Inferences and interpretations must ultimately be based on actual data. Ask students as they examine their Theory sheets, which one contains more examples of observations and experimental data? Which theory is supported mostly by conjecture and "guessing"? Do they have enough information to prove either of these Theories?

IV. Evaluation

You may want to display the class results on the board and discuss any which caused disagreement. Have students return to their seats and write a summary of the theory they feel has the most reliable evidence supporting it and why.

You may want to conclude by returning to the scenario at the beginning of class, telling students:

> Later in the day one of your friends shows you a photograph of his little brother trying to paint their cat with whipped cream. The expression on the cat's face indicates disapproval while the child's shows deep concentration. You laugh…. could this be what the group was looking at earlier? Are you sure?

Teacher notes:
Some of the information on the Evidence cards may be very strange to the students and they may not totally understand the statements. However you can guide them to make a list of words that are more likely to represent inference and those words that indicate actual observations. For instance could, might, suggest, should, predicts, ought to be, theoretical are all terms which would be appropriate for inferences. Specific dates, records of data from specific experiments and numerical records indicate observations. The term empirical refers to actual data from an observation. The most important lesson to be learned from this activity is that good science is experimentally based. Inferences are valuable evidence only if they are theoretical explanations of actual data. The Steady State theory lost most of its support with the prediction and discovery of the cosmic microwave background radiation in 1965. Those who supported it based most of their belief on inferences that had little data to support them. Although the hot Big Bang model has been successful in describing most of the observations we have recorded so far, there are unanswered questions. Refer to
http://www.damtp.cam.ac.uk/user/gr/public/bb_problems.html

The final explanation of the origin of the universe is yet to come.

Results may vary:

- (For a shorter version, use cards 4,6,7,8,9,12,13,14,15,17,19,23,28,29,30,31)
- Steady State observations: 12, 23
- Steady State Inferences: 1, 4, 7, 10, 15, 18, 20, 25, 28, 30, 31
- The observations do not lead to any of the inferences, but the information that Hoyle wrote more science fiction that science might suggest a pattern of thinking that was comfortable with "poetic license"

- Big Bang observations: 5, 6, 8, 9, 14, 16, 17, 22, 24, 27, 32
- Big Bang inferences: 2, 3, 11, 13, 19, 21, 26, 29
- Big Bang observations 5, 16, 22 lead to inference 26 that the universe does show difference through time.
- Big Bang observations 8, 14, 27 lead to inference 13 that some of the low mass elements could only be produced during such a violent event.
- Big Bang observations 24 and 32 lead to inference 21 that the Big Bang would create a perfect Black Body radiation.
- Big Bang observation 6 and 9 lead to inference 19 that the Cosmic Microwave Background indicates a Black Body.
- Both inferences 19 and 21 lead to inference 3
- Big Bang observation 17 leads to inference 29 that the universe is expanding.
- Big Bang inference 11 is suggested by inferences 19 and 21

-1- MODEL: We think that the universe is ever expanding, without beginning or end. The universe is the same at all points, in all directions and at all times. Galaxies of all ages are intermingled.	-2- MODEL: We think that the universe began from nothing as a singularity about 15 billion years ago and has been expanding ever since.
-3- The Big Bang theory predicts a perfect black body temperature curve and a background radiation with very slight differences in density throughout.	-4- In order to both expand in size and create new matter, a reservoir of energy is needed. To prevent the energy from being used up, Hoyle proposed that the energy is negative so that expansion and creation work against each other and equilibrium is maintained.
-5- Maarten Schmidt produced a survey of quasars, small but very brilliant extragalactic systems discovered in 1966. They are found only at several billion light years, and none are found nearby.	-6- The cosmic microwave background is uniform in temperature to more than one part in one thousand.

-7- Hoyle wrote that matter could arise from a field generated by matter that already existed, “chasing its own tail”, in the same manner as the film, *The Dead of Night*.	-8- The observed amount of helium-4 today is more than can be accounted for by the fusion of hydrogen in stars. Almost one quarter of the known matter in the universe today is helium-4.
-9- The cosmic microwave background was discovered in 1965 by Wilson and Penzias. It is very uniform and comes from every direction.	-10- Theoretical studies suggest that collisions between light energy photons and atoms of matter result in loss of energy of the photons. As they approach us they would appear to be red shifted.
-11- The uniformity of the CMB would be difficult to explain if there were many different sources and ages of radiation.	-12- In 1946 Hoyle, Bondi, and Gold saw a movie, *The Dead of Night*, in which the ending of the movie had circled back to the beginning. Hoyle noted that unchanging situations need not be static.

-13- Atoms with masses of one to four amu could have been produced in the extremely high energy in the very early period shortly after the Big Bang. That could account for the hydrogen, deuterium, helium-3, and some lithium found in the universe today.	-14- Experimental chemistry has shown that all of the naturally occurring elements **except** hydrogen can be produced inside of stars. Spectroscopy of starlight has confirmed the presence of most of them.
-15- Bondi suggested that new matter could be created spontaneously due to the interchangeability of matter and energy.	-16- In 2002 the Hubble Deep Field photograph showed the most distant, therefore oldest, view of the universe. It shows unusual galaxies shaped like tooth picks and links on a bracelet that are not similar to galaxies that have formed more recently.
-17- In 1929 Hubble observed that every galaxy he saw exhibited a spectral red shift that was proportional to its distance from us.	-18- If the red shift of distant galaxies is caused by the light coming from them losing energy as it collides with intergalactic matter, the universe might not really be expanding. It could just be very, very large, and there is a lot of matter out there scattering light.

-19- A hot big bang would have produced very high energy, short wavelength radiation. The red shift caused by the expansion of the universe over billions of years would produce a smooth, uniform long wavelength (microwaves), which would come from every	-20- If the universe had been the size of an electron when it was only a fraction of a second old, it must have been a black hole. Therefore, its gravity would have been so intense that it could not have expanded to what we see today.
-21- In the early universe there were no atoms, only free electrons and nuclei. The photons of energy could scatter off electrons and the tiny universe would have been a dense collection of photon energy called a black body.	-22- Radio galaxies have been observed most frequently at billions of light years from earth, but much less frequently at closer distances.
-23- Fred Hoyle wrote, and had published, 15 science fiction novels and 14 non-fiction works.	-24- The FIRAS experiment between 1989-90 on NASA's COBE satellite shows the CMB closely follows the black body spectrum at 34 equally spaced points on the curve.

-25- Hermann Bondi thought that if the universe was expanding, new matter would need to be created continually in order to keep density constant.	-26- Very distant objects such as quasars and radio galaxies that appear very far away, but not nearby, could mean that the universe was different long ago than it is today and therefore is not constant in time.
-27- Although the synthesis of most elements can be explained by the fusions within stars, no theoretical method can account for the deuterium or helium-3 (atomic masses of 2 and 3) that has been observed.	-28- Hoyle proposed a C-field which would have a negative pressure in order to be consistent with conservation of energy and drive the expansion of the universe
-29- Hubble concluded that the universe was expanding because all of the galaxies he observed were moving away from us at a speed proportional to their distance from us.	-30- To keep the overall density of the universe constant, it would be necessary to spontaneously produce 1 atom of hydrogen per cubic meter per billion years. It would also be necessary to produce small amounts of deuterium, helium, and lithium.

-31- Cosmic background radiation was possibly caused by light from very distant, therefore ancient, galaxies that has been scattered by galactic dust.	-32- The cosmic microwave background (CMB) produces a spectrum which fits the curve for an ideal black body radiation which was originally 3000K degrees but is today only 2.73K
-33-	-34-
-35-	-36-

-37-	-38-
-39-	-40-
-41-	-42-