14.E: The Big Bang (Exercises)

Articles

Kruesi, L. “Cosmology: 5 Things You Need to Know.” *Astronomy* (May 2007): 28. Five questions students often ask, and how modern cosmologists answer them.

Kruesi, L. “How Planck Has Redefined the Universe.” *Astronomy* (October 2013): 28. Good review of what this space mission has told us about the CMB and the universe.

Lineweaver, C. & Davis, T. “Misconceptions about the Big Bang.” *Scientific American* (March 2005): 36. Some basic ideas about modern cosmology clarified, using general relativity.

Nadis, S. “Sizing Up Inflation.” *Sky & Telescope* (November 2005): 32. Nice review of the origin and modern variants on the inflationary idea.

Nadis, S. “How We Could See Another Universe.” *Astronomy* (June 2009): 24. On modern ideas about multiverses and how such bubbles of space-time might collide.

Nadis, S. “Dark Energy’s New Face: How Exploding Stars Are Changing our View.” *Astronomy* (July 2012): 45. About our improving understanding of the complexities of type Ia supernovae.

Naze, Y. “The Priest, the Universe, and the Big Bang.” *Astronomy* (November 2007): 40. On the life and work of Georges Lemaître.

Panek, R. “Going Over to the Dark Side.” *Sky & Telescope* (February 2009): 22. A history of the observations and theories about dark energy.

Pendrick, D. “Is the Big Bang in Trouble?” *Astronomy* (April 2009): 48. This sensationally titled article is really more of a quick review of how modern ideas and observations are fleshing out the Big Bang hypothesis (and raising questions.)

Reddy, F. “How the Universe Will End.” *Astronomy* (September 2014): 38. Brief discussion of local and general future scenarios.

Riess, A. and Turner, M. “The Expanding Universe: From Slowdown to Speedup.” *Scientific American* (September 2008): 62.

Turner, M. “The Origin of the Universe.” *Scientific American* (September 2009): 36. An introduction to modern cosmology.

Websites

Cosmology Primer: https://preposterousuniverse.com/cosmologyprimer/. Caltech Astrophysicist Sean Carroll offers a non-technical site with brief overviews of many key topics in modern cosmology.

Everyday Cosmology: cosmology.carnegiescience.edu/. An educational website from the Carnegie Observatories with a timeline of cosmological discovery, background materials, and activities.

How Big Is the Universe?: www.pbs.org/wgbh/nova/space/h...-universe.html. A clear essay by a noted astronomer Brent Tully summarizes some key ideas in cosmology and introduces the notion of the acceleration of the universe.

Universe 101: WMAP Mission Introduction to the Universe: http://map.gsfc.nasa.gov/universe/. Concise NASA primer on cosmological ideas from the WMAP mission team.

Cosmic Times Project: http://cosmictimes.gsfc.nasa.gov/. James Lochner and Barbara Mattson have compiled a rich resource of twentieth-century cosmology history in the form of news reports on key events, from NASA’s Goddard Space Flight Center.

Videos

The Day We Found the Universe: www.cfa.harvard.edu/events/mo...archive09.html. Distinguished science writer Marcia Bartusiak discusses Hubble’s work and the discovery of the expansion of the cosmos—one of the Observatory Night lectures at the Harvard-Smithsonian Center for Astrophysics (53:46).

Images of the Infant Universe: https://www.youtube.com/watch?v=x0AqCwElyUk. Lloyd Knox’s public talk on the latest discoveries about the CMB and what they mean for cosmology (1:16:00).

Runaway Universe: https://www.youtube.com/watch?v=kNYVFrnmcOU. Roger Blandford (Stanford Linear Accelerator Center) public lecture on the discovery and meaning of cosmic acceleration and dark energy (1:08:08).

From the Big Bang to the Nobel Prize and on to the James Webb Space Telescope and the Discovery of Alien Life: svs.gsfc.nasa.gov/vis/a010000...370/index.html. John Mather, NASA Goddard (1:01:02). His Nobel Prize talk from Dec. 8, 2006 can be found at www.nobelprize.org/mediaplaye...p?id=74&view=1.

Dark Energy and the Fate of the Universe: https://webcast.stsci.edu/webcast/de...=1961&parent=1. Adam Reiss (STScI), at the Space Telescope Science Institute (1:00:00).

Review Questions

1. What are the basic observations about the universe that any theory of cosmology must explain?
2. Describe some possible futures for the universe that scientists have come up with. What property of the universe determines which of these possibilities is the correct one?
3. What does the term Hubble time mean in cosmology, and what is the current best calculation for the Hubble time?
4. Describe at least two characteristics of the universe that are explained by the standard Big Bang model.
5. Describe two properties of the universe that are not explained by the standard Big Bang model (without inflation). How does inflation explain these two properties?
6. Why do astronomers believe there must be dark matter that is not in the form of atoms with protons and neutrons?
7. What is dark energy and what evidence do astronomers have that it is an important component of the universe?
8. Thinking about the ideas of space and time in Einstein's general theory of relativity, how do we explain the fact that all galaxies outside our Local Group show a redshift?
9. Astronomers have found that there is more helium in the universe than stars could have made in the 13.8 billion years that the universe has been in existence. How does the Big Bang scenario solve this problem?
10. Describe the anthropic principle. What are some properties of the universe that make it "ready" to have life forms like you in it?
11. Describe the evidence that the expansion of the universe is accelerating.

Thought Questions

1. What is the most useful probe of the early evolution of the universe: a giant elliptical galaxy or an irregular galaxy such as the Large Magellanic Cloud? Why?
2. What are the advantages and disadvantages of using quasars to probe the early history of the universe?
3. Would acceleration of the universe occur if it were composed entirely of matter (that is, if there were no dark energy)?
4. Suppose the universe expands forever. Describe what will become of the radiation from the primeval fireball. What will the future evolution of galaxies be like? Could life as we know it survive forever in such a universe? Why?
5. Some theorists expected that observations would show that the density of matter in the universe is just equal to the critical density. Do the current observations support this hypothesis?
6. There are a variety of ways of estimating the ages of various objects in the universe. Describe two of these ways, and indicate how well they agree with one another and with the age of the universe itself as estimated by its expansion.
7. Since the time of Copernicus, each revolution in astronomy has moved humans farther from the center of the universe. Now it appears that we may not even be made of the most common form of matter. Trace the changes in scientific thought about the central nature of Earth, the Sun, and our Galaxy on a cosmic scale. Explain how the notion that most of the universe is made of dark matter continues this "Copernican tradition."
8. The anthropic principle suggests that in some sense we are observing a special kind of universe; if the universe were different, we could never have come to exist. Comment on how this fits with the Copernican tradition described in the previous exercise.
9. Penzias and Wilson's discovery of the Cosmic Microwave Background (CMB) is a nice example of scientific *serendipity*—something that is found by chance but turns out to have a positive outcome. What were they looking for and what did they discover?
10. Construct a timeline for the universe and indicate when various significant events occurred, from the beginning of the expansion to the formation of the Sun to the appearance of humans on Earth.