**3 – The Big Bang Theory: Observation or Speculation?**

Script

[1] The Big Bang Theory and the Origin of the Universe

[2] The Big Bang—Observation or Speculation?

[3] So far, we have learned that science is a process. / Scientists gather data from observations and experiments and eventually formulate a theory.

[4] Then they use the theory to make predictions, / and they perform experiments to test their predictions. / Over time, they may amass quite a lot of evidence that supports the theory.

[5] But sometimes the results of the experiments *don’t* support the theory. / And sometimes the theory may need to be improved or even replaced.

[6] Then the same process starts all over again. We make predictions and compare them with the results of the experiments.

[7] Then we learned about a specific theory—called the Big Bang Theory—that offers an explanation for the origin of our universe.

[8] In this presentation, we are going to take a closer look at the Big Bang as a scientific theory and try to answer a few questions. But first we need to think about the scientific process in a little more detail.

[9] In a previous video, / you have learned that the scientific process includes gathering data / and interpreting data.

[10] Scientists may get their ideas from observations they make or questions they ask. / Then they make an educated guess—called a hypothesis—about the answer to their questions. / They gather data by performing experiments / and then draw conclusions from their data.

[11] We will be asking whether the Big Bang is data, / or interpretation, / or maybe both…

[12] In another video, you learned the difference between empirical science and historical science.

[13] The scientific process we’ve been talking about so far is empirical science, / where scientists make observations, form hypotheses, experiment, and draw conclusions. / As the body of data grows, generalizations are made, resulting in theories. / Then more predictions are made and more experiments are carried out. Predictions and observations are continually compared, and theories are modified accordingly.

[14] Historical science, on the other hand, seeks to explain events in the past that were not observed and cannot be tested directly.

[15] We’ll be asking whether the Big Bang Theory is part of empirical science, / historical science, / or maybe both…

[16] In other words, / which parts of the Big Bang Theory are actually based on observations / and which parts are seeking to explain events from the past that necessarily must be more speculative in nature?

[17] We will start by learning about three kinds of observational data connected with the Big Bang Theory.

[18] For centuries, the universe had been thought to be eternal, / until some startling discoveries were made in the twentieth century.

[19] An astronomer named Vesto Melvin Slipher was the first to discover that most of the galaxies nearest to earth were moving rapidly away from us. / **(wait)**

[20] Edwin Hubble continued to study these retreating galaxies and learned that the galaxies farthest away from Earth / were moving the fastest. How were they able to tell? By measuring light waves…

[21] Light waves come in different lengths, and what humans see as colors are different wave lengths. / Wave lengths are just the distance between the top of one wave / and the top of the next wave. /

[22] The longest ones appear red, / and the shortest appear blue.

[23] When the source of light is moving away from an observer, / the light shining back toward earth appears redder because the waves are being stretched out. / This is called red shift.

[24] When the source of light is moving toward an observer, / the light appears bluer because the waves are being pressed together. / This is called blue shift.

[25] The red shift that Slipher and Hubble saw as they studied the distant galaxies is observable data. / They interpreted that data to mean that the universe is expanding, a conclusion which was also supported by other scientists who were working with Einstein’s general relativity equations.

[26] The red shift is observable data. / The conclusion that the universe is expanding / is an interpretation of the red shift data.

[27] Extrapolating backward from that conclusion, scientists inferred that at some point in the distant past the entire universe would have been infinitesimally small and infinitely dense.

[28] The term big bang was disparagingly applied by astronomer Fred Hoyle to the beginning that must, at some time in the past, have started the expansion of the universe.

[29] In addition to the red shift observed by astronomers, there was additional observable data.

[30] As scientists thought about the idea of a big bang starting the expansion of the universe, / Ralph Alpher and Robert Hermann predicted that there should still be radiation from that initial explosion detectable in the universe. Before anyone set out to purposely search for the radiation, / Arno Penzias and Robert Wilson from AT & T Bell Laboratories discovered it by accident in 1965. / While looking for something else, they detected radiation that seemed to be coming with equal intensity from all directions, instead of from the sun or any other particular object or galaxy. It seemed that the entire universe was the source of this cosmic microwave background radiation, which is exactly what would have been expected from the initial big bang radiation.

[31] Let’s see how this fits with the scientific process. / Scientists observed the red shift, inferred an expanding universe, / and extrapolated back in time, coming up with the Big Bang Theory. / Using that theory, they predicted that they should still be able to detect the leftover background radiation. / The detection of the predicted radiation provided evidence in support of the theory.

[32] It had been specifically predicted that when graphed, the radiation should form a specific curve, / called a blackbody curve

[33] Many years later, in 1990, / NASA’s COBE (Cosmic Background explorer) allowed cosmologists to measure the radiation accurately enough to see if it matched the blackbody curve. / Using an instrument designed specifically to make this comparison, scientists were able to determine that the radiation does, in fact match the predicted curve.

[34] This cosmic microwave background radiation in the specific pattern of wavelengths that matches the blackbody spectrum is observable data that matches predictions made about the big bang.

[35] In addition to the red shift observed and the background radiation detected, / we will look at one more piece of observable data.

[36] Another prediction scientists made based on the big bang theory involves the ratio of hydrogen to helium and other light elements in the universe.

[37] Based on their understanding of the structure of the elements and their behavior under various conditions, / scientists have predicted that the universe should contain approximately 75% hydrogen / and 25% helium (with tiny amounts of other elements).

[38] Measurements obtained using spectroscopic studies of the stars produce results in precisely the predicted ratios. / The existence of these elements in this ratio is observable data which matches the prediction made based on the big bang theory.

[39] Not only do the elements exist in the predicted ratios, but there is no other explanation for the existence of so much helium. (Read yellow type)

[40] To summarize: The red shift was observable data. / Scientists interpreted that data to mean that galaxies were speeding away from our galaxy, the Milky Way.

[41] Extrapolation back in time led to the big bang theory

[42] Based on this theory, / scientists predicted the existence of cosmic microwave background radiation / and the ratio of hydrogen to helium and other lighter elements. / As it turned out, the observable data matched these predictions.

[43] But it is important to distinguish between these evidence-based observations, predictions, and conclusions

[44] and other ideas surrounding the big bang theory that are NOT based on observational data. / For example, the source of all the energy contained in the original singularity is unknown.

[45] What caused the universe to begin expanding is also unknown. / About this, astronomer Robert Jastrow says that all the evidence needed for a scientific study of the cause of the great explosion was melted down and destroyed in the searing heat of that first moment.

[46] In addition, / how the particles which formed after the big bang managed to stay close enough to each other to coalesce into matter, / but far enough away from each other to avoid creating a gigantic black hole is unknown.

[47] About this, Jastrow says…”There is no explanation in the big bang theory for the seemingly fortuitous fact that the density of matter has just the right value for the evolution of a benign, life-supporting universe.”

[48] To the untrained eye, it is easy to overlook the difference between conclusions drawn from actual observations…

[49] …and ones that are only speculative explanations for certain phenomena

[50] Yet being able to tell the difference may be the single most important factor in accurately evaluating a theory and in communicating effectively with others about it.

[51] At the beginning of this presentation, we set out to determine which part of the Big Bang Theory is data and which is interpretation.

[52] And we saw that it includes both.

[53] We also asked which parts of the Big Bang Theory qualify as empirical science, / and which fall into the category of historical science.

[54] Forming theories based on observable data and using those theories to make useful predictions are definitely part of the process of empirical science.

[55] But suggesting where the energy came from or what caused it to expand falls into the category of historical science.

[56] Because that first major event, was neither observable nor repeatable, / the Big Bang theory really doesn’t explain anything about our ultimate origin. / It only raises question science can’t answer.

[57] Next time, we will explore three interesting implications of the Big Bang Theory