

This panel shows the very early history of the Universe. But to do this, it is necessary to depart from the basic ChronoZoom approach, which is to show panels with linear time scales. The problem is that the unfolding of the Big Bang has been calculated all the way back to the Planck time, 10^{-43} seconds after “the Beginning” (A). To show the Big Bang with linear ChronoZoom drawings would require 46 panels (B), and 60 panels to get to the first stars (C). So the only practical way to portray early-Universe history is on a logarithmic time scale. But since it is only about 2 more factors of ten in time from the first stars to the present day, this drawing can show the entire history of the Universe, from the “Beginning” to now. This problem and its solution point out a fundamental paradox in Big History: On a linear time scale, the Big Bang (the first 3 minutes) is a trivial fraction of Cosmic history, but on a log scale, the Big Bang, with 45 orders of magnitude, is *most* of Cosmic history!

Until the 1960s, the Big Bang theory for the origin of the Universe was controversial, and in competition with the Steady-State theory. Both were explanations for the expansion of the array of galaxies in the Universe, discovered in 1929 by Edwin Hubble and Milton Humason.¹ In the Big Bang theory, the Universe began with a “singularity,” an infinitesimally tiny point, at a particular instant in the past, in which all space and energy were created, with space expanding ever since. In contrast, the Steady-State theory saw an expanding Universe, perhaps of infinite age, that has always looked about the same, with new stars being continually created to fill the space generated by expansion. Today the latter theory is a historical curiosity, with the Big Bang almost universally accepted among astronomers and cosmologists. This acceptance is based on three overwhelming pieces of evidence:

(1) The Universe is expanding, with galaxies or galaxy clusters moving apart (D), with the rate of separation greater for more distant objects. This of course fits both the Big Bang and Steady-State theories, which were each designed to explain it. However the other two lines of evidence unambiguously support the Big Bang theory.

(2) The Cosmos is pervaded by the cosmic microwave background (CMB) radiation (E), an intense flash of light that was released when electrons combined with atomic nuclei to form the first atoms, rendering the Cosmos transparent for the first time, just as the Big Bang theory predicts. The CMB, now stretched into radio waves by cosmic expansion, was discovered in 1964, and has since been mapped in increasingly exquisite detail by the COBE, WMAP, and Planck satellites.

(3) Theory predicts that shortly after the end of the Big Bang, matter would be mostly hydrogen, with about 10% helium, and traces of lithium (the three lightest elements), formed by nucleosynthesis (F) before expansion carried the protons too far apart to fuse together. That is indeed the observed composition of the Cosmos (ignoring elements created later within stars — see “Metallicity” in Panel 1).

In contrast to the Steady-State version, the now-accepted Big Bang theory shows that the Universe is a historical object, with a definite beginning now dated at about 13.8 billion years.² The universe has had a particular history, which astronomers and cosmologists are now working out. The character of the universe was set up during the 3-minute history of the Big Bang, portrayed in this panel, and the working out of the consequences over 13.8 billion years of history is shown in Panel 1.

The expansion of the Cosmos has not been regular. Not only is the rate of expansion now accelerating (D), but the Cosmos is thought to have undergone an episode of extremely rapid expansion early in the Big Bang, called cosmic inflation (G).³ The inflationary episode was extremely brief, from about 10^{-36} to 10^{-33} seconds after the beginning, but would have expanded the dimensions of the Cosmos by maybe 50 orders of magnitude.⁴ Proposed in 1981 by Alan Guth,⁵ the cause of inflation remains controversial, but it explains a number of unexpected features of the Cosmos, notably the question why an initially homogeneous Big Bang could produce a Universe with matter clumped into galaxies and clusters of galaxies; inflation would

have magnified initial quantum fluctuations into the clumping we see today.

As the initially tiny Universe cooled, it went from conditions too hot for any matter to exist, into cooler (relatively speaking!) conditions in which different kinds of matter successively appeared. Cosmologists divide the sequence of conditions into six “epochs” — an amusing word, since the first three lasted only tiny fractions of a second! During the first two epochs energy existed, but no matter, and the four forces (gravity, electromagnetism, and the strong and weak nuclear forces) were in part combined. The initial Grand unification epoch (H) saw only gravity distinct from the other three combined forces, and in the subsequent Electroweak epoch (I), the strong nuclear force also separated and became distinct. Inflation occurred during this epoch.

The era of matter⁶ began with the Quark epoch (J), with quarks being the particles that combine in threes to make protons, neutrons, and the related heavy particles. By a microsecond after the singularity that initiated the Big Bang, the Universe had cooled to the point where free quarks could combine, starting the Hadron epoch (K). Electrons and related particles appeared at one second post-singularity, the start of the Lepton epoch (L). The beginning of the Photon epoch (M) at 3 minutes is commonly taken as the end of the Big Bang proper.⁷ This was also the time when some protons (hydrogen nuclei) combined to form the 10% helium which provides evidence supporting the Big Bang theory. During the Photon epoch, electrons could not yet attach to atomic nuclei (H and He), so the Universe was full of plasma — charged particles that scatter photons. When the Universe cooled to the point where electrons and nuclei could combine (“Re-combination” is confusing jargon), the scattering of light stopped, the Universe became transparent, and the CMB was released — the other observation that supports the Big Bang theory. The subsequent Dark Age (N) and Stelliferous (Starry) Epochs (O) are considered in the Cosmos panel (Panel 1).