Panel 1: Cosmos (13.8 Ga to now)

This panel portrays the entire history of the Universe, spread out on a linear plot. Astronomers and cosmologists have come to an interest in the history of their subject more recently than other historians and historical scientists,[1] and the relevant literature reflects this preliminary character. Unlike other Big Historians, astronomers can actually *see* the past, by looking at galaxies so far away that the light they see has taken billion of years to get to us. Of course very distant galaxies look tiny, and cannot be imaged in detail. The traditions of astronomy are not geared to historical understanding: In the first place, ages of distant objects are not usually given in years, but as red shift — how much the light waves have stretched, due to cosmic expansion — this is understandable, because red shift can be measured directly, but age must be calculated based on imperfectly known parameters **(A)**. Second, distances are commonly given in parsecs, which may be converted to light years, which are of more interest to Big Historians (1 pc = 3.26 l.y.).

Perhaps the most fundamental, essential feature of all of Big History is that the Universe, colossal to a degree that utterly defies comprehension, has been expanding since the beginning of time, with the space between galaxies or between galaxy clusters gradually stretching. Tracing that expansion backward brings us to the Big Bang — the sudden appearance of everything, 13.8 billion years ago — which is treated in logarithmic Panel 0 **(B)**. Cosmic expansion has not been steady — it surged during the period of inflation, early in the unfolding of the Big Bang.[2] More recently, rather than slowing because of gravitational attraction, as cosmologists had expected, expansion is *accelerating*, due to the mysterious phenomenon of dark energy. The evidence for accelerating expansion and dark energy is plotted here **(C)**.[3]

Immediately after the Big Bang, the normal matter in the Universe (excluding dark matter) was essentially all hydrogen and helium. The heavier elements (which astronomers call "metals") were generated in stars by nuclear fusion and spread throughout the galaxies by supernovas — by the explosions of stars that have used up most of the hydrogen fuel that powers them as it fuses to form helium. As a result, the metallicity of the universe — the content of elements heavier than helium — has gradually increased through time **(D)**.[4] (The graphs used here are not recent, but are unusual examples of Cosmic-history plots from the astronomical literature.)

The metallicity of a star, detected by its spectroscopic absorption lines, is given by the ratio of the number of iron atoms to hydrogen atoms, divided by the same ratio in the Sun, whose Fe/H ratio is defined as 1; metallicity is shown here on a log plot. The history of metallicity is not easy to determine, and is probably different in different parts of different galaxies; these problems are reflected in the wide range of uncertainty in this plot. Hints of the historical evolution that probably underlies each galaxy are seen in the fact that stars in the darker halo of the Milky Way are older (of lower metallicity) than those, like the Sun, that lie in the thin bright disk.[5] There are also hints that there may have been a gap in time between formation of these two stellar populations.[6]

Astronomers have two ways of learning about the past — they can look at very distant galaxies, seeing them as they were when the light was emitted, billions of years ago, or they can look for very old stars in the Milky Way and nearby galaxies. The first method yields discoveries about Cosmic events **(E)** back to nearly the beginning of the Stelliferous (Starry) epoch. At the distances for which objects are far enough away to be seen as they were early in Cosmic history, individual stars cannot be resolved, and galaxies are the objects of study. Vast numbers of early galaxies are seen in the Hubble Deep Field (HDF), Hubble Ultra-Deep Field (HUDF), and Hubble Extreme Deep Field (XDF) images,[7] and can be treated statistically. As of 2016, the oldest known galaxy (i.e., with the greatest red shift) is GN-z11, dating from 13.4 Ga, or just 400 Myr after the Big Bang.

In these deep images, there are galaxies of a whole range of ages (as suggested by their size and brightness, and measured by their red shift), so it is possible to recognize a general pattern of galactic evolution. Events that may occur in the history of a galaxy include the formation of a central black hole, or of the kind of supermassive black holes that power the enormously energetic quasars, whose rate of formation peaked about 11-13 Ga;[8] collisions between galaxies, in which gravitational disruption as one galaxy passes through another turns the spirals into a structureless elliptical galaxy;[9] and the progressive conversion of spiral galaxies like our neighbor Andromeda, into barred spirals like the Milky Way.[10] We can expect a great enriching of this picture of Cosmic history over the next few decades.

Returning to historical events about which we know a great deal, the origin of the Sun, the Earth, and the Solar System occurred about 1/3 of the way back through Cosmic history **(F)**. (In fact the easily-remembered age of the Earth, 4.567 Ga is *exactly* 1/3 of 13.7 Ga, which was the best age value for the Cosmos until the recent adjustment to 13.8 Ga. (Too bad!) By the time Earth formed, there had been enough time for "metals" to become abundant through stellar nucleosynthesis, and enough supernovas to spread them around, so that our planet could contain all the chemical elements that make it interesting and suitable for life. Much older stars could not have rocky planets like Earth. The next panel shows the history of the Earth, **(G)** about which a very great deal more is known.