The Early Universe

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The prevailing scientific view is that the universe is not uncreated but has a beginning. The theory of the Big Bang is the most accepted theory in recent decades to explain how the physical universe emerges.

Much of understanding the Big Bang is extrapolating between knowledge of particle physics today, and projections from the mathematical model of an expanding universe in general relativity. The Einstein equations give us a mathematical model for describing how fast the Universe would expanding at what size and time, given the energy density of matter and radiation at that time.

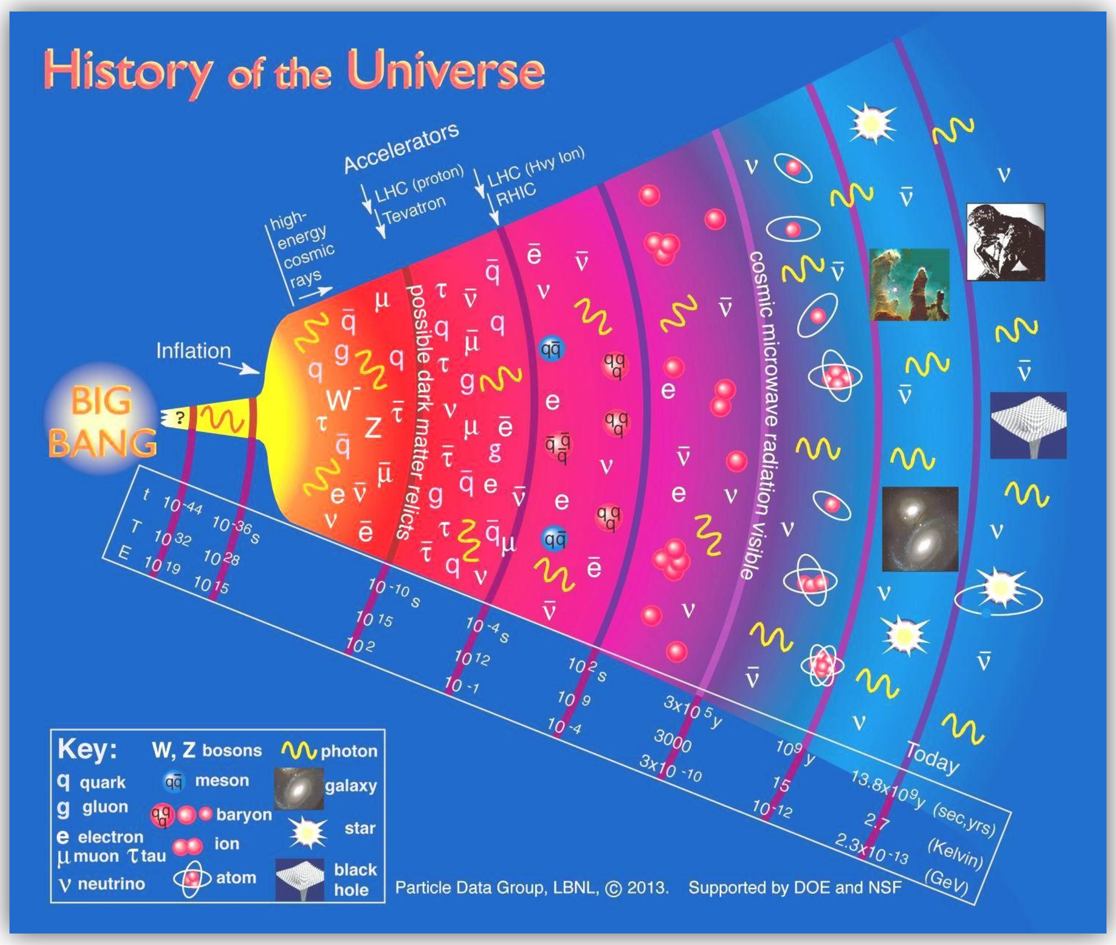

Figure 1: Timeline for the universe.

It is believed that the matter in the universe was created during the Big Bang about 13.8×10^{9} years ago as illustrated in Figure 1. This cosmological model describes the initial conditions and subsequent development of the universe. After the Big Bang, the universe continued to grow in size and fall in temperature. At about 10^{-6} seconds, a quark-hadron phase transition happened when the universe was at a temperature T_c of approximately $150–200\ MeV$.

Timeline of the Early Universe

In the very early moments, the description is a guess because man did not reach such conditions for subjecting them to experience. Before a time classified as a Planck time, 10^{-43} seconds, all of the four fundamental forces are presumed to have been unified into one force. All matter, energy, space and time are presumed to have exploded outward from the original singularity. Nothing is known of this period.

It is not that we know a great deal about later periods either, it is just that we have no real coherent models of what might happen under such conditions. The electroweak unification has been supported by the discovery of the W and Z particles, and can be used as a platform for discussion of next step, the Grand Unification Theory (GUT).

In the era around Planck time, 10^{-43} seconds, it is projected by present modeling of the fundamental forces that the gravity force begins to differentiate from the other three forces. This is the first of the spontaneous symmetry breaks which lead to the four observed types of interactions in the present universe.

At a time around 10^{-36} seconds, present models project a separation of the strong force. Before this time the forces other than gravity would be unified in what is called the grand unification.

In the 1970's. Glashow and Georgi proposed the grand unification of the strong, weak, and electromagnetic forces at energies above $10^{14} GeV$. If the ordinary concept of thermal energy applied at such times, it would require a temperature of $10^{27} K$ for the average particle energy to be $10^{14} GeV$.

Though the strong force is distinct from gravity and the electroweak force in this era, the energy level is still too high for the strong force to hold protons and neutrons together, so that the universe is still a "sizzling sea of quarks".

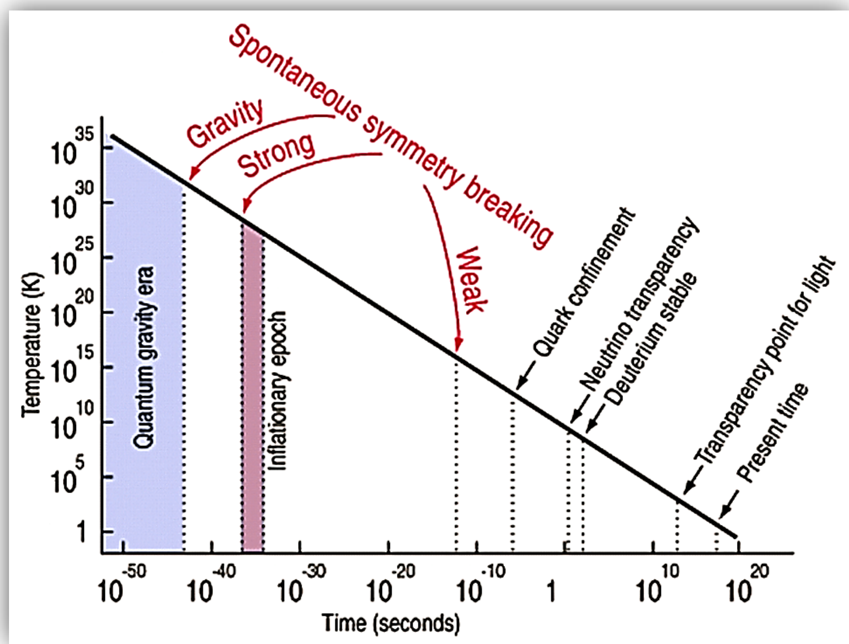

Figure 2-a: Unification and separation of the fundamental forces

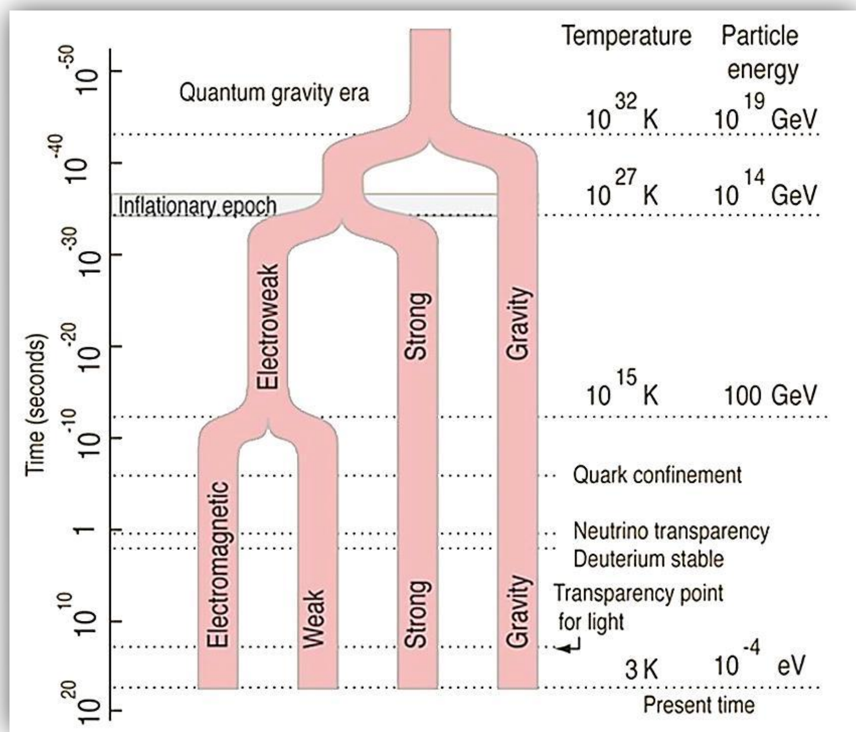

Figure 2-b: Unification and separation of the fundamental forces

Inflationary Period

Triggered by the symmetry breaking that separates off the strong force, models suggest an extraordinary inflationary phase in the era 10^{-36} seconds to 10^{-32} seconds. More expansion is presumed to have occurred in this instant than in the entire period (14 billion years?) since.

The inflationary epoch may have expanded the universe by 10^{20} or 10^{30} in this incredibly brief time. The inflationary hypothesis offers a way to deal with the horizon problem and the flatness problem of cosmological models.

Many physicists also believe that inflation explains why the Universe appears to be the same in all directions (isotropic), why the cosmic microwave background radiation is distributed evenly, why the Universe is flat.

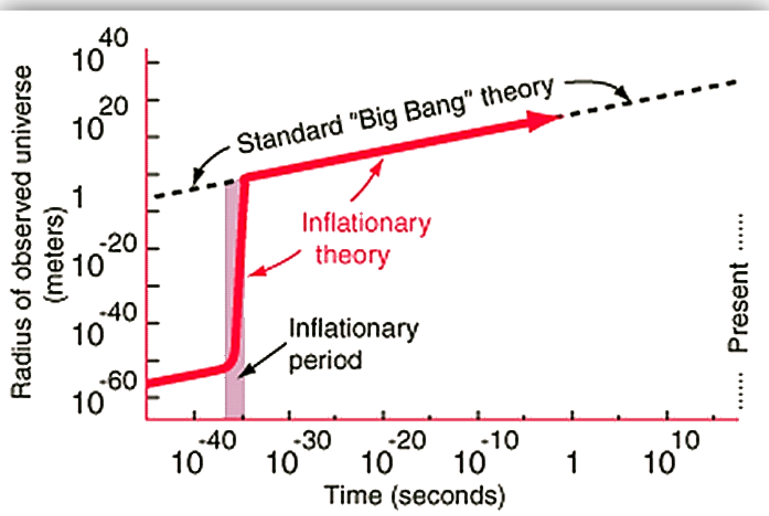

Figure 3: Inflationary Universe

Matter and Antimatter

We know from observing elementary particles in the present era that every known particle has an antiparticle with the opposite charge and the same spin. At the beginning of the Big Bang, the Universe was so hot that quarks and antiquarks were created from radiation and annihilated back into radiation at a high rate. There were an equal number of quarks and antiquarks on the average at any one moment. But as the Universe expanded, it cooled, and the cooler radiation was less likely to create quark-antiquark pairs. As quarks and antiquarks "froze" out of the radiation background, a greater number of quarks than antiquarks was left over.

This time period is estimated at 10^{-32} seconds to 10^{-5} seconds. During this period the electromagnetic and weak forces undergo the final symmetry break, ending the electroweak unification at about 10^{-12} seconds.

Quark Confinement

When the expansion of the "primordial fireball" had cooled it to $10^{13} K$, a time modeled to be about 10^{-6} seconds, the collision energies had dropped to about 1 GeV and quarks could finally hang onto each other to form individual protons and neutrons (and presumably other baryons). At this time, all the kinds of particles which are a part of the present universe were in existence, even though the temperature was still much too high for the formation of nuclei.