THE BIG BANG — 13.7 BILLION YEARS AGO

The Universe is born in an instant in time and expands outwards from one infinitessimally small point.

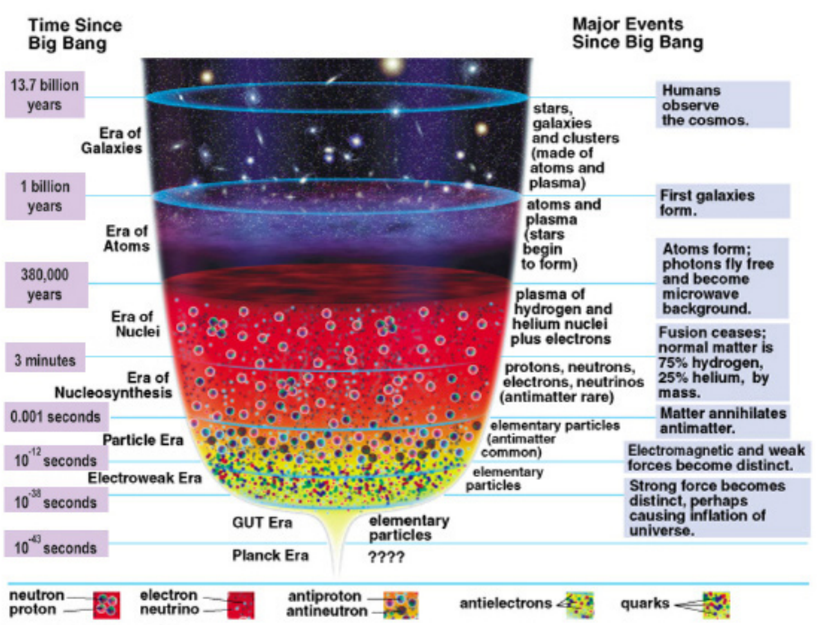
Astronomers observe that galaxies surrounding our galaxy are moving away from us. Rather than indicating that we are special, the observation shows that space itself is stretching, pulling all galaxies, including ours, with it. In other words, our Universe is expanding. If we imagine running a movie of the expanding Universe backwards, we move back in time to when galaxies were much closer together. If we continue running time backwards, we come to the beginning of the Universe, 13.7 billion years ago. There must have been a big explosion of energy – the Big Bang – that created the Universe. Why did it happen? What existed prior? There are more questions than answers to this puzzle. But here is what we know:

The Planck Era — From 0 to 0.00000000000000000000000000000000000000001 (or 10^{-43}) seconds

The Universe is incredibly HOT – 10^{32} Kelvin – and infinitessimally small – smaller than scientists can measure (two points separated by this distance are indistinguishable from each other). No distinction exists between what will later be the four fundamental forces of nature – gravity, electromagnetism, the strong force, and the weak force.

The GUT Era — From 10^{-43} to 10^{-35} seconds

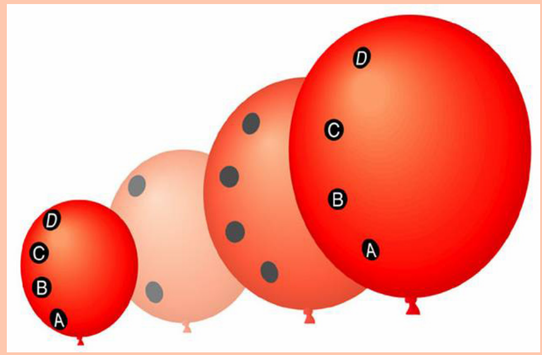
The Universe is incredibly dense (10^{75} g/cm^3 — the entire Milky Way galaxy could easily be stuffed into a volume no larger than a single hydrogen atom) and about a billion billion billion times hotter than today. This early Universe contains only energy and the simplest elementary particles (electrons and quarks) and their anti-particles. Gravity separates from the other fundamental forces, together described by The Grand Unified Theory *(GUT.)*



Major events since the Big Bang — modified from an image by Addison Wesley Publishers ©.

Expanding Universe Balloon Theory

The surface of the balloon represents the entire Universe. There is no inside or outside of the balloon. The dots represent galaxies.



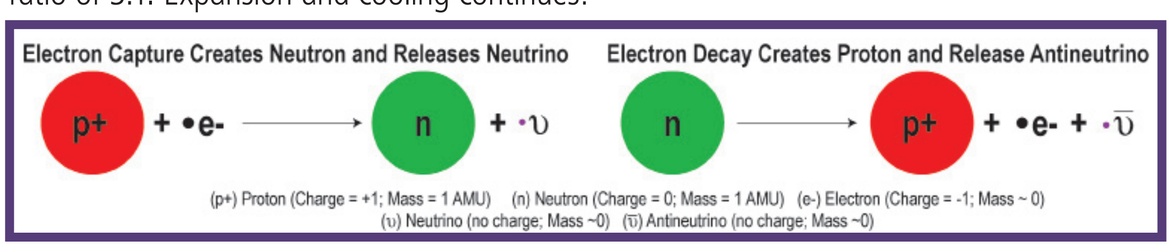
- Space itself is expanding and the galaxies are pulled with it.
- From any galaxy's point of view, the other galaxies are all moving away from it.

The Electroweak Era — From 10^{-35} to 10^{-12} seconds

The strong force breaks away from the others, creating, in the process, a negative pressure that causes the Universe to expand by a factor of 10^{50} (100 trillion trillion trillion trillion) in 10^{-32} seconds to about the size of a grape. Particles of light – **photons** – continue to collide, transforming into matter and antimatter, giving rise to a soup of elementary particles.

The Particle Era — From 10^{-12} to 0.001 (or 10^{-3}) seconds

Particles and antiparticles collide and annihilate each other. Out of every two billion and one particles and antiparticles created by the Universe, only one particle survives. These include protons and neutrons: the building blocks of atomic nuclei. The electromagnetic and weak forces separate, establishing a Universe in which the physical laws and the four distinct forces of nature are as we now experience them.

The Era of Nucleosynthesis — From 0.001 seconds to 3 minutes

Neutrons and protons rapidly change into each other (*see graphic below for explanation*). As the Universe continues to expand and cool, these changes slow. By 100 seconds, with temperature at a billion K, neutrons and protons can stick together during collisions to form a nucleus. All resulting nuclei are ions, as electrons are still too hot to settle down in orbitals around the nuclei. Hydrogen (H) and Helium (He) nuclei are created, in a mass ratio of 3:1. Expansion and cooling continues!