Science for Everyone

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Chapter 1

Back to the beginning

We can't build a space ship that goes backwards in time or faster than light. But let us imagine we have such a space ship. It can take us to any place and to any time. It moves faster than light. It moves at the speed of thought.

We don't need to worry about heat or radiation or pressure or space junk or meteors or stars or black holes. Nothing outside our ship can hurt us. Our spacetime ship protects us from everything. We can go backwards in time in our spacetime ship, but we can't change anything outside the ship.

We can go back to 1963, but we can't get out and stop the assassination of John F. Kennedy. We can go to Wall Street in the depths of the great depression of the 1930's, but we can't get out and buy shares of GE or GM at depressed prices. We can go back to 1865, but we can't save Lincoln. We can go back to 33, but we can't stop the crucifixion of Jesus. We can only look out the windows of our ship. Our spacetime ship protects everything from us.

We get in our spacetime ship, fasten out seat belts, and go backwards in time. We go back many thousands of years, back before people invented science or law or money or writing or religion or tools or languages. We go back millions of years, before some lucky apes evolved into human beings. We go back more than five thousand million years, back before our Sun, our planet Earth, and our solar system condensed out of the ashes of exploded stars. We go all the way back before the universe flashed into existence in the Big Bang nearly 14 thousand million years ago.

We look out the windows of our spacetime ship and see absolutely nothing. It's dark, cold, flat, and empty. Quantum mechanics tells us that everything fluctuates. So there must be fluctuations, but they are too tiny to see.

The energy in any spot of space rises and falls randomly. The smaller the spot, the wider are these fluctuations. We would have to wait a long time for any spot to vary by a large amount. Our pilot knows when and where that will happen. We go to that spot at that time and watch the energy of the spot jump. We don't know how big the spot is. It may be as big as 4 mm or smaller than an atom. We also don't know how high its energy goes.

In the spot, the kind of energy that jumps to a very high value is **potential energy**. Throw a ball up. The energy of motion of the ball becomes potential energy as it stops rising. As the ball falls, its potential energy changes to **kinetic energy** or energy of motion. The potential energy of the spot suddenly jumps to a value that is absurdly high for so small a spot.

Ordinary quantum mechanics would require the energy of the spot to go right back to its normal value of zero very quickly. Big fluctuations are brief. But gravity responds to the energy of the spot and slows its return to zero. Gravity also expands the spot. Right before our eyes, gravity stretches the tiny spot in less than a thousandth of a millionth of a second (a nanosecond) to a sphere more than 100 million km in radius. Alan Guth called this exponentially fast stretching of space **inflation** in 1981, when the US was suffering from monetary inflation.

After less than a nanosecond, the potential energy of the spot changes to radiation. This is the **Big Bang**. Our universe suddenly becomes so hot that we don't know how to describe it. Luckily our spacetime ship is well air-conditioned.

About a tenth of a nanosecond after the Big Bang, the universe has cooled to about ten thousand million million degrees, 10^{16} K, which is the highest temperature at which we understand what physics is like. Above that temperature, all elementary particles are, as far as we know, massless. Below it, they interact enough with the Higgs boson to become massive. The European Center for Nuclear Research (CERN) announced their discovery of the Higgs boson on 4 July 2012. A Higgs boson weighs about as much as an atom of cesium, which has an atomic weight of 132.9.

About a tenth of a thousandth of a second later, the temperature has dropped to a million million degrees, 10^{12} K. Below this temperature, gluons can hold quarks together to form protons and neutrons and many other particles.

About a second later, the temperature has dropped to ten thousand million degrees, 10^{10} K, and the universe becomes transparent to neutrinos, which are very light neutral particles. About a thousand million million neutrinos pass through our bodies every second without harming us. There are three kinds of neutrinos.

During the next three minutes, some of the protons and neutrons combine to form helium nuclei. After the first three minutes, the most common nucleus in the universe is hydrogen at 74 percent of all ordinary matter, and the second most common element is helium at 24 percent (by weight) of all ordinary matter. Other elements, mostly made later in stars, amount to only 2 percent of ordinary matter.

Most matter doesn't interact much with light and is called **dark matter**. Dark matter makes up about 84 percent of all matter. The atoms we know about make up only 15.7 percent of all matter.