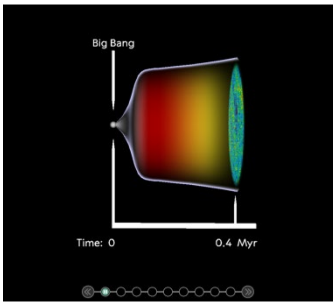
THE NOBEL PRIZE

Teacher's Guide – Nobel Prize in Physics 2019
James Peebles – For theoretical discoveries in physical cosmology

1) Time 0: The Big bang

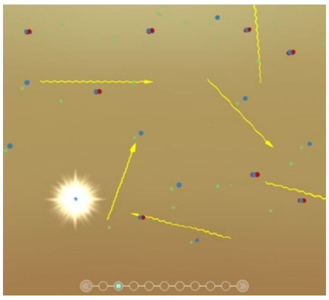


Here we see the moment when the universe began to expand, which we call the "The Big bang". The term Big bang is however misleading. It was not an explosion of matter into a previously empty space, but an expansion of the very space in which matter was located.

The entire universe that we can observe then existed as a single point, and the expansion formed space, time and matter as we know it. After one second, the universe was extremely dense and hot (about 1 billion degrees Kelvin), like a thick impenetrable glowing porridge-like gas of elementary particles such as electrons, quarks and photons. Because of the high temperature, stable atoms had not yet been formed.

The Big bang left behind microwave radiation (the same type that we have in our microwave ovens). By rotating the visualisation – for example by holding down the left mouse button on the visualisation and rotating it to the left – you can see this radiation at 400,000 years after the Big bang as a lumpy disk. We can still detect the remnants of this radiation, which we refer to as cosmic background radiation. It is for the calculations and the properties of this background radiation that James Peebles was awarded the 2019 Nobel Prize in Physics.

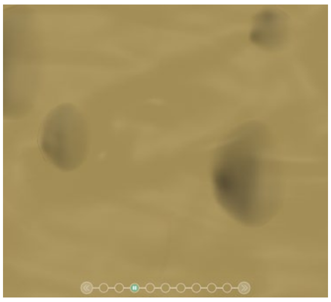
2) The formation of atoms



By using the lower "View menu" and choosing the next view (View 2), we now zoom in on the dense, hot porridge-like matter that has begun to cool off. We see how atomic nuclei of hydrogen, helium and a small amount of lithium is formed. We also see how electrons, neutrons and protons try to form entire atoms, but photons (shown as yellow arrows) collide with the atoms and prevent their formation. After more time had passed, the atoms started to become more stable.

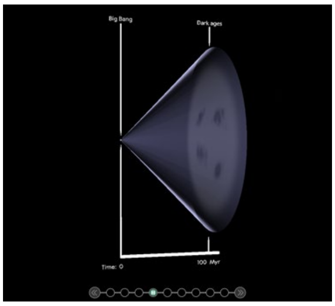
Due to the expansion matter cooled down, and then the first stable atoms were able to form (mainly hydrogen and helium).

3) 0.4 M years: Galaxies started to form



In View 3 we zoom in on 400,000 years after the Big bang. Atoms have now formed and the universe have become transparent. Matter vibrate and form sound waves. These sound waves help to shape the gas into clump-like structures that are pulled together by gravity. What we see is a precursor of the galaxies that would later be formed.

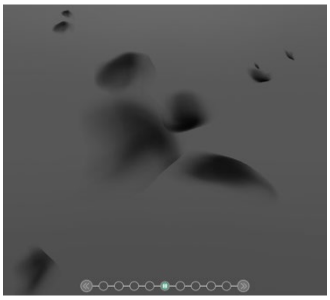
4) 0.4M-100 M years: The Dark ages



In View 4 we see how the universe continue to expand and cool off. The photons that had previously given the universe a glowing orange colour, change with the expansion into wavelengths that are not visible to us. By rotating the visualisation, at the far end of the expansion we now see black clouds/future galaxies.

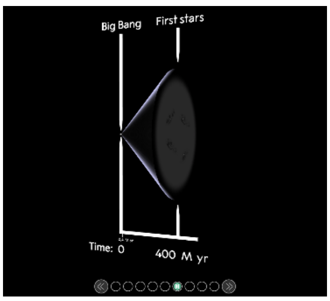
No stars had formed yet in these galaxies, and there was thus no visible light. We call this the Dark ages.

5) 80-100 M years: The first galaxies



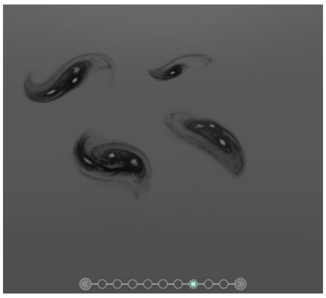
In View 5 we now zoom in on the Dark ages and see dark structures that will become galaxies. These future galaxies consist mainly of hydrogen gas that is held together by gravity and unknown dark matter. Because of gravity, the galaxies also begin to rotate around each other and pull together in bigger clusters. As a result, the galaxies will eventually assume a disk-like spiral shape.

6) 400 M years: The first stars



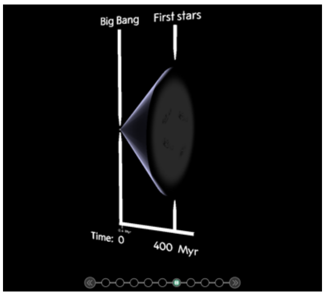
In View 6 we continue the constant expansion, and at the far end we now see the first galaxies. In these galaxies, hydrogen atoms are pulled together by gravity, forming helium by means of fusion. In this reaction, large quantities of energy is released that heats the gas and in begins to glow. The universe has its first stars.

7) 400 M years: The first stars, zoom in



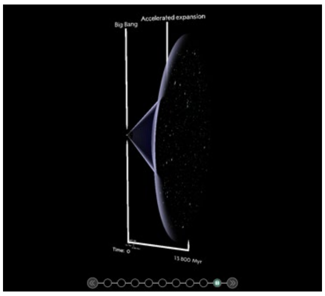
In View 7, we zoom in and see how the first stars begin to form in the rotating galaxies.

8) 1000 M years: The first planets



In View 8 we see the continued constant expansion of the universe. By rotating the visualisation, at the far end we now see the first galaxies with shining stars. In these galaxies, which rotate around each other, planets has now also been formed.

9) 13 800 M years The expansion accelerates



In View 9 we see how, about 4 billion years ago, the expansion of the universe begin to accelerate. If we rotate the visualisation, we see how the expansion of the universe might conceivably have looked.

In order for increasing acceleration to be possible, dark energy is needed. This dark energy drives the expansion of the universe and makes it go faster. Thanks to the nobel laureate James Peebles, we know that the universe consists of about 5 % matter as we know it, 26 % dark matter (which we do niot know what it consists of) and 69 % dark energy. But what dark energy is, remains one of the greatest mysteries of physics.