THE HISTORY AND FATE OF THE UNIVERSE

Ancient light from sources billions of light-years away, such as galaxies and the cosmic background radiation, show us events occurring billions of years ago. These events map out the history of the universe and even predict its fate. The scales in this figure are often greater by many orders of magnitude than can be shown here (especially for inflation).

The Big Bang, Inflation & the Expanding Universe

The universe has been expanding since an initial moment called the Big Bang that occurred 13.8 billion (13.8 x 10^9) years ago. The earliest expansion – called "inflation" – was extraordinarily rapid and smoothed out any wrinkles or imperfections, just as we can stretch out a wrinkled fabric. After inflation ended in a tiny fraction of a second, the universe continued to expand, becoming cooler and less dense. The expansion causes the distance between distant galaxies to increase, and thus the distance from us to them.

A Relic from the Early Universe

For the first 380,000 years the universe was so hot that hydrogen atoms had not yet formed, but were separate electrons and protons. Photons, the particles of light, bounced back and forth from collisions with the electrons. With further cooling, the electrons and protons stuck together in neutral atoms, nearly invisible to the photons, which then escaped. We can see these very same photons today. After traveling for 13.8 billion years they arrive, but with their wavelength stretched by a factor of 1100, since the universe itself has stretched by this factor during that time.

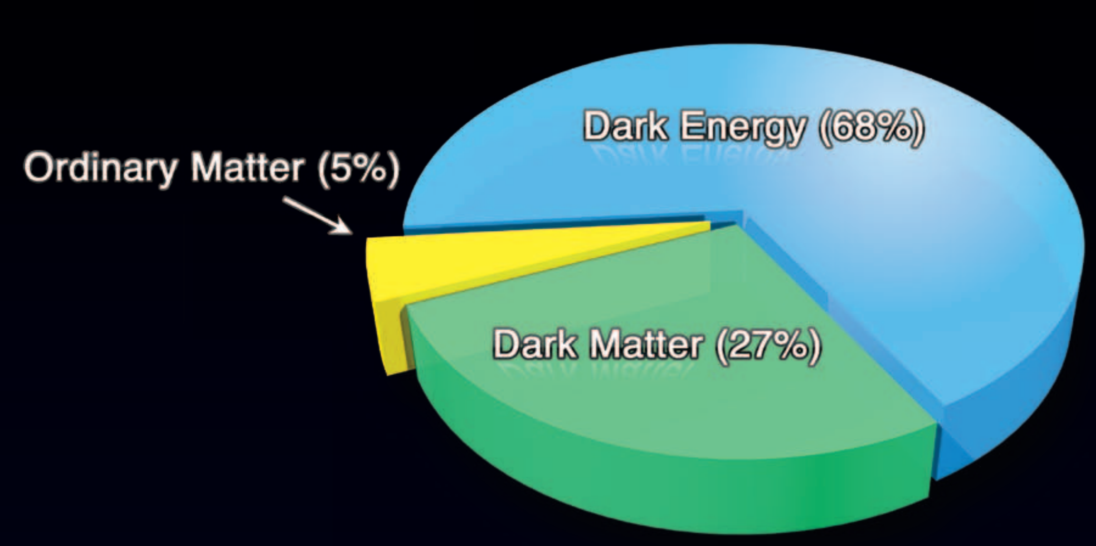
This Cosmic Microwave Background (labeled in the central figure) is nearly the same viewed in every direction. The very small variations – a part in 100,000 – are evidence of the small variations, which grew through gravitational attraction, to make the much larger variations we see today, things such as galaxies and solar systems.

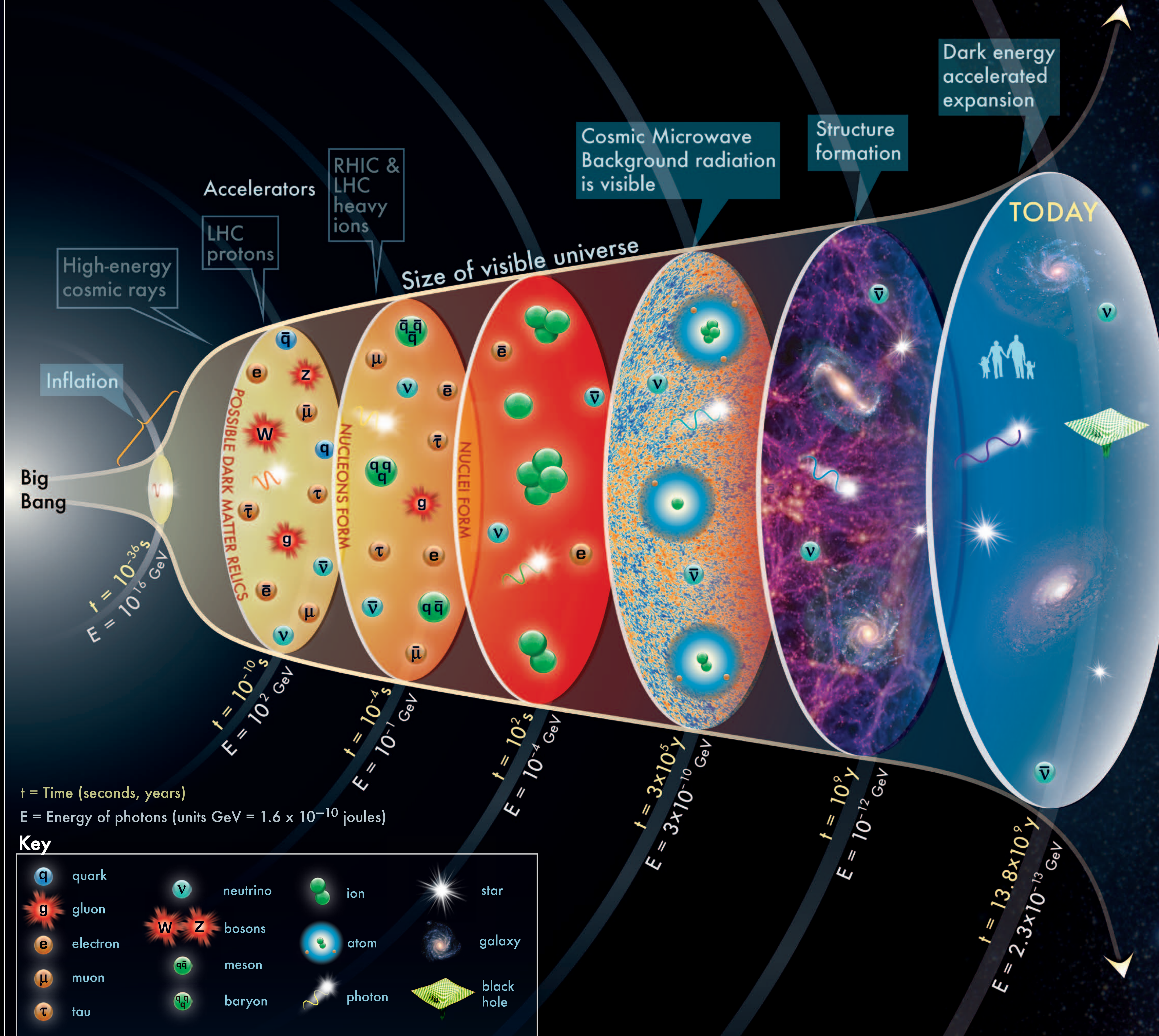
Dark Matter

Astronomers discovered that stars far out in a rotating galaxy move just as fast as those nearer the center. This is completely unlike our solar system where the innermost planets move the fastest. This couldn't happen if the matter in the galaxy is concentrated where we see stars; there must be much more unseen matter in the galaxy. This matter doesn't emit light or reflect it, so we call it dark matter. Since dark matter doesn't clump together with ordinary matter, we believe it interacts only feebly with the matter that makes up stars, planets, and people.

We have observed the results of a collision of two clusters of galaxies where the dark matter from the two clusters seems to have passed right through the other cluster, leaving behind the debris from the collision of the ordinary gas in the two clusters. Detailed measurements show that there is about six times more dark matter than ordinary matter in our universe.

Composition of the Universe





The concept for the above figure originated in a 1986 paper by Michael Turner.

Our Cosmic Address

Our sun is one of 400 billion stars in the Milky Way galaxy, which is one of more than 100 billion galaxies in the visible universe.

Invisible Skeleton of our Universe

Dark matter played a crucial role in the early universe creating all the structures we see today. Gravity caused the dark matter to coalesce into strands forming an invisible skeleton, as shown in the central figure (indicated by "Structure formation"). The gravity from the dark matter pulled ordinary matter to it. Then galaxies grew at the intersections of these filaments.

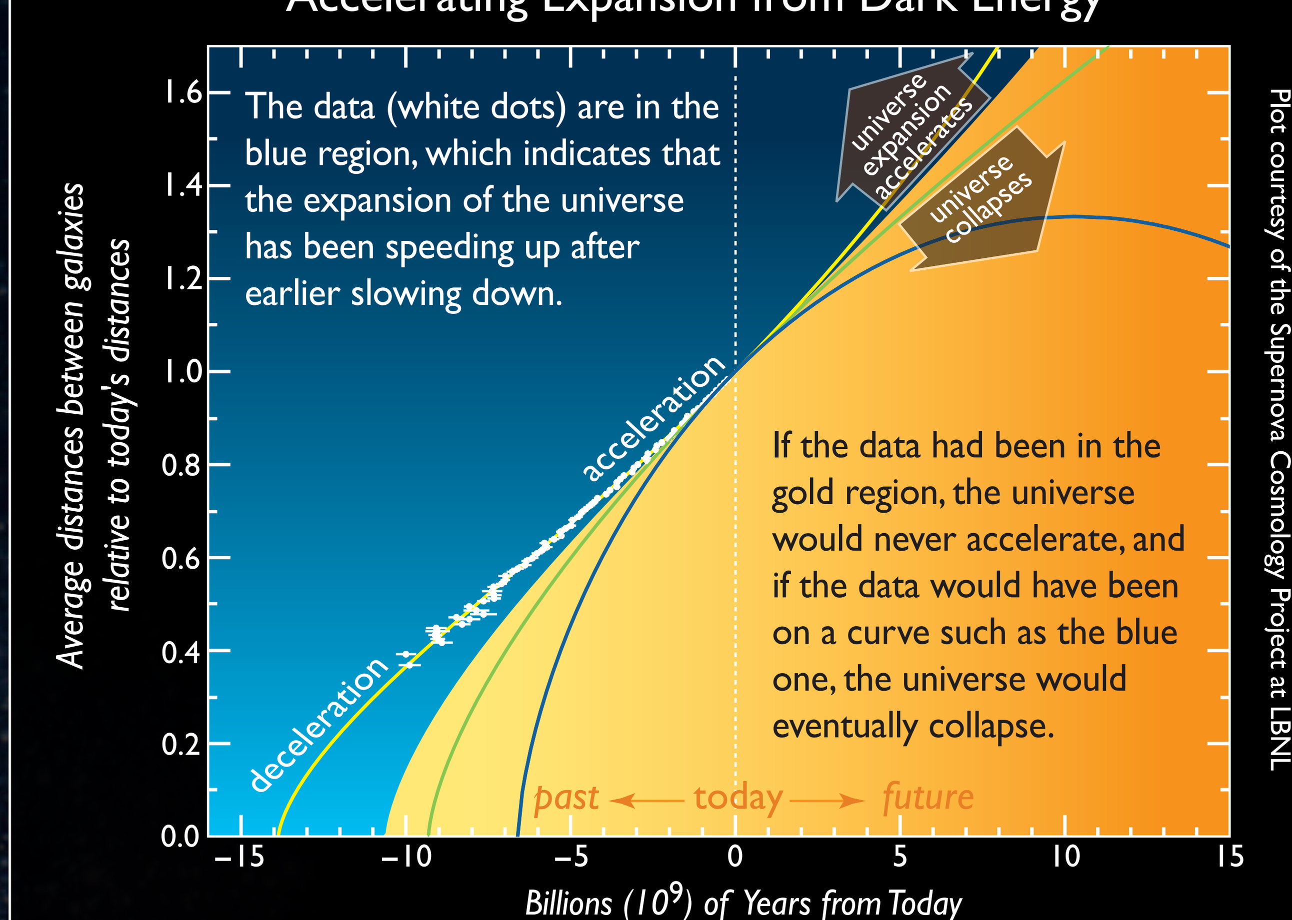
Dark Energy and the Accelerating Universe

By making detailed observations of distant supernovae, which are stars that exploded long ago, scientists discovered that the expansion of the universe is getting faster and faster instead of slowing down as would be expected from the effect of gravity pulling everything back together.

The plot shows data (white dots) from distant supernovae. From the brightness of a supernova we can infer how far away it is. By measuring the wavelengths of light from the supernova, we can determine how much the universe has expanded since the supernova explosion. Combining these gives the expansion history of the universe.

The yellow curve, with the best fit to the supernovae data, shows that about 6 billion years ago the expansion of the universe began to accelerate (the data curve upward slightly). This can only be explained by hypothesizing a new form of energy called "dark energy," which must be unlike any previously known source of energy.

Accelerating Expansion from Dark Energy



The Fate of the Universe

Whether the expansion of the universe will speed up, slow down, or even reverse into collapse depends on the types and amounts of matter and energy in it. Current observations imply that the universe will keep expanding forever, with galaxies becoming ever more distant from one another.

We have an excellent understanding of ordinary matter and all the particles discovered at accelerators, but these account for less than 5% of the energy and matter in the universe. The natures of dark energy (68% of the universe) and of dark matter (27%) are two of the greatest challenges scientists face today.

Learn more at UniverseAdventure.org and at CPEPphysics.org

This chart has been made possible by the generous support of: **U.S. Department of Energy and Lawrence Berkeley National Laboratory.** Photos courtesy of **NASA.**