Introduction to Cosmology

Big Bang-Big Crunch-Dark Matter-Dark Energy

The Story of Our Universe

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The Age of the Universe

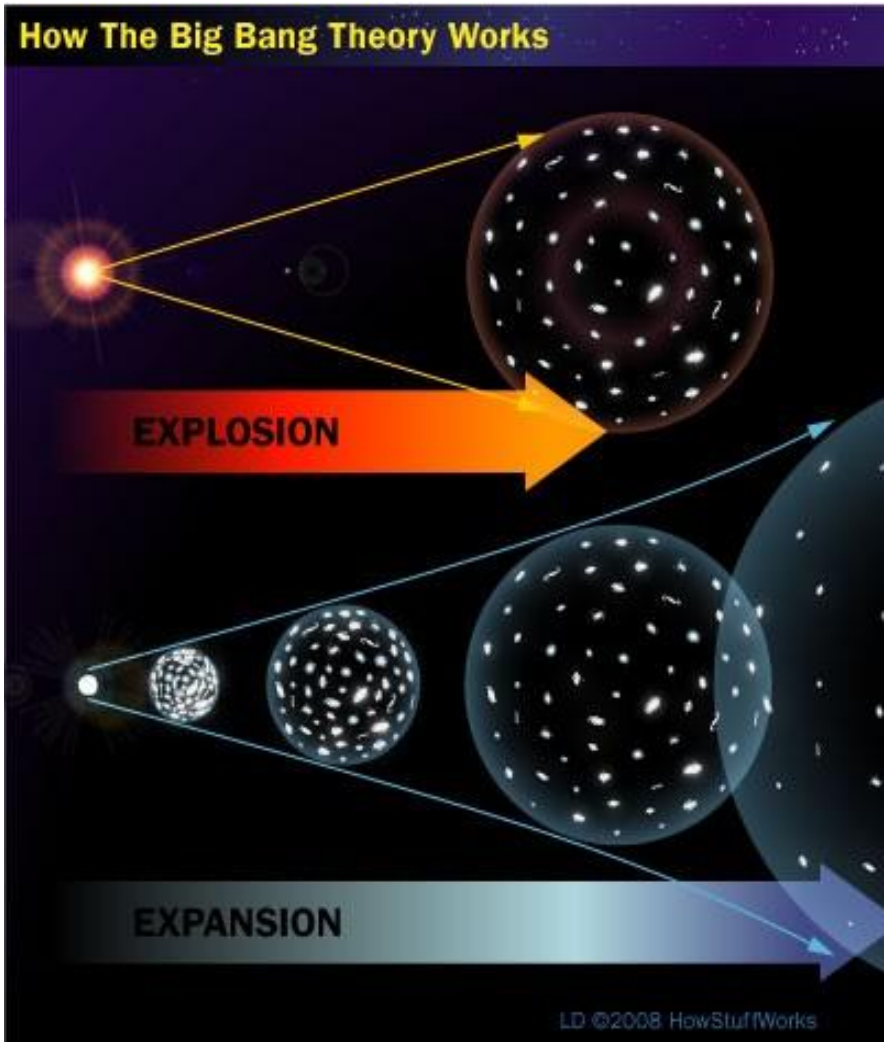
- Through various measurements and experiments, the scientists believe that the age of the universe is around 13.8 billion years.

Big Bang – Creation Theory

- Many scientists now believe that the universe was created through the Big Bang Theory.
- According to the Big Bang theory, the universe was born as a very hot, very dense, single point in space.
- Before Bing Bang there was nothingness in the universe.

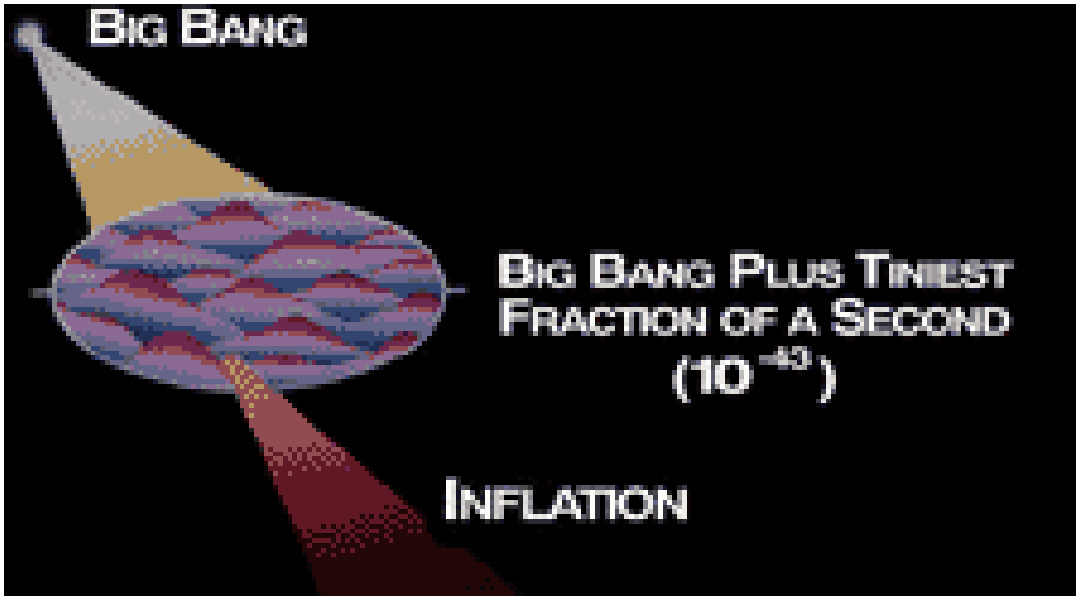
A Giant Bubble in the Beginning

- During the first roughly 10 to the minus 34 seconds (0.00000000000000000000000000000001 seconds), the universe underwent exponential expansion, doubling in size at least 90 times. During this early stage, matter was in a much different state than it is now.



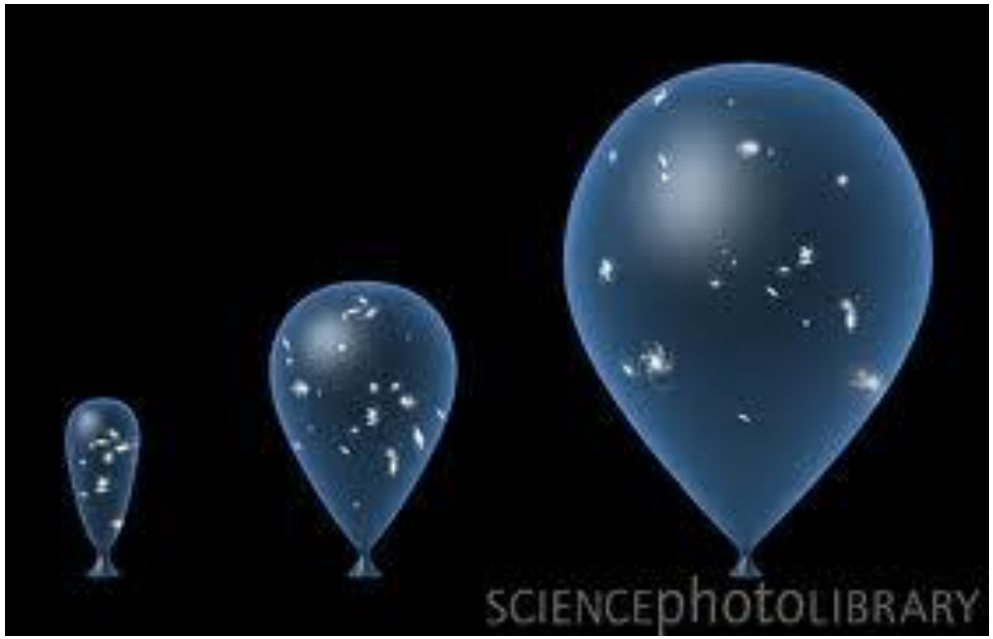
Expansion in the First Moments

- At the beginning of existence, the universe had a temperature of 1×10^{32} degree Celsius and only covered a region of 1×10^{-33} centimeters.



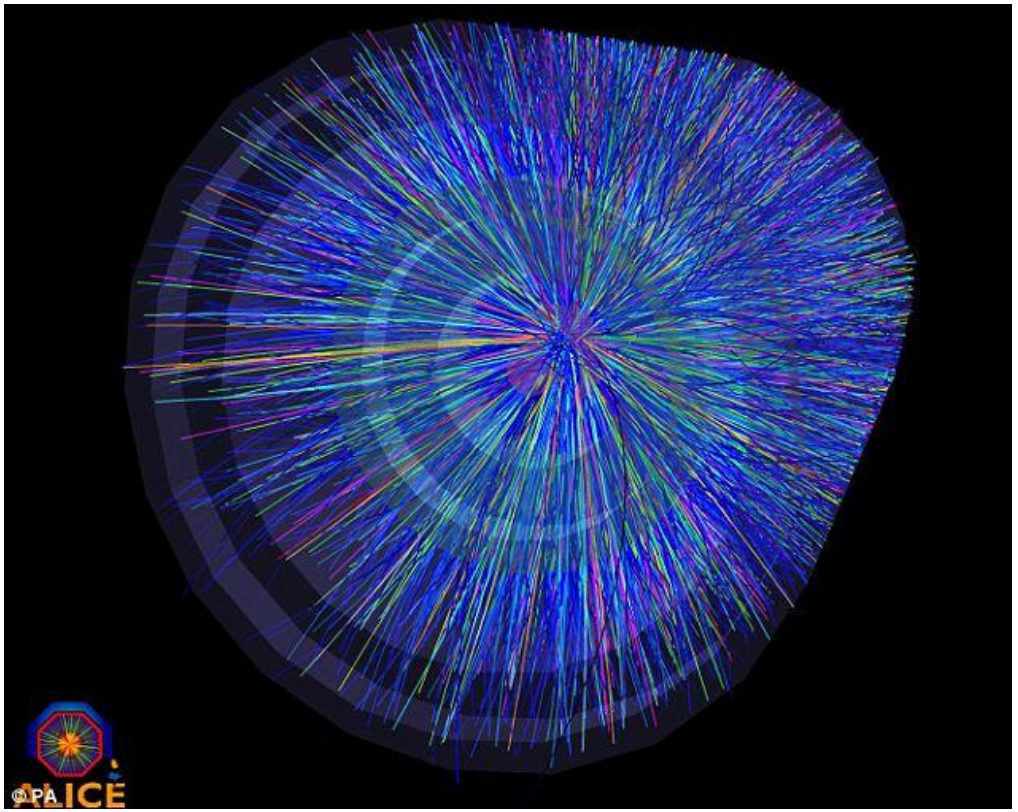
Formation of Subatomic Particles

- The period of standard cosmology began .01 seconds after the big bang. Here, protons and neutrons are fully formed.
- After a full second, the nuclei of light elements like hydrogen, helium, and lithium were forming.
- However, the stable atoms could not be formed yet because the conditions were still too dense and hot for electrons to join the nuclei.



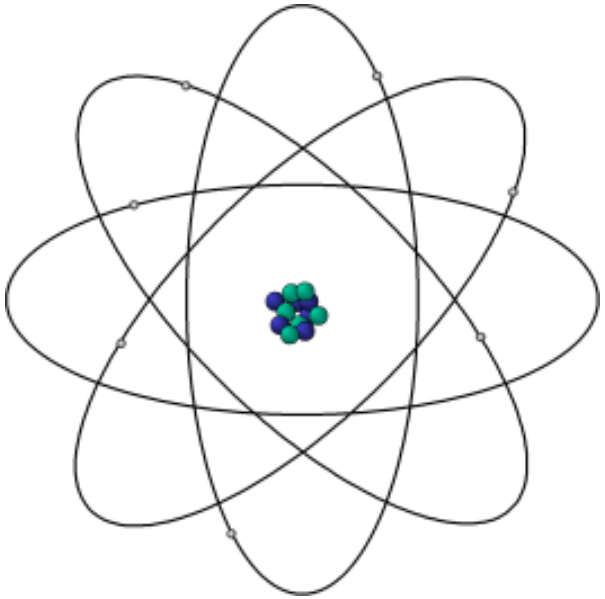
The First Minute of the Universe

- After 100 seconds, the universe's temperature cooled to 1 billion degrees Celsius (but it was still too hot for electrons to bond with nuclei).



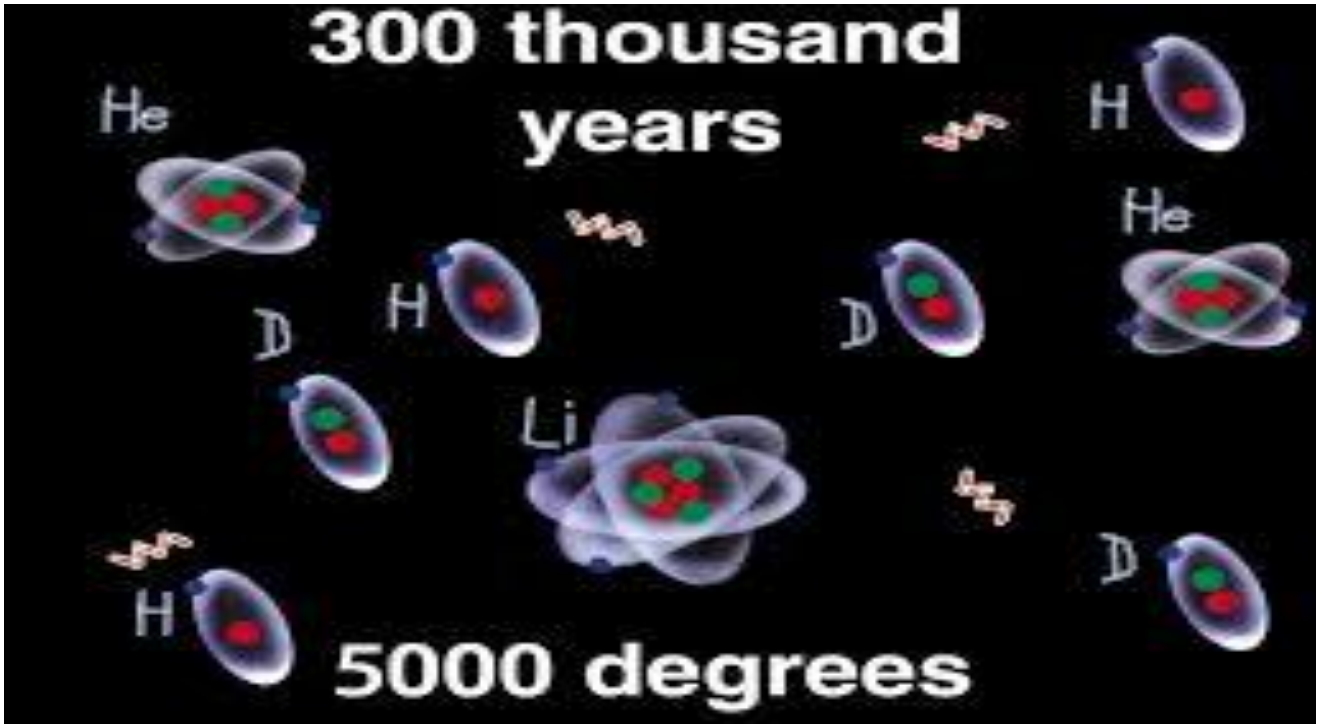
Formation of Protons and Electrons

- After 56,000 years, the universe had cooled to 8,726 degrees Celsius and the density of the matter distribution in the universe matched the density of radiation.
- After 324,000 years, the universe had expanded enough to cool down to a temperature where protons and electrons could finally combine to form neutral hydrogen atoms.



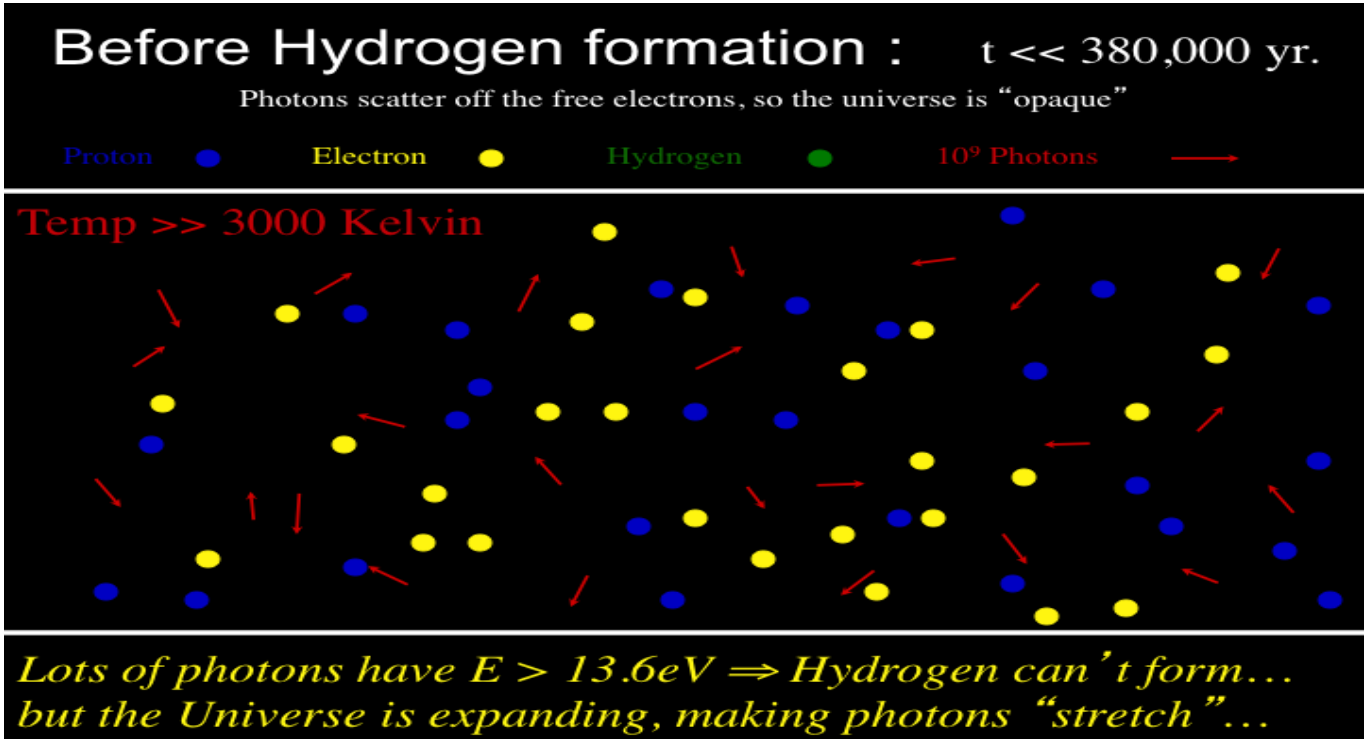
Formation of Elements

- After 300,000 years, we have only light elements forming. These light elements will combine to form stars after 100 million years. (heavier elements come much later after supernovas)



Universe is Opaque

- Photons scatter off free electrons. So the photons are scattering off the electrons all the time, hardly moving at all before they bump into another one. If photons can't travel far in a straight line, then you can't *see* very far… it's like living in a fog.
- Because hydrogen atoms could not form (they're immediately broke up by photons), there isn't any hydrogen yet.
- Because hydrogen atoms could not form (they're immediately broke up by photons), there isn't any hydrogen yet. As the universe grows older and expands, the photons feel the expansion and their wavelengths grow. Eventually, once the universe has expanded enough, the photons have lost enough energy that only a few are able to ionize a Hydrogen atom

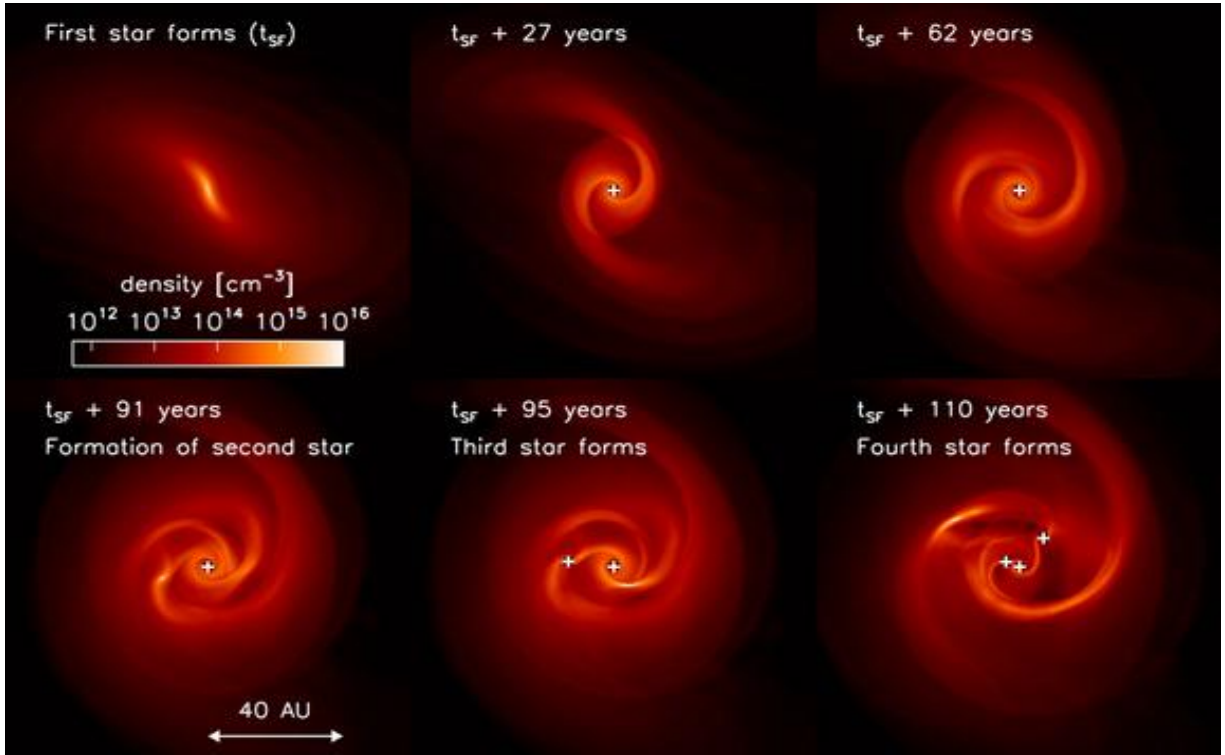


Let There Be Light!!

- At 380,000 years after the initial event, the universe became transparent so that light could shine throughout the universe.

Formation of Stars

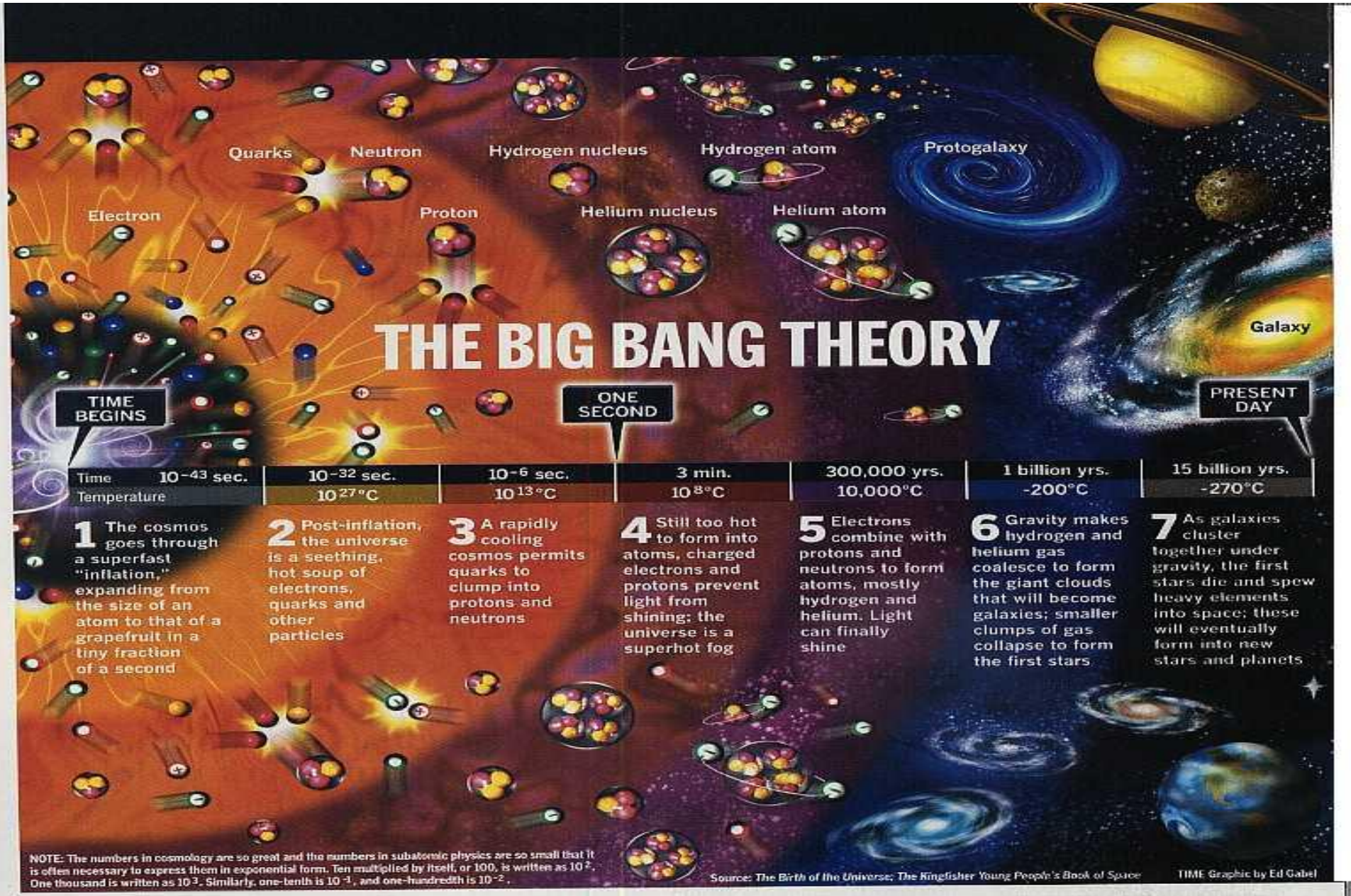
- For the 100 million years or so following, the universe continued to expand and cool. During this time, small gravitational fluctuations caused particles of matter to cluster together, collapsing gases in the universe into tight pockets.
- 100 to 200 million years after the big bang started, stars formed from these pockets.



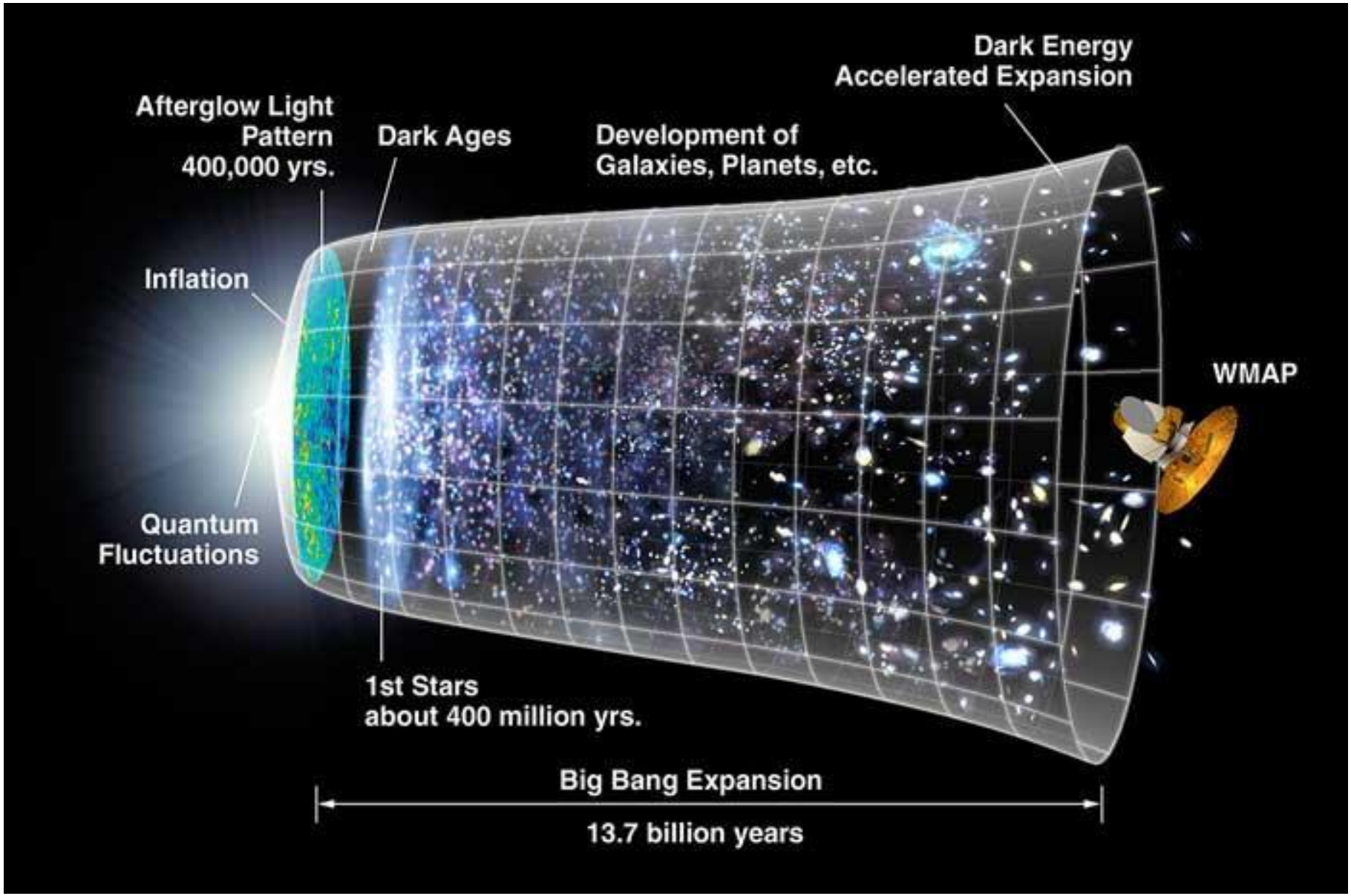
Formation of Galaxies

- Stars clustered together to form galaxies. Some stars went supernova and exploded, shooting out matter across the universe. This matter includes the heavier elements we find in nature (everything up to uranium).
- These galaxies also in turn formed their own clusters, which we know now as solar systems.
- Our solar system formed about 4.6 billion years ago

Timeline of Big Bang

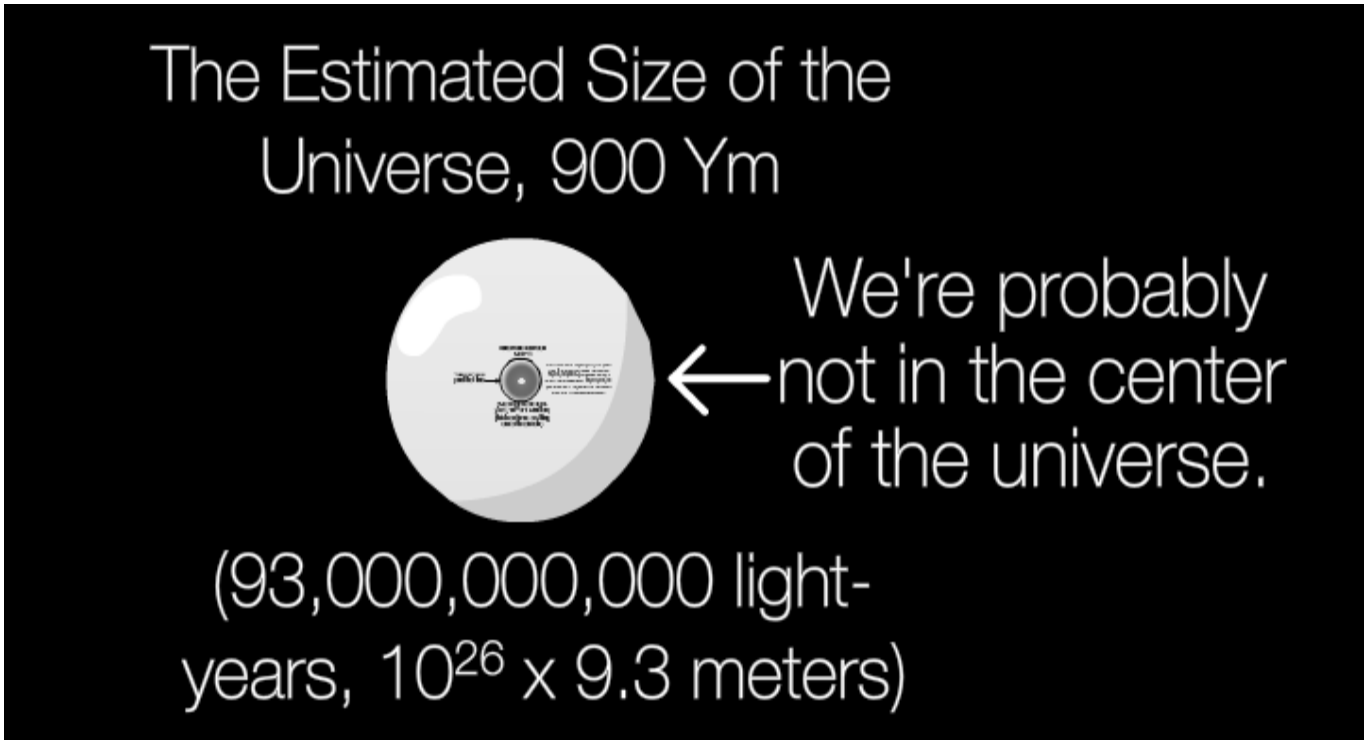


Big Bang Expansion



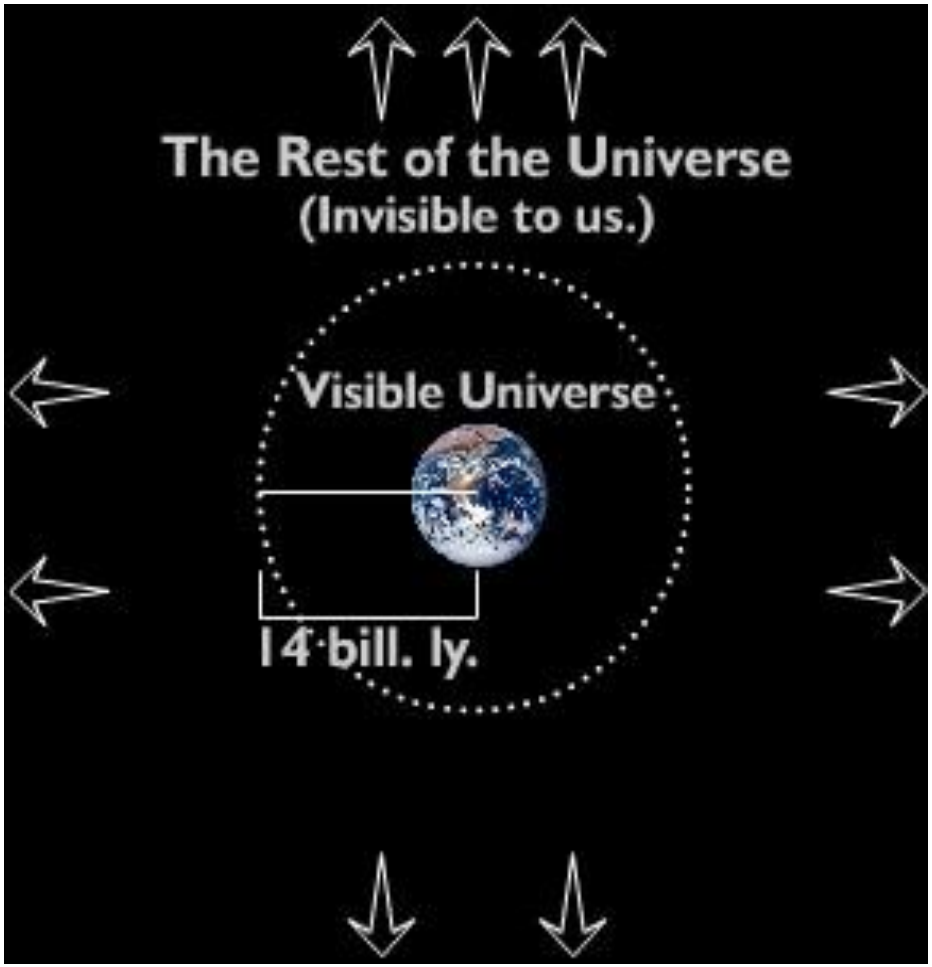
Our Universe Today

- Today, the temperature of the universe is -270 degrees Celsius and our best guess of the size of the universe is 1 x 10^{29} centimeters across (6.21 x 10^{23}miles)



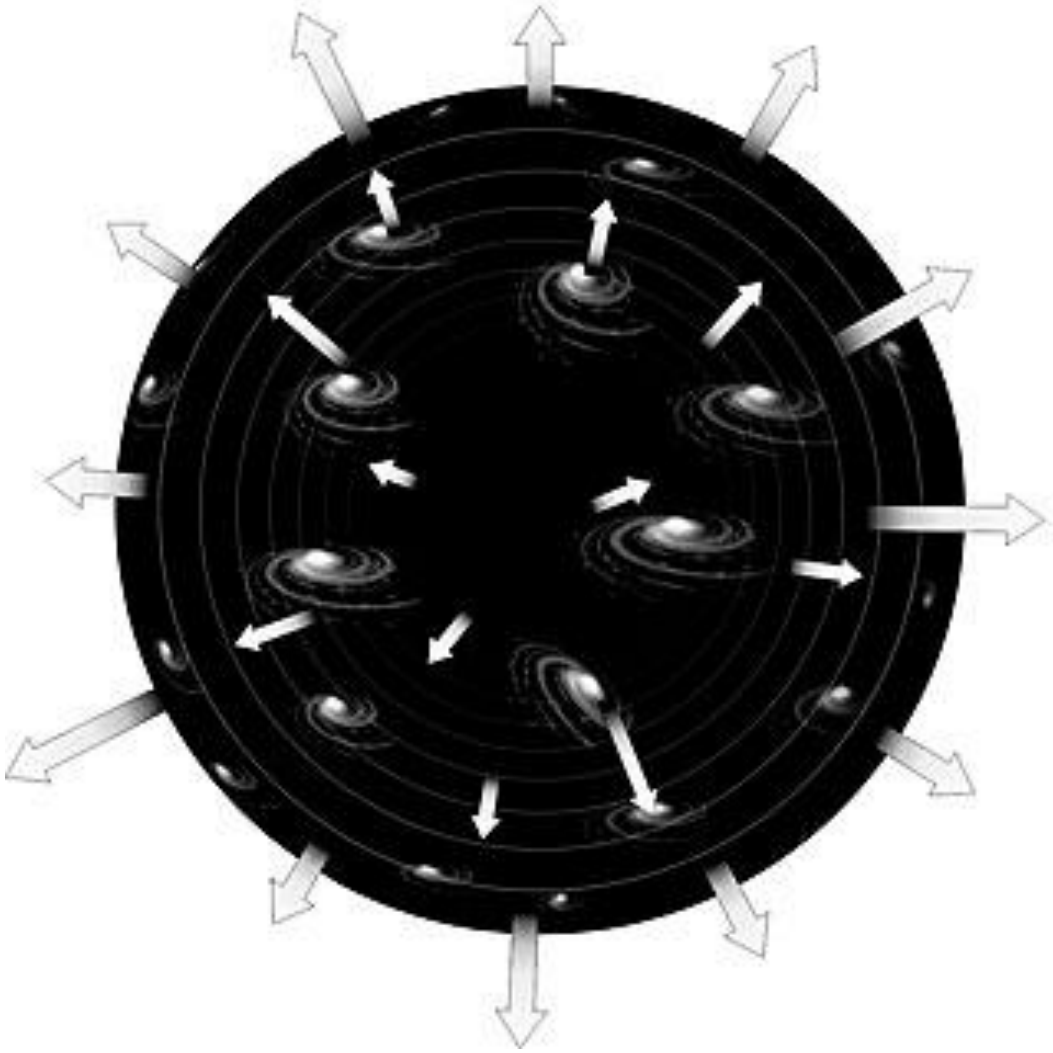
Observable Universe

- Actually our observable universe is roughly 14 billion light years across, but this is only the light that is reaching us now. How about the previous past?



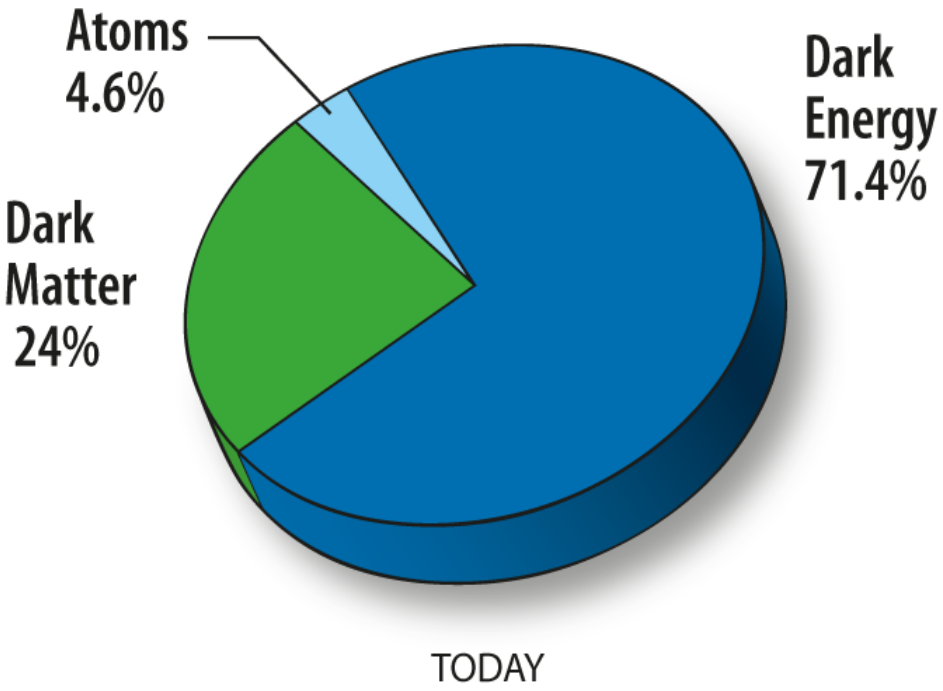
Expansion of The Universe

- Our universe is still continuing to expand as we can determine from the redshift of the faraway galaxies.

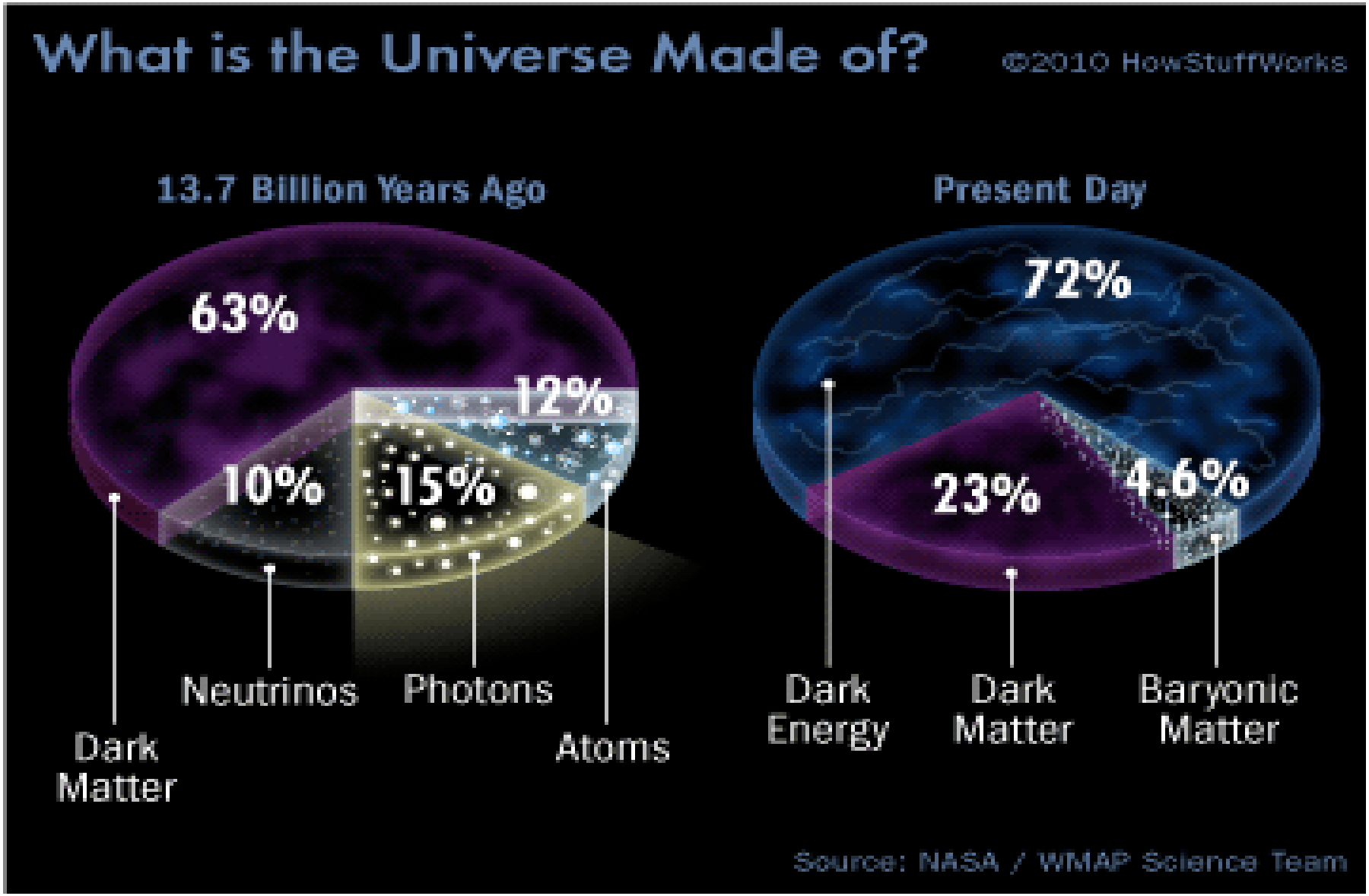


Content of the Universe

- Based on the standard model of cosmology, the total mass–energy of the known universe contains:
- 4.6% ordinary matter
- 24.01% dark matter
- ~ 71-72 % dark energy

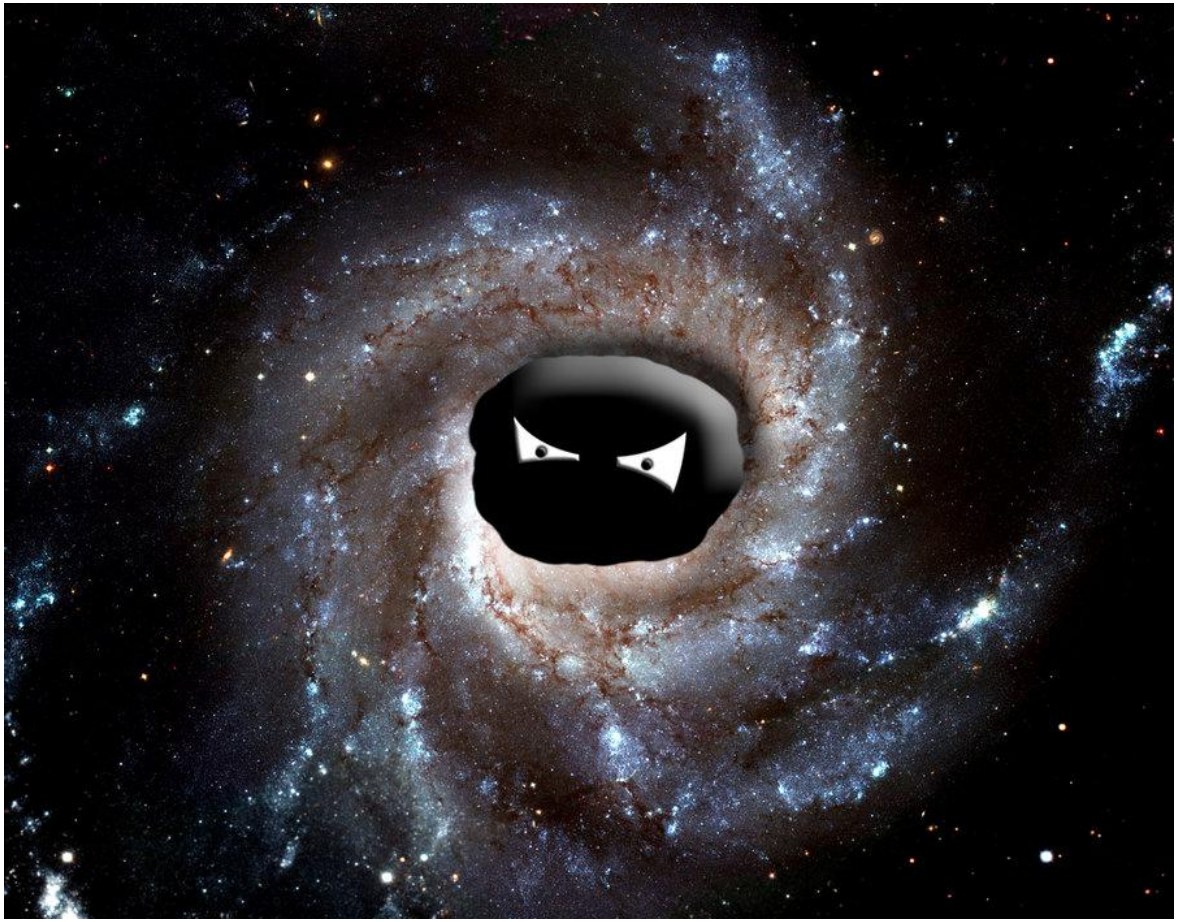


Universe: Change in Composition



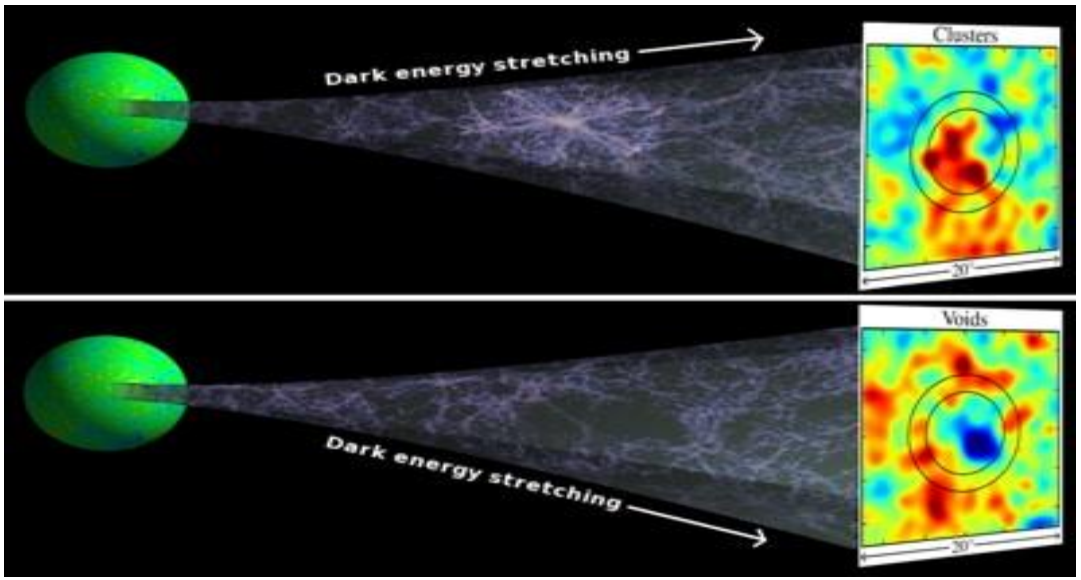
Dark Matter

- It is dark, meaning that it is not in the form of stars and planets that we see. Observations show that there is far too little visible matter in the Universe to make up the 27% required by the observations.
- The most common view is that dark matter is not baryonic at all, but that it is made up of other, more exotic particles like axions or WIMPS (Weakly Interacting Massive Particles) such as neutrinos.
- Astronomers deduced its presence by noting its gravitational pull on stars in galaxies.

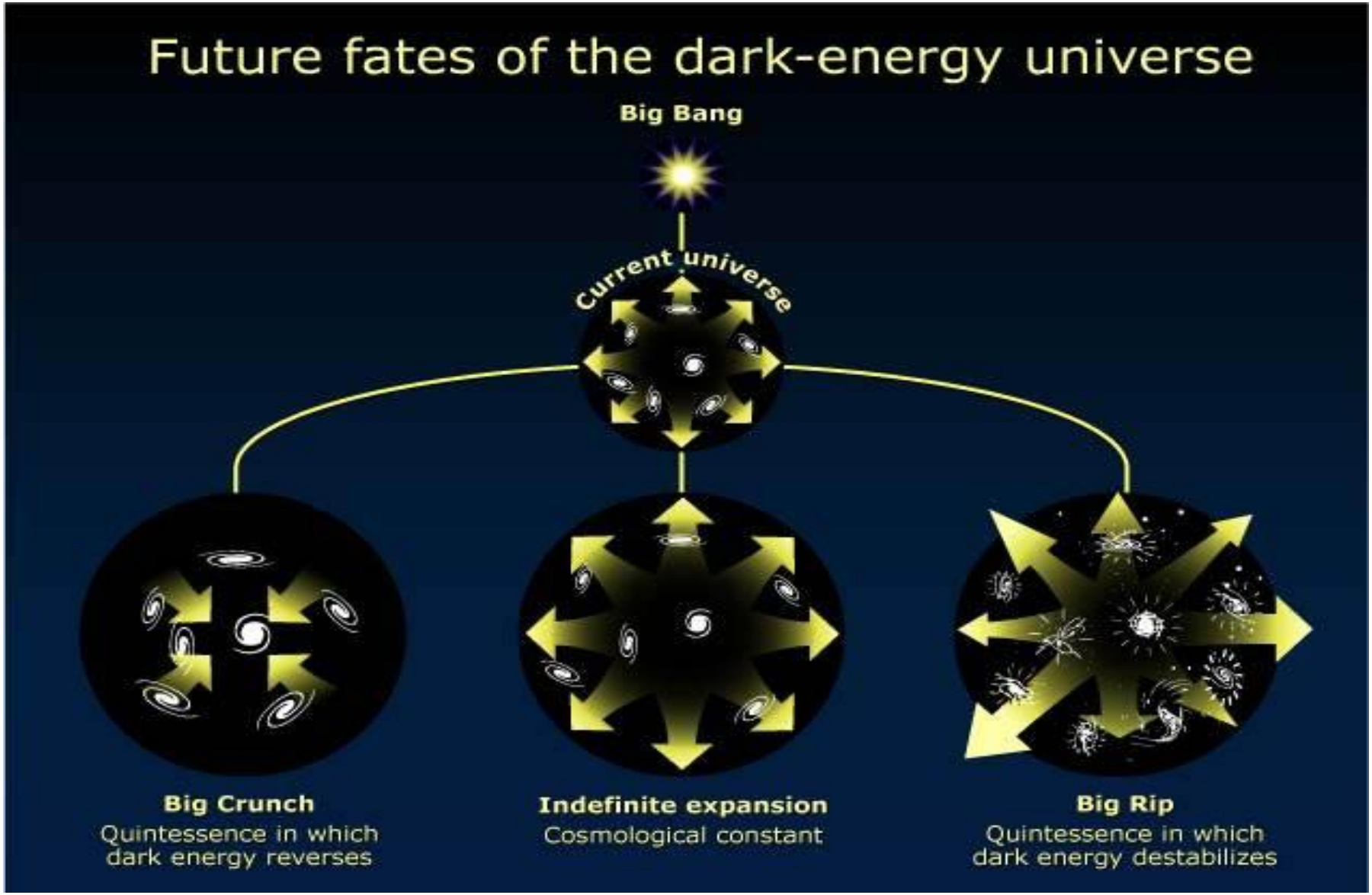


Dark Energy

- Normally the expansion of the universe should have slowed down due to the effect of gravity of so many galaxies pulling on each other.
- Dark energy is the name given to an unexplained force that is drawing galaxies away from each other, against the pull of gravity, at an accelerated pace.
- Dark energy is a bit like anti-gravity. Where gravity pulls things together at the more local level, dark energy tugs them apart on the grander scale.
- Dark energy is persistent: its density remains constant (experimentally, within a factor of 1:10), i.e. it does not get diluted when space expands.
- Is it zero point vacuum energy? (Cassimir Effect)

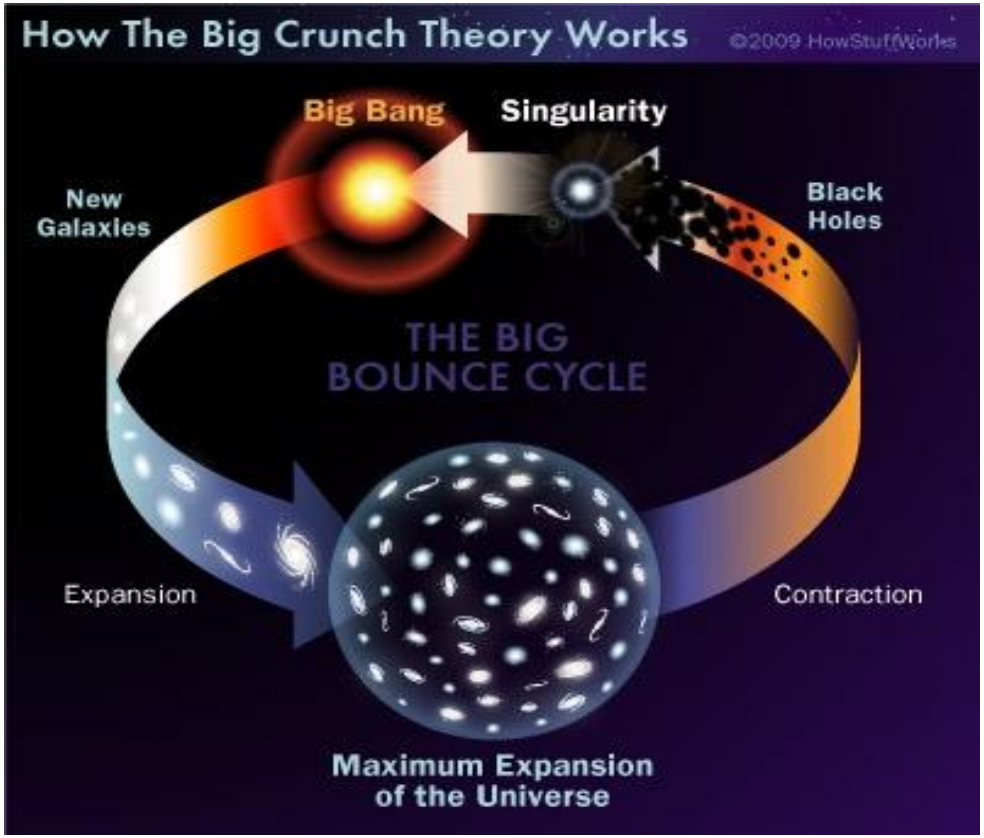


Future of the Universe



Big Crunch

- It tells us that the Universe's expansion, which is due to the Big Bang, will not continue forever. Instead, at a certain point in time, it will stop expanding and collapse into itself, pulling everything with it until it eventually turns into the biggest black hole ever.



Big Freeze

- The Big Freeze is a scenario under which continued expansion results in a universe that asymptotically approaches absolute zero temperature.
- In this scenario, stars are expected to form normally for 10^{12} to 10^{14} (1-100 trillion) years, but eventually the supply of gas needed for star formation will be exhausted. As existing stars run out of fuel and cease to shine, the universe will slowly and inexorably grow darker.
- Eventually black holes will dominate the universe, which themselves will disappear over time as they emit Hawking radiation. A related scenario is heat death, which states that the universe goes to a state of maximum entropy in which everything is evenly distributed, and there are no gradients — which are needed to sustain information processing, one form of which is life.