Big Bang and Its Consequences. Dark Matter and Dark Energy

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The Big Bang Theory In Short

The big bang is the way in which scientists explain how the universe began. The idea that the universe started as just a single point, then gradually expanded and stretched to grow as large as it is right now. That it is still stretching and it would probably continue to stretch forever.

Consequences of the Big Bang

In few words, the whole universe was developed, from quarks to whole stars and galaxies. The four fundamental forces appeared. Additionally, dark matter and dark energy emerged.

The Big Bang Theory Theory Development

1. Lemaître's Theory:

In 1927, the Belgian astronomer Georges Lemaître had a big idea. He stated that a very long time ago the universe started as just a single point. He explained that the universe stretched and expanded to get as big as it is now, and that it would probably keep on stretching.

2. Hubble's Observation:

Just two years later, in 1929, an astronomer named Edwin Hubble noticed that other galaxies are moving away from the Earth. And that's not all. The farthest galaxies were moving faster than the ones close to our planet. This observation served as a proof that the universe was still expanding, just like Lemaître said. If things were moving apart, it meant that long ago, everything had been close together.

The Big Bang
How Did It Look Like?

According to the theories of physics, if we were to look at the Universe one second after the Big Bang, what we would see is a 10-billion degree (K) sea of neutrons, protons, electrons, positrons, photons, and neutrinos. Then, as time went on, we would see the Universe cool, the neutrons either decaying into protons and electrons or combining with protons to make deuterium. As it continued to cool, it would eventually reach the temperature where electrons combined with nuclei to form neutral atoms. Before this “recombination” occurred, the Universe would have been opaque because the free electrons would have caused light (photons) to scatter the way sunlight scatters from the water droplets in clouds. But when the free electrons were absorbed to form neutral atoms, the Universe suddenly became transparent. Those same photons - the afterglow of the Big Bang known as cosmic background radiation - can be observed today.

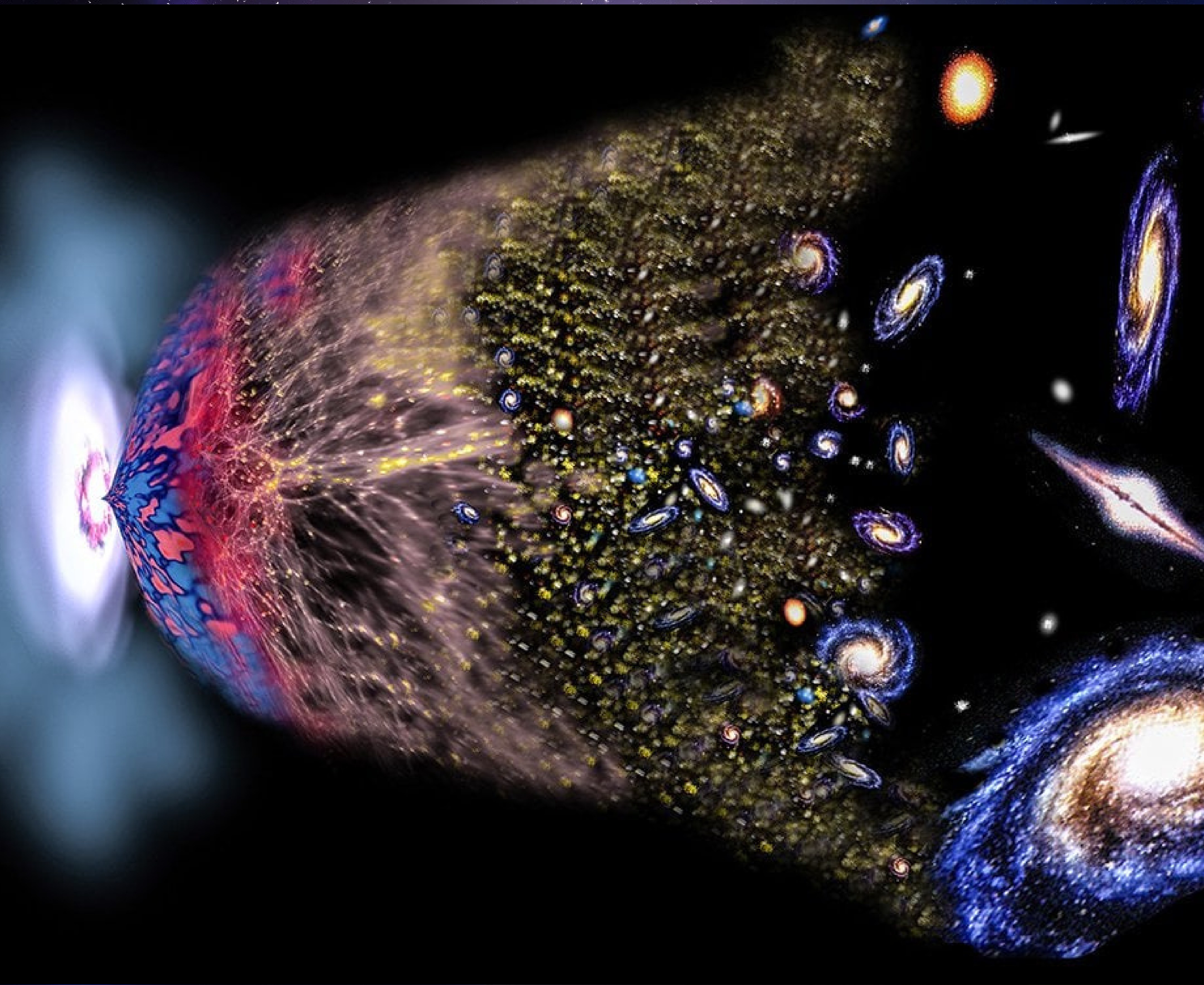
The Big Bang Theory
Epochs of the Universe

1. Singularity a.k.a. Plank's Era:

- Infinite density and extreme heat
- Can only be measured in Plank time (0 to 10^-43 seconds)
- Highly unstable
- NO separate fundamental forces

2. Inflation Epoch:

- Rapid expansion and cooling
- Baryogenesis: imbalance of matter
- Particle-anti- particle pairs
- Elementary particles



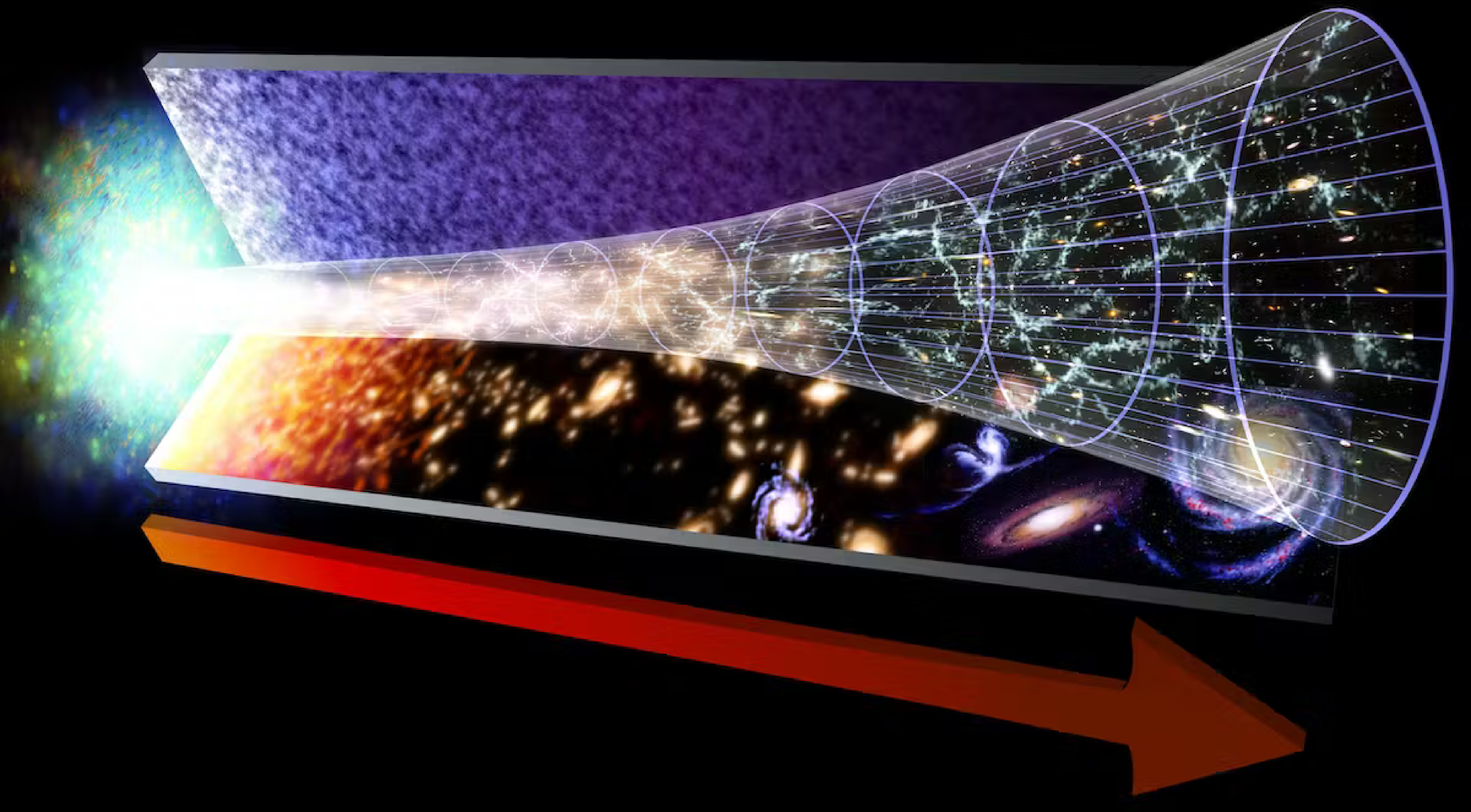
The Big Bang Theory Epochs of the Universe (Continued)

3. Cooling Epoch:

- Present form of particle physics
- Mass annihilation
- Photon and neutrino domination
- Nucleosynthesis: deuterium; He; H+ nuclei
- Radiation and CMB

4. Structure Epoch:

- Gravitational attraction between matter
- Formation of astronomical structures
- Modern Universe
- Dark matter and dark energy



Interesting Facts Regarding the Big Bang

1. The Beginning:

The universe started expanding before 13.8 billion years.

2. The Theory:

The idea of the Big Bang had been around since 1915, but was widely dismissed for decades.

3. Explanation:

The Big Bang itself doesn't necessarily mean the very beginning anymore.

4. A Black Hole?:

Black holes also contain singularities, as the one our universe arose from.

5. Einstein's Opinion:

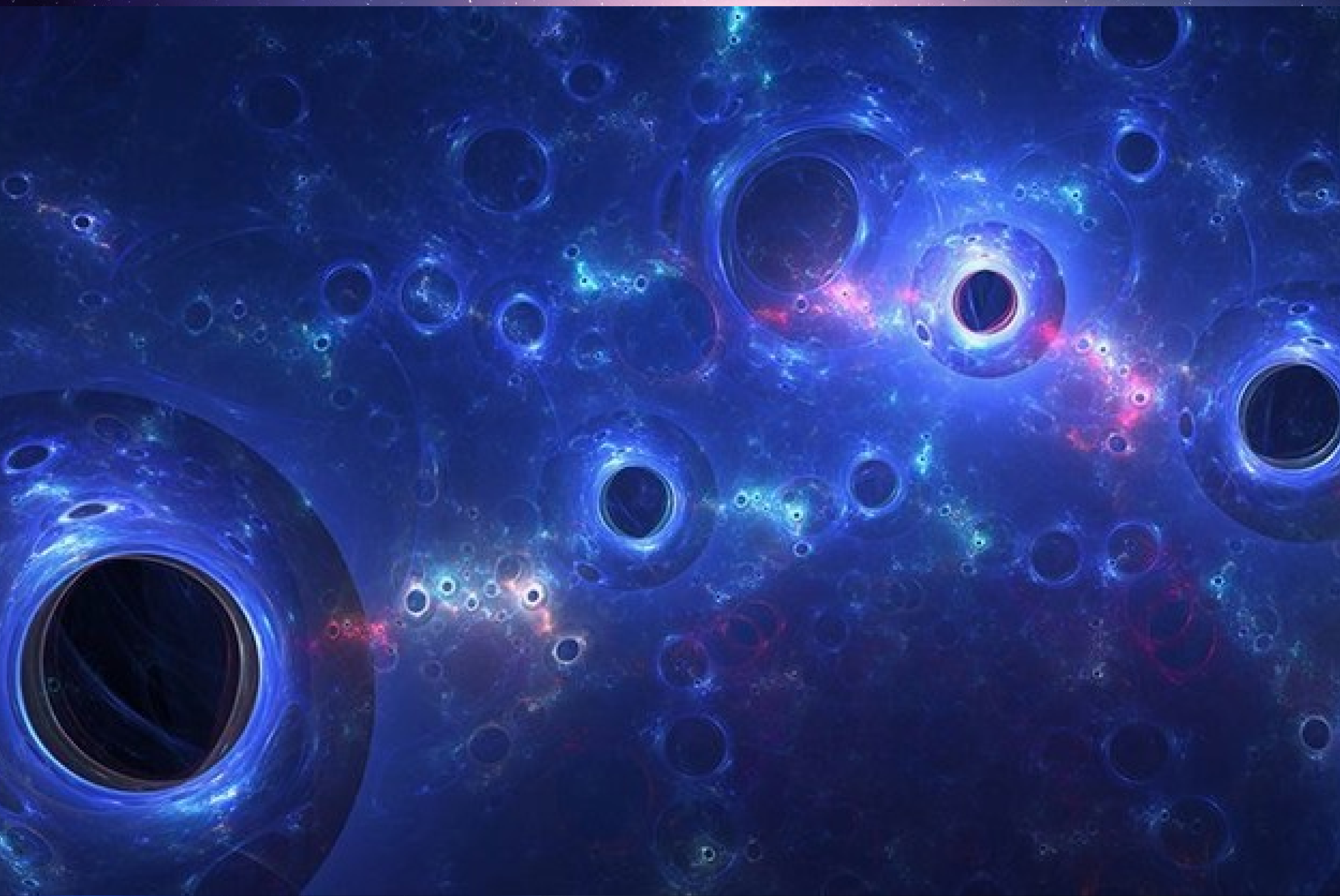
After he read through Lemaître's theory for the Big Bang, Einstein said to him: "your calculations are correct, but your physics is abominable!"

Dark Matter Overview

- The universe composition: ~68% dark energy, ~27% dark matter, ~5% normal matter
- Dark matter is completely invisible
  - emits no light or energy
  - cannot be detected by conventional sensors and detectors
- Most scientists believe that dark matter is non-baryonic
- Candidates for these special particles:
  - WIMPs (weakly interacting massive particles)
    - ten to a hundred times the mass of a proton
    - weak interactions with "normal" matter make them

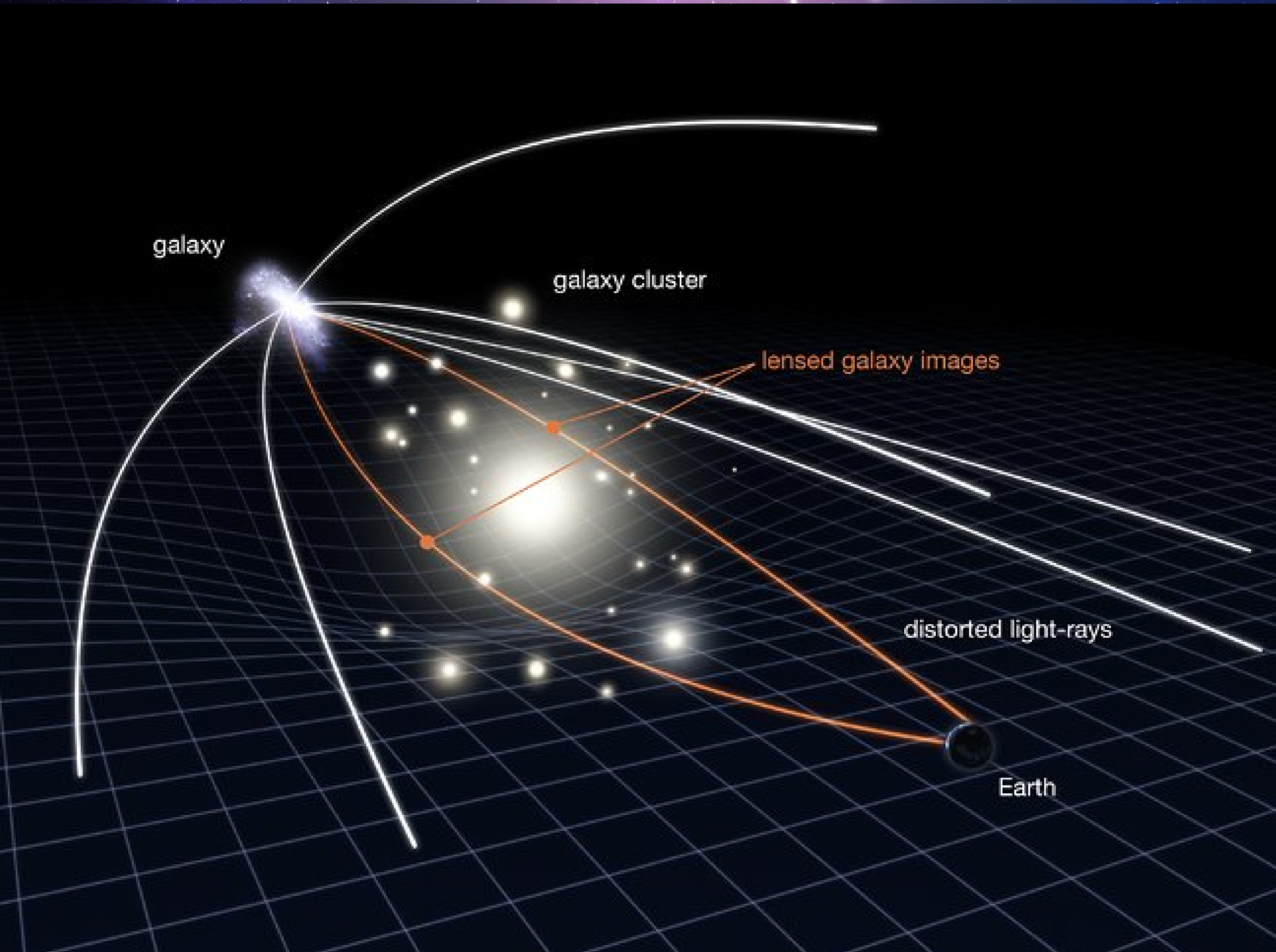
difficult to detect

- Sterile neutrinos (interacts with regular matter only through gravity)



Dark Matter Evidence

- Gravity, a force exerted by objects made of matter, is proportional to the object's mass
- The gravitational forces appear stronger than the visible matter alone would account for:
  - Clusters of galaxies would fly apart if the only mass they contained was the mass visible to conventional astronomical measurements.
- Gravitational lensing
  - massive objects in the universe bend and distort light due to the force of their gravity
  - By studying how light is distorted by galaxy clusters related to their mass, astronomers have been able to create a map of dark matter in the universe.



Dark Matter: Additional Info

- Hypothesized sources
    - Dark matter might be concentrated in black holes
        - created in the Big Bang together with all other constituting elements of the universe
    - Brown dwarfs
        - Failed stars that do not have enough mass to ignite the nuclear fusion of ordinary hydrogen
- Studying dark matter
    - The IceCube Neutrino Observatory is hunting for the hypothetical sterile neutrinos.
    - The Large Underground Xenon dark-matter experiment (South Dakota) hunts for signs of WIMP and xenon interactions.
    - CERN
    - The James Webb Space Telescope

Dark Energy

A hypothetical form of energy that is proposed by physicists to explain why the universe is not just expanding but is doing so at an accelerating rate.

Theories

- hypothetical particles that travel faster than light and thus back in time
- particles popping in and out of existence in empty space
- a "fifth force" responsible for the negative pressure
- a low-energy field dubbed "quintessence"

What Does Dark Energy Do?

The greater the distance that separates these cosmic objects, the more rapidly they race away from each other.

Dark energy is expanding the fabric of space at such a rate that GN-z11 is moving away from us at speed over twice the speed of light.

"Nothing can move faster than light" only applies to the motion of objects through space. The rate at which space itself expands has no physical bounds on its upper limit.

Galaxies are getting 0.007% further away from each other every million years.

Dark Energy

What Evidence Do We Have?

First detection - 1990.

Conducting surveys of Type Ia supernovas, cosmic explosions that occur when massive stars die and that produce light emissions.

As the universe expands light from distant sources that takes a long time to travel to Earth has its wavelength "stretched out."

The further away a light source is, the more its light is red shifted.

What they found was more distant supernovas that had exploded when the universe was much younger were fainter than expected. This meant these supernovas were further away than they should be