ISSN:2790-1688 DOI: 10.56028/aetr.4.1.527.2023

Dark Matter Final Project Research Paper

ShuaiShuai Guo

Crean Lutheran High School, Irvine, 92618, United States

Abstract. The identity of dark matter and dark energy which makes up 85-90% of the total mass in the universe, is one of the biggest unresolved issues in particle physics according to BBC Science Focus Magazine. So what do dark matter and dark energy do? They play an important role in galaxy formation and the universe's expansion. It is one of the most accepted theories that support the universe's expansion that gravity pulls galaxies together, while dark energy pushes them apart. Which force is stronger? Gravity or dark energy determines whether the cosmos is expanding or contracting. [1]. As an illustration, the Big Bang diagram down below shows that the universe's expansion speed is increasing and eventually getting progressively faster and is affected by dark energy.

Keywords: Dark Matter; Dark Energy; BBC Science Focus Magazine.

1. Introduction

Dark matter is not a matter we can normally see or sense. It is because the electromagnetic force does not interact with dark matter. According to CERN, it does not absorb, reflect, or emit light, making it extremely difficult to detect with current instruments. Nevertheless, scientists can still use mathematical equations to calculate the existence of dark matter. In addition, scientists think dark matter-rich areas bend light passing nearby and substantially alter the look of background galaxies as seen from Earth. In fact, scientists have only inferred the presence of dark matter based on its apparent gravitational pull on visible matter. As a result, there is something out there we do not fully understand that is interacting with gravity and can not really detect it. Some common types of dark matter are explained in the next few topics.

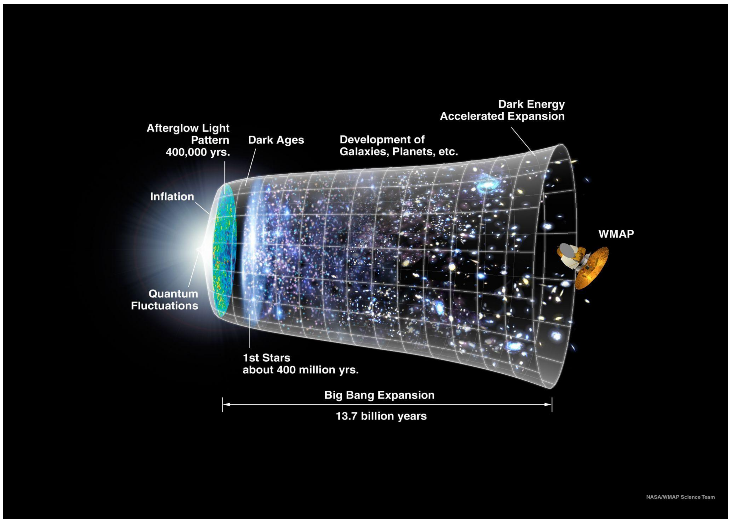

Figure 1.Topology of expanding space

1.1 Dark Matters

2.1.1 Fuzzy Dark Matter

Fuzzy dark matter(FDM) is a hypothetical type of dark matter that is thought to be made up of incredibly light scalar particles and is one of the most practical candidates for dark matter. It is well-recognized that this stuff is challenging to replicate because of its unique qualities [2]. FDM is also inspired by string theory and has recently become a popular thing to explain dark matter, and

ISSN:2790-1688 DOI: 10.56028/aetr.4.1.527.2023
its quantum effects play an important role in cosmological structure formation like the galaxies according to scientists.

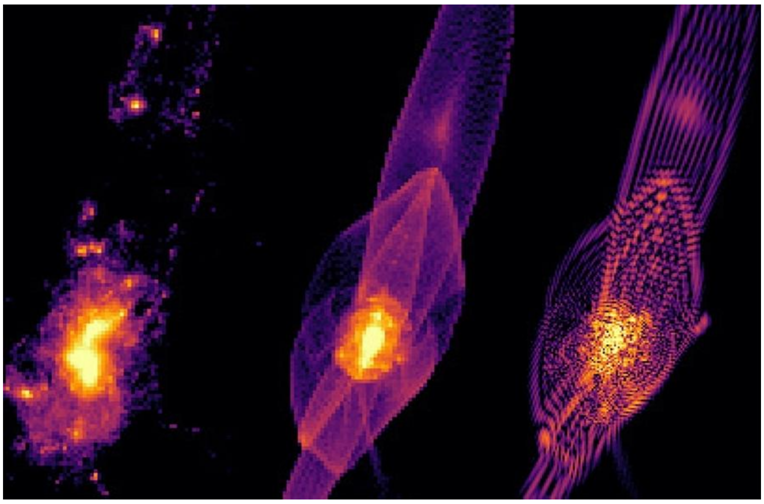

Figure 2 This is how a “fuzzy” universe may have looked

This picture is a simulation made by scientists at MIT, Princeton University, and Cambridge University. They observed the early galaxy formation in a universe of fuzzy dark matter or “ultralight”, rather than cold or warm. In addition, this simulation also demonstrate how stars and galaxies might have grown and congregated at the beginning of the universe if dark matter had a very low mass as opposed to the heavy mass that the majority of scientists have assumed. It also shows a fuzzy universe with filaments appearing striated and with galaxies forming first in extended, tail-like filaments. According to this stimulation, scientists concluded that 85 percent of matter made up of universe is fuzzy dark matter.

2.1.2 Axion Dark Matter

It is still unclear why the strong interaction abides by time-reversal symmetry. A common answer to this problem is the existence of axion dark matter. The scientists examined the mathematically explicable properties of axions and demonstrated how these properties connect to the fundamental symmetries of the Standard Model of particle physics. The strong interaction, the force that holds quarks in protons and neutrons together, defies time-reversal symmetry, which is explained by the axion [3]. This implies that if time were to move in the opposite way, processes brought about by the strong interaction would still appear the same at the subatomic level.

1.2 Discovery

A Bose-Einstein condensate (BEC) is a state of matter in condensed matter physics that often develops when a gas of bosons with very low densities and a very low temperature close to absolute zero (273.15 °C or 459.67 °F). It is also one of the 6 types of matter. In these circumstances, a significant portion of bosons occupies the lowest quantum state, when quantum mechanical processes become macroscopically visible, in particular wavefunction interference, emerge. A BEC is created by rapidly cooling gas with an incredibly low density (about 100,000 times less dense than normal air). Albert Einstein typically made the first prediction about this condition in 1924-1925, and he gave Satyendra Nath Bose credit for his groundbreaking study on the emerging science of quantum statistics.

ISSN:2790-1688 DOI: 10.56028/aetr.4.1.527.2023

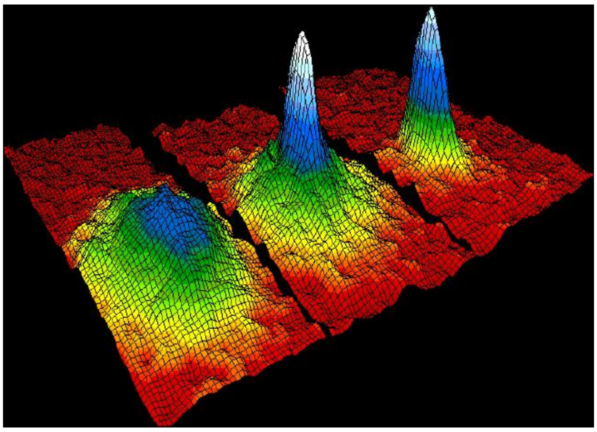

Figure 3.Bose-Einstein Condensates with Rubidium Atoms

This illustration demonstrates the velocity-distribution (3 perspectives) for a gas of rubidium atoms, supporting the identification of the Bose-Einstein condensate as a novel phase of matter. The image on the left is a form shortly before a BEC materializes. The image in the center is a form just after the condensate first appears. The image on the right is a form after more evaporation, a sample of almost pure condensate remained.

2. Dark Matter Theory

According to researchers at Cornell University, BEC could be a possibility that the dark matter explains vast distances from the galactic center. The reason to this is Newtonian Bose-Einstein gravitational condensate gas whose density and pressure are connected by a non-relativistic barotropic equation of state can be used to characterize dark matter [4].

References

[1] Shea, Shannon Brescher. “Our Expanding Universe: Delving into Dark Energy.” energy.gov, Office of Science, June 21, 2017, www.energy.gov/science/articles/our-expanding-universe-delving-dark-energy#:~:text=The%20energy%20from%20the%20Big,dominates%2C%20gravity%20or%20dark%20energy. Accessed September 22, 2022.

[2] Fadelli, Ingrid. “Astrophysicists simulate a fuzzy dark matter galactic halo.” phys.org, May 30, 2022,

[3] phys.org/news/2022-05-astrophysicists-simulate-fuzzy-dark-galactic.html. Accessed September 22, 2022.

[4] Chadha-Day et al. “Axion dark matter: What is it and why now?” science.org, Science Advances, February 22, 2022.

[5] www.science.org/doi/10.1126/sciadv.abj3618. Accessed September 22, 2022. Accessed September 30, 2022.

[6] C. G. Boehmer, T. Harko. “Can dark matter be a Bose-Einstein condensate?” arxiv.org, Cornell University, February 1, 2008. arxiv.org/pdf/0705.4158.pdf. Accessed October 15, 2022.