Possible Particles that Build Up for the Existence of Dark Matter

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Abstract. Even in the view of modern physics, dark matter is still one of the most mysterious topics. Although physicists have not yet been able to confirm the exact particle that makes up for dark matter, or even if there are any, some self-consistent theories are established. This paper explores two most convincing explanations about the composition of the dark matter, the axions and weakly interacting massive particles (WIMPS) theory. The content and development of the two theories regarding the composition of the dark matter are mainly discussed.

Keywords: physics, possible particles, (wimps) theory.

1. Possible Particles that Build Up for the Existence of Dark Matter

One scientific breakthrough in the realm of physics is understanding that the universe is not entirely built up by visible matter, but with invisible ones, too. Such substances are named as dark matters. Though physicists are not able to directly observe dark matter in the cosmic universe, the gravitational effect enables an indirect deduction of dark matter, Dark matter cannot absorb, reflect, or emit electromagnetic waves. In other words, dark matter can not be seen physically and is completely invisible. Due to these unique properties, it is difficult to understand the fundamental quality of dark matter and confirm that particle composes dark matter. One of the few hints of dark matter is that it has gravitational effect on other visible matter. This is the reason why axions and weakly interacting massive particles (WIMPs) are some popular theories of what composes dark matter. Both of these particles possess the properties of having only mass and unable to interact with electromagnetic waves.

When most people living in a world with only the baryonic matters visible, it is difficult to imagine the existence of dark matter or anything non-baryonic around us. However, the universe is filled with such non-baryonic matters. Tracing back to the 1933,

Fritz Zwicky, a Swiss astronomer, could not comprehend the high velocity between galaxies in his calculations and argued that there was some type of materials that increases the gravitational potential other than visible matter. Forty years later in the 1970s, it has widely been recognized that there is something other than visible matter in the vast universe. Astronomers began to theorize a matter that is not visible, known as the dark matter (Moore, B., 1999).

Many theories of the composition of dark matter have risen in the 20th century. For example, scientists had once believed that dark matter might be composed of baryonic matter but due to certain limitations, they are unable to emit light (Moore, B., 1999). Yet later on, the theory of dark matter being composed of non-baryonic matter began to spread rapidly among astronomers, thus, igniting the popular theory of the hypothetical particle axions and WIMPs.

2. Axions

In the beginning of 1970s, quantum chromodynamics (QCD) was proposed and was successful in predicting the strong force and interactions between quarks (Rosenberg, L. J., 2015)). A few years later, it was found that there were flaws in this theory, and this led to the well-known CP Violation that physicists have not yet solved today. It was initially thought that charge-conjugation and parity are symmetrical in particle interaction. However, later on it was discovered that parity is not conserved in particle decay which occurs through weak force (Sarkar, U., 2008). In other words, the

QCD theory was not complete. In 1977, Roberto Peccei and Helen Quinn proposed the Peccei-Quinn theory and introduced a hypothetical particle, axion, which would solve the CP Violation in the quantum chromodynamic theory (Rosenberg, L. J., 2015).

The hypothetical particle axion is thought to be extremely low in mass, rarely interact with electromagnetic forces, and have an extremely long lifetime. Although the initial purpose of this particle was to resolve the CP Violation, it also offers an insight of the composition of dark matter, too, since many of its properties were closely matched to dark matter. As a result, it became one of the most idealistic candidates for the composer of dark matter.

There have been many experiments attempted to detect axions. One of the largest ongoing experiments includes the Axion Dark Matter Experiment (ADMX) at the University of Washington. Using the wave-particle duality property that could be applied for all particles, ADMX hopes to resonate with the frequency of axions through using a powerful magnet. In January 2017, the ADMX hit the mass range of axions. Other experiments have been conducted to detect axions. For example, the Cosmic Axion Spin Precession Experiment (CASPEr) has attempted to tease out axion through using nuclear MRI Technology (Mann, A. 2017). These experiments aim to discover the decisive proof on whether or not axion truly exists.

3. WIMPs

In particle physics, the supersymmetry theory states that every boson or fermion has a super-partner in the other category. WIMPs are supersymmetric partner of other particles. For example, neutralino, one of the most popular WIMPs proposed to be a composer of dark matter, is the supersymmetric partner of neutral bosons (Carr, J., 2003).

Unlike axions which was proposed to solve the CP violation, the purpose of WIMPs was to offer an insight on the unseeable part of the universe. The theoretical characteristics of WIMPs includes possessing an electroweak scale, only interacting with the gravitational and weak force, and having a larger mass than other particles (Kamionkowski, Marc., 1997).

Physicists have approached WIMPs in two different ways: Direct and Indirect Observations. Since WIMPs are much more massive than axions and other particles, it is possible to directly detect the existence of this hypothetical particles. Direct detection are set-ups that use laboratory-based detectors to directly observe WIMPs and its interaction with other particles (Carr, J., 2003). Many direct detection experiments have been conducted over the past years. One of such is through observing the nuclear recoil caused by WIMP as it undergoes an elastic scattering. Another method uses the cryogenic detector aiming to detect WIMPs through observing the heat signal in particle interactions (Schumann, M., 2019).

Indirect detection differs from direct detection since it aims to detect the annihilation of WIMPs at locations in the galaxy instead of on Earth. Physicists search for gamma rays in the universe as they are the end product of annihilation. A neutrino telescope project known as ICECUBE was set up in the South Pole to search for signals of WIMPs within the solar system (Carr, J., 2003).

4. Conclusion

Dark matter remains one of the most mysterious areas to understand. Scientists to this day are not completely convinced whether dark matter truly exists. In fact, there are many other alternative theories against dark matter with the most well-known one as the Modified Newtonian Dynamics (MOND).

With the assumption that dark matter exists, figuring out the composition of dark matter is more challenging. The unique properties of dark matter make it difficult for detections. Despite the countless experimental set-up such as the ICECUBE observatory and ADMX and decades of detections, no absolute evidence has been found to prove the existence of hypothetical particles axions and WIMPs.

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