# Analysis of the Composition and Characteristics of Dark Matter

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**Abstract.** Today, astronomers use different methods to study the structure and evolution of the universe. However, they will all be affected by other factors such as light or electromagnetic radiation. It is impossible to accurately observe the structure of the universe in the distant past. To find objects that fit the criteria, the existence of dark matter was assumed. It only has a gravitational effect and will be less affected. The composition and characteristics of dark matter are important research foundations. In this paper, the Cosmic Microwave Background (CMB) and power spectrum are used to study the status of dark matter in the universe. The search found Weakly Interacting Massive Particles (WIMPs) to be a candidate in the dark matter component. The three types of dark matter are cold dark matter, warm dark matter, and hot dark matter. Comparing their respective characteristics, it is concluded that cold dark matter (CDM) is the condition for observing large-scale structures. The result is that dark matter constitutes the second largest component of the universe. WIMPs are more suitable candidates than Neutrinos. CDM is best suited for studying large-scale structures over time. Eventually, it will be discovered that dark matter has strong stability, which will help astronomers find the process of universe evolution. Dark matter is also an important player that is best used to study the structure and evolution of the universe.

**Keywords:** Cold dark matter, Warm dark matter, Hot dark matter, Weakly Interacting Massive Particles, Composition and Characteristics of Dark Matter.

## 1. Introduction

To research dark matter is vital to understand how to make a large-scale structure of the cosmos, the origin and changes of the universe. People can find what conditions allow for survival or other trace of life. Dark matter plays an important basic role in researching different cosmic phenomena. So, the composition of dark matter becomes an important part of scientists' research.

Dark matter is a hypothetical substance that does not interact with optical or electromagnetic fields. Therefore, scientists need to prove the existence of dark matter through indirect observation and use the gravity generated by the object's mass to find dark matter. This gravitational effect method helps scientists verify their existence using experiments such as galaxy rotation curves, gravitational lensing, the cosmic microwave background (CMB), and large-scale structures, etc. There is much history and speculation on the material path to proving this hypothesis. In 1884, Lord Kelvin proposed that most stars may be dark bodies --- invisible matter. In 1906, Henri Poincaré defined the term "dark matter." Neta and David's article mentioned that Swiss astrophysicist Fritz Zwicky confirmed in 1933 that most matter is dark [1, 2]. Spergel thinks that through the proofs of different scientists, dark matter finally became part of cosmology in the 1980s [2].

Dark matter can be used to detect the origin of the universe. "Structure formation" is the gravitational force that attracts different matter in the same direction after the Big Bang. The different matter slowly gathers to form stars, galaxies, and galaxy clusters of different large scales. However, ordinary substances such as dust, gas, etc., and the large structures they form cannot allow density perturbations to grow to the time range of the currently observable large-scale structures. Dark matter does not affect radiation, and its density perturbation can grow faster. Therefore, the biggest advantage of dark matter is that it will not be interfered with by radiation and light in the universe.

This paper studies the components and characteristics of dark matter through astronomers' guesses. The analysis of the model of cosmic microwave background (CMB), then researches what dark-matter components are. To analyze the weakly interacting massive particles (WIMPs) and axions in dark matter [3]. WIMPs and axions are models of the dark matter candidates. Second, structural features of dark matter theoretical models are learned, and the stability of dark matter is analyzed. In addition, the features of gravitational interaction, large-scale distribution, and non-luminescence. Dark matter divides the three types of dark matter are classified into cold dark matter (CDM), warm dark matter (WDM), and hot dark matter (HDM). They have something special about themselves, it is not only the temperature. On the other hand, dark matter is stable, because dark matter's interference is caused by gravity, which is smaller than the interference caused by electromagnetic force on ordinary matter. Dark matter that cannot easily relate to common matter. Not emitting light allows dark matter to conserve more energy. It leads to slow energy consumption is slow. Therefore, the stability of dark matter brings more opportunities to explore large-scale structures further in early times. The purpose is to let people study the basic components of dark matter and the characteristics of dark matter.

The composition of dark matter is a guess, and the components of WIMPs and axions are research objects of theories and hypotheses. There is no conclusive proof of their existence directly. Only by continuously updating detection techniques can we continue to explore dark matter. Seeking the composition of dark matter helps to refine models of cosmological evolution. In this process, human wisdom and technology are also advancing. Whether it's verifying Einstein's theory of relativity or more advanced machines, there will be huge academic gains. The study of dark matter has driven developments in astronomy, physics, and particle physics.

## 2. The Composition of Dark Matter

### 2.1. Cosmic Microwave Background (CMB)

CMB is a type of thermal radiation produced by the thermal expansion and contraction of the universe. CMB uses temperature fluctuations (power spectrum) to measure the structural distribution of the universe, as shown in Figure 1 and Figure 2.

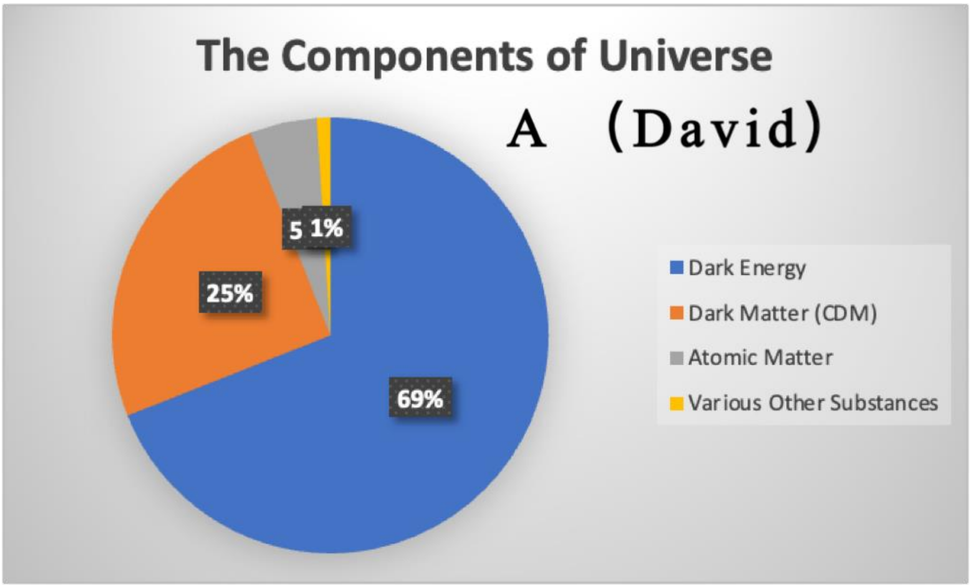


**Figure 1.** The Components of Universe A(David) [2].

The structure of the universe is divided into 69% dark energy, 25% dark matter, and 5% atomic matter. The remaining ~1% is various other substances.

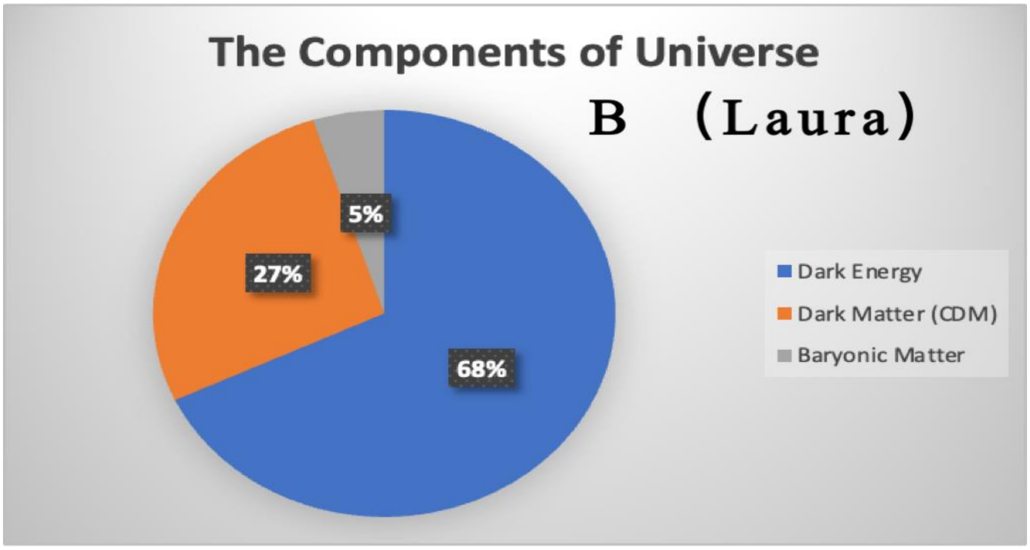


**Figure 2.** The Components of Universe B(Laura) [3].

This power spectrum: 68% dark energy, 27% CDM, and 5% baryonic matter. The data in the two charts are not much different. Because this is a rough guess, there are different data. But the data is not much different. According to descriptions in many materials, the proportion of dark matter is on average 25% to 27.5%; while the proportion of dark energy is around 68% to 71%.

Although dark energy and dark matter differ by one word, they have completely different definitions. Dark energy is the phenomenon of the accelerated expansion of the universe, and dark matter is the formation of the structure of the universe. Atomic matter refers to particles composed of protons, neutrons, electrons, etc. It interacts with light and electromagnetic radiation. This is exactly the opposite of dark matter.

Dark matter is the second largest component in the structure of the universe of macroscopic structure formation.

### 2.2. Weakly Interacting Massive Particles (WIMPs)

There are main candidates regarding the composition of dark matter: Weakly Interacting Massive Particles (WIMPs).

Weakly Interacting Massive Particles (WIMPs) have weak interactions with ordinary matter, making them difficult to detect or decompose. This is also the same as the properties of dark matter, and it is the most important part. It mainly serves as a candidate for CDM. Laura compared neutrinos to WIMPs to explain why were candidates [3]. In Figure 3. He believes that in experiments and observations, the mass is very light. Speed affects its formation: starting from a super galaxy, and then breaking up small matter. This result may be related to hot dark matter (HDM). However, WIMPs are different in that they are slower, allowing small matter to form and first, then into large structures.

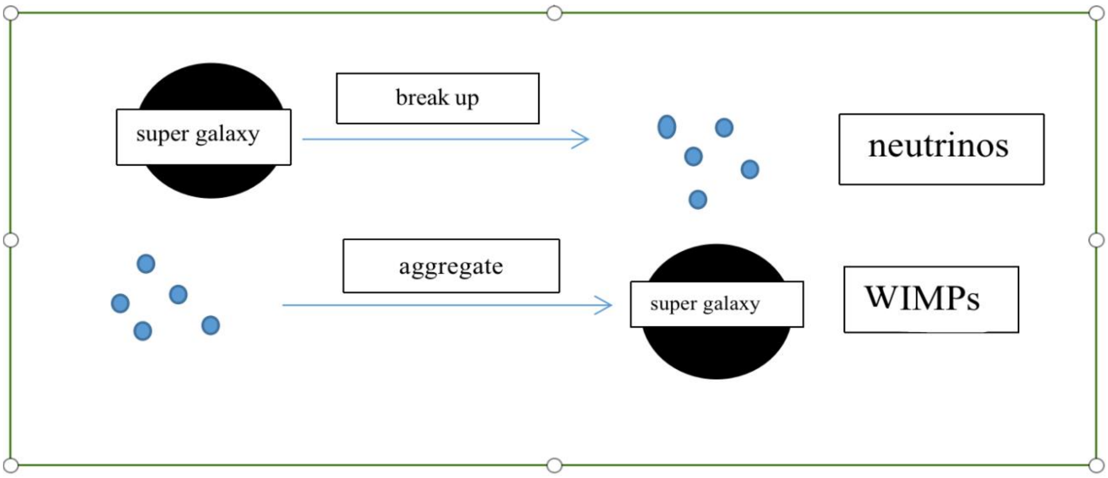


**Figure 3.** A simple process diagram of neutrinos and WIMPs (Photo/Picture credit: Original).

The results of WIMPs are consistent with the results of CDM model experiments. And it verified supersymmetry theory, they are the lightest supersymmetric particles [3].

WIMPs serve as a satisfactory component for detecting the origin of the universe and the structure of dark matter. Its weak force is consistent with the characteristics of dark matter, and theoretically supported. So, this is the most suitable choice.

## 3. Characteristics of Dark Matter

### 3.1. Three Types of Dark Matter are Classified

Cold dark matter (CDM), warm dark matter (WDM), and hot dark matter (HDM) are three types of dark matter. Their characteristics are related to the mass and speed of dark matter particles.

### 3.2. Cold Dark Matter (CDM) and Cold Dark Matter Halos

Cold dark matter (CDM) is the most important part of dark matter. Most researchers use CDM as a hypothesis [3]. It is a particle replaced by candidate WIMPs, which only interact with gravity. According to the theory of cosmic expansion, cold matter is a particle with a very low temperature that escapes from thermal equilibrium and moves at a very low speed. In thermal equilibrium, the slower dark matter moves, its kinetic energy is relatively low. The less internal energy and heat energy converted when particles collide, the easier it is to maintain equilibrium capabilities. Einasto proposed that dark matter particles move slowly and small-scale perturbations will not be affected [4]. Therefore, the gravitational force between large-scale structures will be powerful.

Cold dark matter halos meet the conditions for observing large-scale galaxy structures. This gravitational gathering creates the cold dark matter halos. Navarro's research showed that numerical simulation showed that the structure of the cold dark matter halo is the same as the dark matter halo around the spiral galaxy [5]. First, verify the similarity of the cold dark matter halo mass and over density. Secondly, the circular velocity (Vc) uses the function formula to obtain that the velocity is unchanged, which is as stable as the characteristics of the cold dark matter halo. Finally, the cold dark matter halo conforms to the rotation curve of spiral disks. The rotation curve of the spiral disk refers to the variation between the speed and distance of the material in the spiral galaxy disk, which is composed of gas and stars. Navarro proposed that the rotation curve of the spiral disk deviates from Newton's law of gravity [5]. Because the general rotation curve speed is that the closer it is to the center, the speed increases; the further away from the center, the speed decreases. However, the speed of the spiral rotation curve is relatively stable.

### 3.3. Warm Dark Matter (WDM)

WDM is a hypothetical particle that is faster and lighter than CDM, which cannot form a large-scale galaxy structure dark matter halo because it is very fast and escapes from the thermal equilibrium state earlier than the CDM. It is more suitable for the study of small-scale structures. Paduroiu explained the verification process of the WDM model and discovered the characteristics of Shells and Caustics [6]. In Table 1, a comparison of cold dark matter and warm dark matter is shown.

**Table 1. S**ummary of the Shells and Caustics features of CDM and WDM [6].

| | Cold Dark Matter (CDM) | Warm Dark Matter (WDM) |
|---|---|---|
| Features | Gravitational collapse, halo mergers, and satellite tidal disruption are enhanced. | Filament intersections are formed from top and bottom, absorbing material. |
| Features | Not visible in high-resolution | High visibility in high-resolution |

Shells and Caustics are used as detection standards because their density can be used as detection signal data. At the high density, when particles meet and collide, they may produce an observable signal. When dark matter particles meet, the greater the interaction, which means they are at a location with high density. At this time, warm dark matter is the best observation object. Because its visibility is higher than cold dark matter.

### 3.4. Hot Dark Matter (HDM)

Hot dark matter (HDM) is a particle that is faster than CDM and WDM. The relationship between their speeds can be expressed as follows: Vhot >Vwarm>Vcold. The relationship between their escaping speeds from the thermal equilibrium structure can be expressed as follows: V hot escaping>V warm escaping>V cold escaping. The characteristics of the large-scale structural evolution of HDM are opposite to the CDM. Einasto compared a numerical simulation of the structural evolution of hot dark matter with that of cold dark matter. The structure formation of the CDM begins with early superclusters composed of networks of small galaxy filaments, and the CDM simulates the observed structure well, including quantitative features.

Therefore, CDM is the most suitable particle for studying the large-scale structures of the universe. WDM and HDM are suitable for studying small-scale structural problems. However, their research currently faces great challenges, and there are not many results yet.

### 3.5. Stability

Dark Matter has strong stability. It is related to the stable properties of CDM. This stability provides an advantage in observing large-scale structures over extended periods. As time elapses, the influence of external factors remains minimal. The longer preservation of structures allows for exploration over more extended periods. Hambye through the principle, proposed that assuming dark matter is a scalar, both fermion and boson models can obtain signals at the Large Hadron Collider (LHC) [7]. The result is that dark matter is a high-energy stable mechanism, which remains undecayed during the evolution of the universe. These characteristic forms the foundation for cosmological observations of large-scale structures. It allows dark matter to endure and persist in the cosmos.

## 4. Conclusion

Through the study of CMB (cosmic microwave background) and power spectrum, it is concluded that dark matter plays a crucial role in shaping the cosmic framework. It is the second-largest component in the construction of the universe. WIMPs, compared to neutrinos, are more suitable candidates for Cold Dark Matter (CDM) as a process of aggregating into massive galaxies. Two significant results regarding the characteristics of dark matter emerge. In the velocity, CDM has a slower velocity than Warm Dark Matter (WDM) and Hot Dark Matter (HDM), it is not easy to change its energy and resist collapse, thereby maintaining the structure of galaxies. CDM is the most stable particle and is suitable for studying large-scale galaxy structures. In contrast, WDM and HDM have faster velocities, making them more prone to expending energy and altering structures, they are suitable for studying small-scale galaxy structures. This demonstrates the close relationship between the stability of dark matter and Cold Dark Matter. This stability is one of the important drivers in observing large-scale structures.

Only by studying the basic characteristics of dark matter can make more accurate hypotheses, which are the most suitable reference objects to appear in research. These fundamental research directions help astronomers and physicists to find the next targets and eliminate interfering factors. It is also to let more people understand the basic knowledge of dark matter. The exploration of dark matter components requires more technological innovation and new ideas. There are further questions about how long cold dark matter can explore the large-scale structure, and what role WDM and HDM can play in exploring the origin of the universe.

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