Analysis Of the Dark Matter Searching for Axions, Wimps and Mini-Blackholes

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Abstract. With the development of science and technology, human beings are no longer satisfied with exploring visible objects. Under the help of gravity, scholars have noticed dark matter and dark energy. Unfortunately, dark matter is ethereal and has not been discovered by human beings for the time being, but through various experiments, astronomers have narrowed the scope of dark matter and defined some matter to guess the nature of dark matter. These are known as candidates for dark matter. This study makes a theoretical analysis of the three dark matter candidates, Axions, WIMPs and mini black holes, and lists various experimental evidences and principles, so as to give readers a clearer understanding of these three types of candidates and their high possibility of existence. These three are currently the hottest candidates and the most important objects for analyzing dark matter. At the same time, in a deeper analysis, their possible existence also indicates that the possibility of the existence of dark biological intelligence is extremely small, and that none of these three substances can rely on conventional physicochemical changes to form complex and cohesive enough matter, let alone to form a normal size organism. Therefore, these results help to understand the status quo and prospect of dark matter research, and provide sufficient theoretical evidence for the discovery of dark matter.

Keywords: Dark matter; axions; WIMPs; mini-blackholes.

1. Introduction

For centuries, human curiosity has been attracted by the abundance of celestial bodies that can be seen in the observable universe. However, there are some evidences of dark matter that is neither reflective nor emitting light. The rotation curve of a galaxy is the first. It has been demonstrated by astronomical observations that a large number of stars in the periphery of galaxies are rotating at a significantly faster rate than predicted by theory in the galaxy's center [1]. If visible matter is the only source of a galaxy's gravity, then stars on the galaxy's periphery that move too quickly will be expelled from the galaxy due to insufficient gravity to produce the centripetal force. That was not the case. Thus, it may be concluded that the galaxy most likely contains a large amount of invisible matter that acts as a gravitational pull on the outer stars, tying them to the galaxy. This represents the initial empirical proof of dark matter.

The gravitational lens effect provides the second piece of observational evidence. The bullet galaxy cluster observation results from 2006 demonstrated that dark matter's existence was inevitable since there was no overlap between the gravitational lens effect and the light signal distribution, proving that visible matter could not dominate the mass distribution [2].

Anisotropic measurements of cosmic microwave background radiation provide additional conclusive evidence. The exploration satellite's background radiation is not dispersed uniformly around the sky, as evidenced by the map of cosmic microwave background radiation created from the data. Anisotropy can be quantitatively described by obtaining a spectral function by the application of the spherical harmonic function expansion method [3]. This spectral function's curve will be influenced by a variety of universally elements. Theoretically, one can obtain spectral functions with varying shapes by varying the quantity of different components in the universe (seen from Fig. 1). The author may thus reverse the percentage of different components of the cosmos based on the shape of the spectral function that is actually recorded by astronomical measurements. The study finds that before the observed spectral function can be well fitted, five times as much dark matter must be added to the cosmos as visible matter [4].

Many candidates have been put out over time, including sterile neutrinos, axions, and weakly interacting massive particles (WIMPs). To find these possibilities, a variety of methods, including collider searches, indirect detection, and direct detection, have been used in numerous experiments. The research will examine the present status of dark matter research in this overview of the literature, with an emphasis on the top contenders and the most recent detection attempts.

2. Basic Descriptions

Dark matter, which accounts for eighty percent of the total mass of the universe, continues to be a mystery, and several hypotheses have been offered to explain its existence. Using detection techniques like as X-ray emission searches, Warm Dark Matter (WDM), which is composed of particles with energies ranging from one to one hundred keV and includes sterile neutrinos, has the potential to resolve inconsistencies on tiny scales. Similar to neutrinos, hot dark matter (HDM) is characterized by high velocities, although it only makes a marginal contribution to the density of dark matter. Neutrino characteristics are investigated using experiments such as KATRIN. Cold Dark Matter (CDM) is a concept that incorporates slow particles, such as supersymmetric neutralinos and axions, as well as direct detection investigations such as LUX, XENON1T, and CDMS that are looking for these particles [5]. The ultra-light fuzzy dark matter (FDM), the self-interacting dark matter (SIDM) with a dark force, and the asymmetric dark matter (ADM) with a net dark charge are some of the other contenders. These potential possibilities will be investigated in ongoing and upcoming studies in order to discover the real nature of dark matter.

3. Axions

Axions, light pseudo scalar particles, were proposed in the late 1970s to overcome the strong CP problem in quantum chromodynamics (QCD). Because they don't interact significantly with regular matter, axions have been proposed as dark matter particles to explain the universe's high dark matter content. This page describes axion dark matter, how it is found, and the latest findings. Axions are neutral, tiny particles with weak interactions. They form when the Peccei-Quinn symmetry breaks independently. This symmetry solved quantum mechanics' strong CP problem [6]. Breaking this symmetry reveals the axion, a new particle. The axion mass decreases as the energy level where Peccei-Quinn symmetry breaks rises. Axions may have formed the dark matter relic density, a Bose-Einstein condensate, in the early cosmos [7]. Axions may also explain why powerful interactions don't break CP. Axions don't interact significantly with ordinary matter, making them hard to find. Several approaches have been proposed to find axion dark matter: In a high magnetic field, resonant holes convert axions into microwave photons. The second experiment is Light-through-wall experiments: Laser light is focused at a strong magnetic field. Axion-to-photon conversion may explain photons on the other side of the field and the GammeV search for Chameleon Particles employ light to travel through walls. There are some astrophysics observations: the Sun and neutron stars can be used to search for axion dark matter [8]. In powerful magnetic fields, axions may become photons. Researchers continue to search for it. New data and axion parameter space constraints from several experiments have been returned. Firstly, ADMX, the Axion Dark Matter Experiment, is crucial to axion dark matter research [9]. They explore photon-axon interactions with a cavity-based haloscope. In 2022, ADMX presented results for various coupling strengths taking out axion masses between 2.66 and 3.31 μeV [10]. As ADMX is developed and more data is collected, the experiment will be able to explore into a larger section of the axion parameter space and maybe find axions. Secondly, Any Light Particle Search This experiment shoots light through walls and watches photons transforms back into axions to find particles like them. ALPS put new limits on how strongly axion-like particles can link to photons of masses below 10 neV [11]. These findings help future studies by narrowing the range of parameters utilized to explain axion-like particles. Thirdly, the experiment to use the X-ray Telescope (SAX) to locate solar axions by looking for X-ray photons created when axion and

photon change forms in the Sun's magnetic field. A new SAX article placed new limitations on axion-photon coupling strength for axion masses below 1 eV. These results constrain the axion parameter space and demonstrate that astrophysical and axion dark matter studies are complementary.

4. Massive Particles with Weak Interactions (WIMPs)

WIMPs are one type of dark matter that has been studied a lot. A group of scientists in 1996 named Jungman and others called "WIMP" particles. These are particles with masses between a few GeV and a few TeV that interact through the weak nuclear force and possibly other forces that are not part of the Standard Model of particle physics. The next sections will talk about what WIMP dark matter is, how it can be found, and ongoing tests that are being done. A WIMP could be dark matter because they interact with each other through the weak nuclear force and have a lot of mass. Traditional ways of finding things can't pick them up because they don't interact with electromagnetic or strong nuclear forces. This means they are "weakly interacting." WIMP is based on theoretical extensions of the Standard Model, such as supersymmetry, which says that new particles will exist with the right properties [12]. There are three main types of methods used to find WIMP dark matter. First, studies on direct detection. In these studies, sensitive monitors are used to look at WIMPs that reflect nuclei that are not on target.

There are two studies called LUX and XENON1T that are direct detecting experiments. In these tests, Noble liquid monitors do a good job of picking up low-energy nuclear recoils. Second, in astrophysics, indirect detection tests find gamma rays, neutrinos, and cosmic rays as byproducts of WIMP destruction or decay. There are studies called Fermi-LAT and H.E.S.S. that are looking for gamma-ray signs from the destruction of WIMPs [13]. Some of the results are summarized in Fig. 1. Third, Large Hadron Colliders (LHC) and other high-energy particle colliders may be able to make WIMPs, which would make it possible to find them using Standard Model particles. ATLAS and CMS at the LHC have looked for WIMPs in a number of different end states, which has helped us figure out what they are like. Recently, despite many tests, no solid proof of WIMP dark matter has been found. New tests have limited the properties of WIMPs and helped shape future search strategies which say that the LUX and XENON1T tests only show small cross-sections between WIMPs and nucleons for a few GeV to several TeV. These results have called into question easier WIMP models, which has led to the study of other theoretical options [14]. The Fermi-LAT and H.E.S.S. experiments have limited the width of the WIMP annihilation cross-sections by looking for gamma-ray signals from dwarf spheroidal galaxies and the center of the galaxy, which have a lot of dark matter. The WIMP dark matter parameter space has become smaller because of these results, but no solid proof has been found. Standard Model particles like the Higgs boson and top quark have been used in the ATLAS and CMS LHC studies to look for WIMP formation. These searches haven't turned up any WIMP production signs, which narrows down the list of possible WIMP characteristics even more.

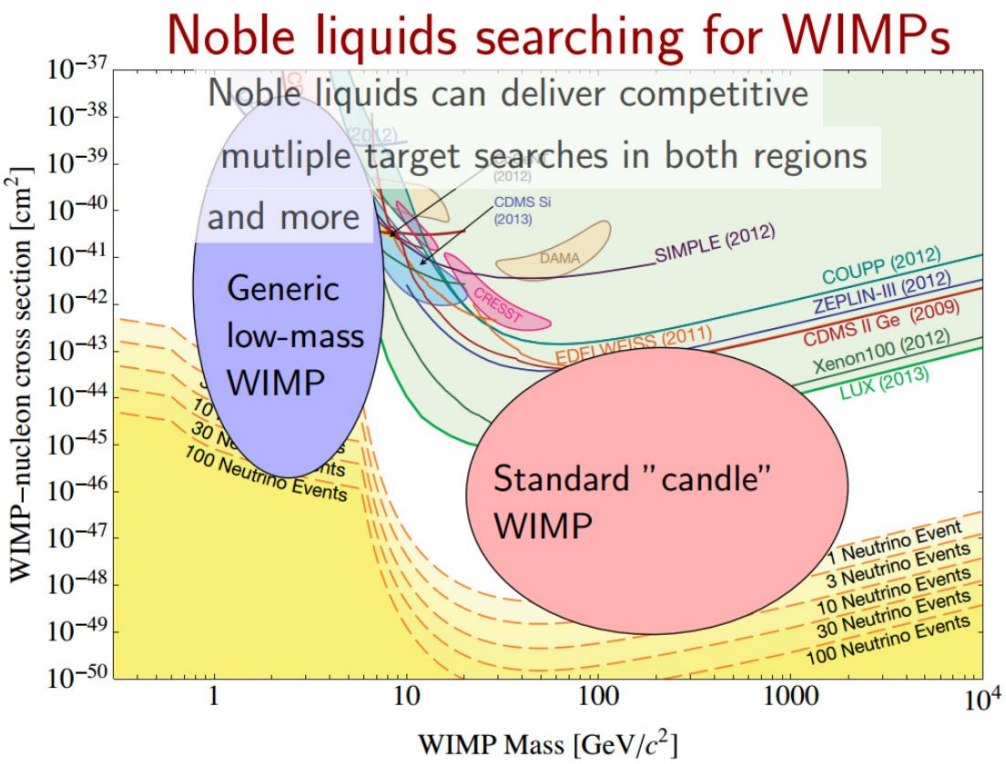


Fig. 1 Some search results for WIMP [13].

5. Mini Black Holes

Mini black holes are small, dense things that were made when the universe was very young because of big changes in the energy density. Astrophysical black holes are made when very large stars fall apart, but PBHs could have formed straight from the dense parts of the early cosmic soup [15]. From the Planck mass (10^{-5} grams) to masses as big as rocks or even bigger, these black holes can have a wide range of masses. When it comes to dark matter, PBHs with masses below the cosmic scale are especially interesting because they might add to the quantity of dark matter that has been seen. Gravitational waves may be emitted when PBHs evaporate through Hawking radiation. These waves could be picked up by interferometric devices like Virgo and the Laser Interferometer Gravitational-Wave Observatory (LIGO) [16]. When PBHs take in matter from their surroundings, the heated accretion ring can give off radiation signals that can be picked up. Observations at different wavelengths might be able to find these signals and limit the PBH population. Here are the most recent detection results. As of now, there has been no clear proof of PBH dark matter. But new tests and observations have put limits on how common they are and what part they might play as dark matter candidates: From the Optical Gravitational Lensing Experiment (OGLE) and the Microlensing Observations in Astrophysics (MOA), one knows that there are a lot of PBHs with masses between 10^{-8} and 10^{2} solar masses [17]. Based on these findings, PBHs with masses in this range probably don't make up all of dark matter. Second, LIGO and Virgo have limited the number of PBHs with masses below 10^{7} grams because they have not been able to identify gravity waves from PBH evaporation. However, these devices should become more sensitive over time, which could make it possible to find PBH dark matter. Third, looking for X-ray and radio emissions from PBH accretion disks has limited the number of PBHs whose masses are less than 10^{3} solar masses [18]. These results make it even less likely that PBHs could be dark matter possibilities.

6. Limitations and Prospects

One of the primary limitations in dark matter detection is the weakly interacting nature of dark matter particles, which makes them extremely difficult to observe directly. As dark matter particles

interact only very weakly with normal matter, their detection relies on observing the rare and minute signals produced by their scattering off atomic nuclei in highly sensitive detectors. The development of low-background experiments and advanced detection techniques is necessary to overcome the challenges posed by the faint and rare nature of dark matter signals. Besides, indirect and collider-based searches for dark matter face their own set of limitations. Indirect detection relies on observing the products of dark matter annihilation or decay, such as gamma rays, neutrinos, or cosmic rays. The challenges in this approach include the difficulty in disentangling dark matter signals from astrophysical backgrounds and uncertainties in the modeling of dark matter distributions and annihilation processes. Collider-based searches, such as those conducted at the Large Hadron Collider (LHC), face the challenge of identifying the rare production of dark matter particles amidst a vast background of Standard Model processes. The theoretical uncertainties associated with dark matter models further complicate the interpretation of experimental results. For instance, the behavior of dark matter particles at the microscopic level remains largely unknown, with questions regarding their self-interaction, particle-antiparticle asymmetry, and connections to other unresolved mysteries in particle physics, such as the nature of dark energy.

To enhance the prognosis for the future, the primary focus should be on enhancing the instrument's precision to address the above constraints, with a key emphasis on detecting genuine dark matter particles. Furthermore, the author offers additional personal suggestions for further investigation. Given the presence of visible beings, visible energy, and visible matter, one can still speculate about the possibility of dark organisms in the context of investigating dark matter and dark energy. It is uncertain if it will happen or not. Humans are still speculating on the nature of dark matter, and the understanding is purely hypothetical. Dark matter is believed to interact via strong and electromagnetic forces, while being affected solely by weak interaction and gravity, making it challenging for the generation of organic organisms. The proximity of the weak force and gravity is insufficient, and their strength is inadequate to create intricate structures such as living organisms. To create a live organism, it must resemble a living organism on a cosmic scale, and its classification as a genuine living entity is contingent on the criteria used to define living organisms. Possibly, stellar organisms might exist.

7. Conclusion

Dark matter, continues to be a mystery, and several hypotheses have been offered to explain its existence. Using detection techniques like as X-ray emission searches, Warm Dark Matter (WDM), which is composed of particles with energies ranging from one to one hundred keV and includes sterile neutrinos, has the potential to resolve inconsistencies on tiny scales. Similar to neutrinos, hot dark matter (HDM) is characterized by high velocities, although it only makes a marginal contribution to the density of dark matter. Neutrino characteristics are investigated using experiments such as KATRIN. Cold Dark Matter (CDM) is a concept that incorporates slow particles, such as supersymmetric neutralinos and axions, as well as direct detection investigations such as LUX, XENON1T, and CDMS that are looking for these particles. The ultra-light fuzzy dark matter (FDM), the self-interacting dark matter (SIDM) with a dark force, and the asymmetric dark matter (ADM) with a net dark charge are some of the other contenders. These potential possibilities will be investigated in ongoing and upcoming studies in order to discover the real nature of dark matter.

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