The dark matter and dark energy

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Abstract. The dark matter and dark energy are one of the biggest challenges facing contemporary physics and astronomy. Dark energy and dark matter play an important role the universe. The amount of dark energy and dark matter determines how the universe changes. When there's more dark energy, the universe is accelerating. If there were more dark matter, the universe might slow down, or even stop expanding and start contracting. So in this paper, the basic definition of dark matter and dark energy are introduced. And how were dark matter and dark energy discovered and their respective detection methods and the current progress of experiments to detect dark matter and dark energy respectively.

1 Introduction

Dark matter and dark energy determine the direction of human exploration of theuniverse, the fate of the universe depends on what dark matter is. Because according to astronomers' current analysis of the composition of the universe, about 70 percent of the energy in the universe is dark energy, and about 25 percent of the universe is made up of dark matter. Astronomers believe the galaxy is surrounded by dark matter, otherwise it should be expanding. This suggests that dark matter is not a hypothetical concept designed to eliminate some flaws in the theory of gravity, but a real state of matter. According to the gravitational theory of physics, without dark matter, galaxies would collapse into separate parts and stars would move in completely different orbits. Moreover, the accelerating expansion of the universe is caused by dark energy. So dark matter and dark energy are very important for space exploration. The main problem with dark matter and dark energy is that we haven't been able to actually detect them and figure out its nature. As a result, many people interested in the universe do not understand dark matter and dark energy. Therefore, the purpose of this article is to shed some light on the theories that scientists have developed about dark matter and dark energy. This paper mainly introduces the discovery and detection of dark matter and dark energy and the results of detection and related theories.

Scientists think dark matter came from the Big Bang. At some point in the early universe, when the universe was so hot and energetic that particles collided violently, all kinds of matter, including dark matter, were created.Dark matter is an unidentified particle of matter whose electromagnetic emission and refraction are so weak that it cannot be detected directly. The detection method of dark matter is the key to the study of dark matter. Here are some basic ways of dark matter detection. The direct detection of dark matter is one of the most widely used methods to search for dark matter particles.The method directly detects signals from collisions between dark matter particles and atomic nuclei in space. The indirect method is used to observe the stable particles produced by the annihilation or decay of dark matter particles in space, such as antiprotons, positrons, gamma-ray, neutrinos and so on. The third way is accelerator detection. Accelerator detection is to create dark matter particles at ground accelerators by accelerating them to extremely high energies and smashing them into each other. Then produce the dark matter particles. In this paticle, the properties about dark matter and dark energy will be discussed, evidence of dark matter, possible ways to detect dark matter and dark energy.

2 The properties of dark matter and dark energy

Dark matter is one of the unknown properties of matter particles in the universe and is an important part of the universe. About which has gravity, so it holds everything together. Dark matter is currently thought to come in three states: cold dark matter, hot dark matter and warm dark matter.Dark matter is mainly cold dark matter, which is non-relativistic, and relativistic hot dark matter only accounts for a small part, while warm dark matter is still only a conjecture of some scientists due to the unsatisfactory simulation results of experiments. On a cosmic scale, gravity tends to hold dark matter together, and the motion of dark matter causes the opposite, so it clumps together and through the Standard Model of cosmology, scientists think dark matter particles have high mass.

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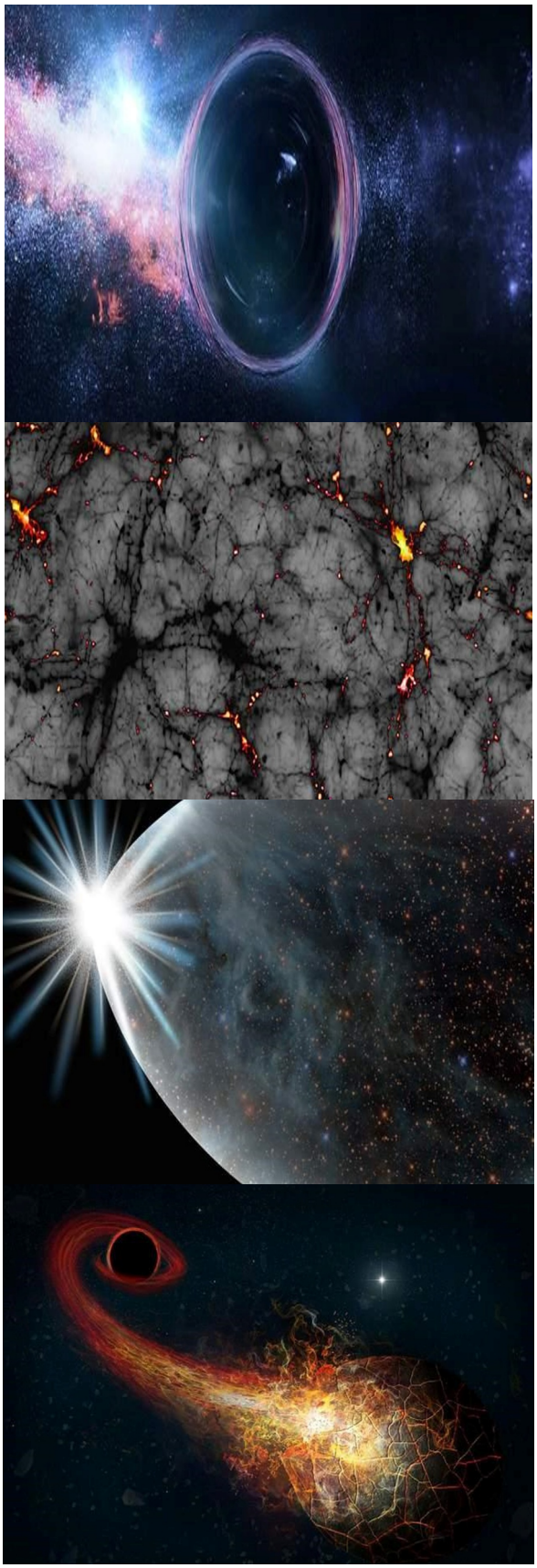

Figure 1. Dark matter in the universe [1]

The ΛCDM model attempts to explain observations of the cosmic microwave background, supernovae which can accelerate the expansion of the universe and the large-scale structure of the universe, Λ stands for cosmological constant. There are two possible particle guesses for dark matter: axions and inert neutrinos. Axons can be connected to nucleons, electrons and, at ring level, photons, all of which are proportional to 1/fa or ma [2] Inert neutrinos are particles of what scientists suspect to be the warm dark matter. Neutrinos, a type of lepton, are very small, extremely light, travel at close to the speed of light and have no electric charge, so they rarely interact with other detection particles, making them hard to detect. Neutrinos that do not participate in any interaction other than gravity are considered inert.

A new study finds that some dark matter is disappearing, and scientists think it's caused by dark energy, which means it is likely consuming dark matter. There are two important paradoxes in the prediction and observation of cold dark matter theory with regard to the emergence and formation of galaxies and galaxy clusters in space. They are galactic halos: cold dark matter simulates a halo with a sharper spin curve than the observed one. Disappearing satellite galaxy problem: The Cold Dark Matter model can simulate a large number of small dwarf galaxies, about a thousand times the mass of the Milky Way, but humans do not observe. But two of them have solvable problems: WIMP (weakly interacting massive particle), which can only be detected directly in particle accelerators using highly sensitive detectors. Massive compact halo objects Such dark-enveloped objects may be detected using gravitational lensing. Therefore, if dark energy really does continue to devour dark matter, then our universe will eventually disappear. Dark energy is the kind of energy that drives the universe, it works as a repulsive force in the universe. Dark energy and dark matter don't absorb, reflects or radiate light, so human have to use special methods to detect them indirectly.

3 The evidence of dark matter and dark energy

Findings about dark matter.the first is in 1884, a man named William Thomson scientists estimate that the quality of the Milky Way. But the quality is surprisingly big, when astronomers think that the quality of a galaxy is provided by the visible stars, but estimate the quality of the Milky Way is far larger than visible, so they think there is some material was not observed. Then in 1933 and in 1936, both the astronomer Fred Zwicky and Sinclair Smith has found members around the core region of the coma cluster of galaxies movement speed is too fast, but the coma cluster cannot through the visible material produced by the gravity to maintain complete. Therefore they believe that there must be no matter at work. But the dark matter was actually discovered in 1970. When two astrophysicists studying the rotation velocity curves of galaxies determined that there was a lot of dark matter in the universe. In the new study, scientists compared observations of distant galaxies with central black holes to those of local elliptical galaxies. They found that the mass of galaxies with central black holes has increased by 7 to 20 times compare to 9 billion years ago, a rapid increase that cannot be explained by known principles. Therefore, scientists think black holes might contain dark energy, so the

increase in mass is related to the expansion of the universe. As the universe expands, so does the mass of black holes.Some scientists think that the expansion rate of the universe is related to the density of dark matter, which is being absorbed by dark energy, so the density of dark matter is getting smaller and smaller, which causes our universe to accelerate its expansion and the mass of black holes to accelerate.

4 The possible ways to detect dark matter and dark energy

4.1 Dark matter

And the some ways of dark matter detection are in particle accelerators and by direct detections of scattering in terrestrial detectors, and indirect detection of products from dark matter particle annihilation in the galactic halo.direct detection of dark matter is one of the most widely used methods in the search for dark matter particles.The method directly detects signals from collisions between dark matter particles and atomic nuclei in space. Because the probability of such a collision is small, the resulting signal is very weak So the detector used for the direct detection is buried at a depth of 700 meters. The rock, plastic, lead, copper and other materials surrounding the probe are used to prevent cosmic particles other than dark matter from reaching the probe. This may have lowered the background from which the signal was generated. The detector itself is small, like a ball of ice, and made mostly of germanium and silicon. If a nucleus of a germanium or silicon atom is touched by a dark matter particle, it bounces off and sends a signal to the detector. However, this method is susceptible to other interference and detects less data. So there's no great certainty that dark matter has been detected. Although this flux is relatively small, we can in principle use it to detect WIMPs as they cross the core with ground-based detectors and decay elastically [3]. The data of dark matter' s local density is about 7×10^{-25} g cm−3 (0.4 GeV cm −3) [4,5].

The indirect method is used to observe the stable particles produced by the annihilation or decay of dark matter particles in space, such as gamma rays, positrons, antiprotons, neutrinos and so on. According to current theoretical models, dark matter particles may decay or interact to produce stable high-energy particles that could be detected if humans could accurately measure their energy spectra.By the way when use this method , there's not really strong evidence that it's dark matter.Accelerator detection is to create dark matter particles at ground accelerators by accelerating them to extremely high energies and smashing them into each other. Then produce the dark matter particles.The world's largest Hadron Collider is currently located in Europe. By colliding two beams of protons spinning in reverse, the LHC is expected to create conditions similar to those of just a trillionth of a second after the Big Bang. These collisions are extremely energetic and produce unusual particles, including dark matter particles. It is hoped that evidence of dark matter particles will be found by colliding tests. But to do dark matter experiments on accelerators, it takes a lot of energy.

Axions are subatomic particles that exist in nature in particle physics. Axion particle is a kind of accessory particle after the supersymmetric particle of any particle collides with the positive and negative electrons. Axions are one of the particles that scientists have hypothesized make up dark matter, because they interact with each other through forces so small that they can't stay in thermal equilibrium. In most axion searches, the axion is coupled with two photons, allowing for an axion-photon conversion in an external electric or magnetic field. There are three main methods to search for axions in the laboratory: Halogen mirrors, helioscopes and experiments in which light passes through walls [6]. Axion halos are specifically designed to find cold dark matter axions. In a stationary external magnetic field, axions can be converted into photons. In this field, virtual photon will instead of one of the photons, while the other photon would maintain the axion's energy. In a light-through-wall experiment, laser photons traveling in a transverse magnetic field are converted into axions, which pass through the optical barrier and are then converted back into photons in a second magnetic field.The helioscopic experiment looked for axions that might be produced inside the hot sun using a axion fluorescent lamp. CAST established an upper limit of axon-photon coupling of $g_{agg} < 8.8 \times 10^{-11}$ GeV $^{-1}$ (at 95% CL) , at axon mass $m_a < 2 \times 10^{-2}$ eV, and achieved a larger axon mass at different pressures with buffer gases 3He and 4He, to reach the axon QCD zone.This is converted into X-rays by the macroscopic magnetic field of the dipole magnet facing the Sun and detected by the X-ray detectors at the ends of the magnet[7,8].The ADMX experiment can be used to detect axons[9]. A new ADMX experiment is currently being commissioned at the University of Washington. The experiment will use tunable cavities with higher quality factors and lower intrinsic noise due to dilution cooling and quantum-limited SQUID amplifiers [10]. WIMPs can also detect dark matter, with predicted WIMP masses ranging from a few GeV to ~10 TeV, well within the range of direct and indirect dark matter searches and high energy collider searches [11].

4.2 Dark energy

There are four ways to detect dark energy: baryon acoustic oscillations, by la type supernova, galaxy clusters, and weak gravitational lensing. Dark energy can affect the expansion rate of the universe. The baryon acoustic oscillation is the periodic density fluctuations of the visible baryonic matter in the universe. Baryon is a composite particle made up of three quarks. Since baryons are composite particles, they are not elementary particles. The most common baryons are protons and neutrons. Baryon acoustic oscillation is a standard measure of cosmological distance. Baryons can oscillate back and forth in these overly dense regions, and one can use this redshift to measure how fast the universe is expanding over time. Therefore, the baryon acoustic oscillation can measure the acceleration speed of the expansion of the universe, and estimate the scale of the acoustic oscillation through the magnitude of the sound speed, so as to calculate the expansion acceleration. The inhomogeneity of matter density causes acoustic

oscillations, which stop when matter and photon are decoupled. This oscillation leaves a trail in the distribution of matter, with slight increases or decreases in inhomogeneity at certain scales. These peaks and troughs can be found by observing the uneven distribution of galaxies, which can determine cosmic distances and the rate of expansion. The la type supernovae. The Ia supernova requires a binary star system, a giant star and a White Dwarf. One characteristic of Type la supernovae is that they occur at 1.44 times the mass of the sun, so the energy and luminosity produced by the explosion are basically the same, which provides scientists with a standard for measuring the distance of celestial objects in the universe, astronomers call it standard candle.

The la type supernovae are so bright that they are used as a standard light to measure distances in space, allowing the acceleration of the expansion of the universe caused by dark energy to be calculated, proving its existence.When use the detection way of galaxy clusters , people need to find the brightest and largest galaxies in the cluster, mark their locations, and measure the distance between each cluster's locations, which can be used to calculate the acceleration of the expansion of the universe to prove the presence of dark energy. The last way is using weak gravitational lensing. Galaxy clusters are self - gravitationally bound systems of galaxies. Typically measured in millions of parsecs or millions of light years, it contains hundreds to thousands of galaxies. Clusters with a small number of galaxies are called clusters. The weak gravitational lensing is an image distortion caused by light from a distant galaxy being slightly distorted by the gravitational pull of a closer galaxy. It is a pure gravitational effect that reflects perturbations in the density of matter in the universe. Unlike strong gravitational lensing, this effect does not produce as strong a deformation as Einstein's ring or arc distortion. Weak gravitational lensing is an optical phenomenon of spatial curvature caused by perturbations of the density field of matter in the universe due to general relativity. It is described by Einstein's general theory of relativity and the power spectrum of matter disturbance. As we all know, the universe is not completely uniform, the density is different everywhere, where the density is high, the gravity is strong, it will attract more matter, then the density will become larger. Therefore, dark energy can be detected by calculating the distortions caused by gravity.And here are two possible ways to detect dark matter. The gamma rays can be used for high-speed detection. The γ rays have strong penetration, so when the uniform intensity of the ray beam through the object, if there are defects in the local area of the object or the structure of the difference, different parts of the transmitted ray intensity is different, so it can be determined by detecting the distribution of galaxies in the universe to determine the existence of dark matter. Antiparticles could also be used to detect dark matter. Since antiprotons in the universe are mainly produced as secondary products of cosmic rays, one can try to prove the existence of dark matter by measuring the energy spectra of antiprotons.

5 Conclusion

Dark matter and dark energy are important parts of the universe, which have a good development prospect and are important directions for human to explore the universe. In this paper, the definition of dark matter and dark energy and how dark matter was discovered, as well as the detection methods of dark matter and dark energy used by people and several possible detection methods are described.

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