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Demystifying Dark Matter

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Abstract— Dark matter, proposed years ago as a conjectural component of the universe, is now known to be the vital ingredient in the cosmos, eight times more abundant than ordinary matter, one quarter of the total energy density and the component which has controlled the growth of structure in the universe. However, all of this evidence has been gathered via the gravitational interactions of dark matter. Its nature remains a mystery, but, assuming it is comprised of weakly interacting sub-atomic particles, is consistent with large scale cosmic structure. This paper discusses and sheds new light on the possible nature and prospects of the dark matter in the Universe.

Index Terms—gravity, higher dimension, light, mass, multiverse

1 Introduction

DARK matter is, mildly speaking, a very strange form of matter. Although it has mass, it does not interact with everyday objects and it passes straight through our bodies. Physicists call the matter dark because it is invisible. Yet, we know it exists. Because dark matter has mass, it exerts a gravitational pull. It causes galaxies and clusters of galaxies to develop and hold together. If it weren't for dark matter, our galaxy would not exist as we know it, and human life would not have developed. Dark matter is more than five times as abundant as all the matter we have detected so far. As cosmologist Sean Carroll says, "Most of the universe can't even be bothered to interact with you." According to consensus among cosmologists, dark matter is composed primarily of a not yet characterized type of subatomic particle. Whatever dark matter is, it is not made of any of the particles we have ever detected in experiments. Dark matter could have—at the subatomic level—very weak interactions with normal matter, but physicists have not yet been able to observe those interactions. Experiments around the world are trying to detect and study dark matter particles in more direct ways. Facilities like the Large Hadron Collider could create dark matter particles. Other theories including quantum gravity, measurement interpretation errors, and hyper-dimensional interactions at supra galactic distances, are some of the alternative theories proposed to try to explain the anomalies for which dark matter is intended to account.

2 HISTORY

2.1 Evidences for the 'missing mass'- Observing the Invisible

Understanding something you cannot see is difficult—but not impossible. Not surprisingly, astronomers currently study dark matter by its effects on the bright matter that we do observe. Dark matter was discovered in 1905 by astronomers at the University of Groningen who studied the motions of globular clusters and found much larger gravitational effects than they could account for from observations in visible light of objects in our neighbourhood; the name was then "missing mass". The first person to interpret evidence and infer the presence of dark matter was Dutch astronomer Jan Oort, who in 1932 while studying stellar motions in the local galactic neighbourhood found that the mass in the galactic plane must be more than the material that could be seen, but this measurement was later determined to be essentially erroneous. In 1933 the Swiss astrophysicist Fritz Zwicky, who studied clusters of galaxies, made a similar inference. Zwicky obtained evidence of unseen mass. Zwicky estimated the cluster's total mass based on the motions of galaxies near its edge and compared that estimate to one based on the number of galaxies and total brightness of the cluster. He found that there was about 400 times more estimated mass than was visually observable. The gravity of the visible galaxies in the cluster would be far too small for such fast orbits, so something extra was required. This is known as the "missing mass problem". Based on these conclusions, Zwicky inferred that there must be some non-visible form of matter which would provide enough of the mass and gravity to hold the cluster together.

When the orbits of stars and clouds of gas were observed as they circle the centers of spiral galaxies, it was found that they move too quickly. These unexpectedly high velocities signal the gravitational tug exerted by something more than that galaxy's visible matter. From detailed velocity measurements, it was concluded that large amounts of invisible matter exert the gravitational force that is holding these stars and gas clouds in high-speed orbits. Assuming the gravitational mass is due to only the visible matter of the galaxy; stars far from the center of galaxies have much higher velocities than predicted. Galactic rotation curves, which illustrate the velocity of rotation versus the distance from the galactic center, cannot be explained by only the visible matter. Assuming that the visible material makes up only a small part of the cluster is the most straightforward way of accounting for this.

Gravitational lensing observations of galaxy clusters allow direct estimates of the gravitational mass based on its effect on light from background galaxies, since large collections of matter (dark or otherwise) will gravitationally deflect light. In galaxy clusters such as Abell 1689, lensing observations confirm the presence of considerably more mass than is indicated by the clusters' light alone.

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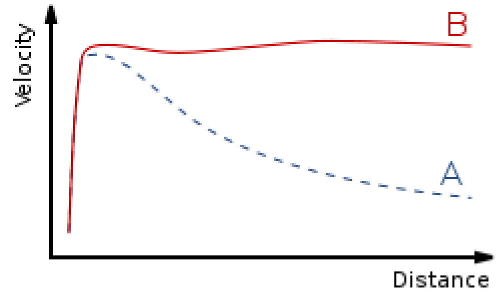

Fig. 1 Rotation curve of a typical spiral galaxy: predicted (A) and observed (B). Dark matter can explain the 'flat' appearance of the velocity curve out to a large radius

Fig. 2 Strong gravitational lensing as observed by the Hubble Space Telescope in Abell 1689 indicates the presence of dark matter

2.2 Amount of Dark matter in the Universe

According to the observations made, the dark matter component has much more mass than the "visible" component of the universe. Only about 4.6% of the mass-energy of the Universe is ordinary matter. About 23% is thought to be composed of dark matter. The remaining 72% is thought to consist of dark energy, an even stranger component, distributed almost uniformly in space and with energy density non-evolving or slowly evolving with time. Determining the nature of this dark matter is one of the most important problems in modern cosmology and particle physics.

2.3 Identifying dark matter-Cosmic hide and seek

Although dark matter had historically been inferred by many astronomical observations, its composition long remained speculative. Currently the astronomical jury is still out as to exactly what constitutes dark matter. In fact, one could say we are still at an early stage of exploration. Many candidates exist to account for the invisible mass, some relatively ordinary, others rather exotic. Early theories of dark matter concentrated on hidden heavy normal objects, such as black holes, neutron stars, faint old white dwarfs, brown dwarfs, as the possible candidates for dark matter, collectively known as MACHOs. Astronomical surveys failed to find enough of these hidden MACHOs. Some hard-to-detect baryonic matter, such as MACHOs and some forms of gas were additionally speculated to make a contribution to the overall dark matter content, but evidence indicated such would constitute only a small portion. Furthermore, data from a number of lines of other evidence, including galaxy rotation curves, gravitational lensing, structure formation, and the fraction of baryons in clusters and the cluster abundance combined with independent evidence for the baryon density, indicated that 85–90% of the mass in the universe does not interact with the electromagnetic force. This "nonbaryonic dark matter" is evident through its gravitational effect. Consequently, the most commonly held view was that dark matter is primarily non-baryonic, made of one or more elementary particles other than the usual electrons, protons, neutrons, and known neutrinos. The most commonly proposed particles then became WIMPs (Weakly Interacting Massive Particles), though many other possible candidates also have been proposed. If they exist, these particles have masses tens or hundreds of times greater than that of a proton but interact so weakly with ordinary matter that they're difficult to detect. WIMPs could include any number of strange particles, such as:

- Neutralinos (massive neutrinos) – Hypothetical particles that are similar to neutrinos, but heavier and slower. Although they haven't been discovered, they're a front-runner in the WIMPs category.
- Axions – Small, neutral particles with a mass less than a millionth of an electron. Axions may have been produced abundantly during the big bang.
- Photinos – Similar to photons, each with a mass 10 to 100 times greater than a proton. Photinos are uncharged and, true to the WIMP moniker, interact weakly with matter.

And an even weirder explanation for dark matter comes from the idea that there are tiny hidden dimensions wrapped up inside the known four dimensions of space-time in our universe. If that's the case, there could be accompanying particles called Kaluza–Klein particles that account for dark matter. However, these would be even harder to detect

Scientists around the world continue to hunt aggressively

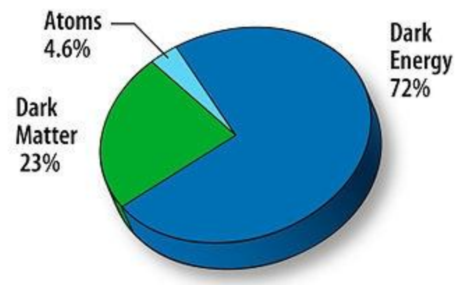

Fig. 3 Composition of the Universe

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for all these particles.

3 Alternatives to Dark Matter

Although dark matter is the widely accepted explanation for the various astronomical observations of galaxies and galaxy clusters, numerous alternatives have been proposed to explain these observations without the need for a large amount of undetected matter. Most of these modify the law of gravity in some way, replacing the laws established by Newton and Einstein.

The earliest modified gravity model to emerge was Mordehai Milgrom's Modified Newtonian Dynamics (MOND) in 1983, which adjusts Newton's laws to create a stronger gravitational field when gravitational acceleration levels become tiny (such as near the rim of a galaxy). Its basic idea was that at very low accelerations, corresponding to large distances, the second law broke down. To make it work better, a new mathematical constant is added into Newton's famous law. It had some success explaining galactic scale features, such as rotational velocity curves of elliptical galaxies, and dwarf elliptical galaxies, but did not successfully explain galaxy cluster gravitational lensing. However, MOND was not relativistic, since it was just a straight adjustment of the older Newtonian account of gravitation, not of the newer account in Einstein's general relativity. Soon after 1983, attempts were made to bring MOND into conformity with General Relativity; this is an ongoing process, and many competing theories have emerged based around the original MOND theory.

Another modified gravity theory based on the Non-symmetric Gravitational Theory (NGT) that claims to account for the behaviour of colliding galaxies. This theory requires the presence of non-relativistic neutrinos, or other candidates for (cold) dark matter, to work.

Another proposal uses a gravitational backreaction in an emerging theoretical field that seeks to explain gravity between objects as an action, a reaction, and then a back-reaction. Simply, an object A affects an object B, and the object B then re-affects object A, and so on: creating a sort of feedback loop that strengthens gravity.

Recently, another group has proposed a modification of large scale gravity in a theory named "dark fluid". In this formulation, the attractive gravitational effects attributed to dark matter are instead a side-effect of dark energy. Dark fluid combines dark matter and dark energy in a single energy field that produces different effects at different scales. Dark fluid can be compared to an atmospheric system. Atmospheric pressure causes air to expand, but part of the air can collapse to form clouds. In the same way, the dark fluid might generally expand, but it also could collect around galaxies to help hold them together.

4 New Approach towards Dark Matter

Among this whole league of possible explanations for dark matter a possibility may be that Dark matter is nothing but ordinary matter in another universe interacting with ours via gravity.

Three dimensional world (length, width, height) is common sense. No matter how we move an object in space, all positions can be described by these three coordinates. In fact, with these three numbers we can locate any object in the universe, from the tip of our noses to the most distant of all galaxies. A fourth spatial dimension seems to violate common sense. If smoke, for example, is allowed to fill up a room, we do not see the smoke disappearing into another dimension. Nowhere in our universe do we see objects suddenly disappearing or drifting off into another dimension. But this may not be the case. Imagine fish swimming in a shallow pond. They might never suspect the presence of a third dimension, because their eyes point to the side, and they can only swim forward and backward, left and right. A third dimension to them might appear impossible.

Three spatial dimensions form the fundamental basis of Greek geometry. Then a fourth dimension of time was introduced by Einstein leading to a 4 dimensional universe. All this has changed with the coming of two startling new theories, called the superstring theory and M- theory. String theory proposes that the fundamental constituents of the universe are one-dimensional “strings” rather than point-like particles. What we perceive as particles are actually vibrations in loops of string, each with its own characteristic frequency. One of the very important thing in this theory is that it also requires six extra dimensions of space; a total of 10 dimensions. This theory also describes cases where the position in some of the dimensions is is described by a complex number rather than a real number. The notion of space-time dimension is not fixed in string theory: it is best thought of as different in different circumstances. But with the addition of the eleventh dimension the the string theory got extended into M-Theory. It suggests that the four-dimensional universe is restricted to a brane inside a higher-dimensional space, called the "bulk". Electrons, protons, photons and all the other particles in the Standard Model cannot move in the extra dimensions; electric and magnetic field lines cannot spread into higher-dimensional space. Only gravitational field lines can extend into the higher dimensional space. Our entire three-dimensional universe could be just a thin membrane in the full space of dimensions.

It may be that our universe is not the only universe. There may exist a hypothetical set of multiple possible universes or simply the Multiverse that together comprise everything that exists and can exist: the entirety of space, time, matter, and energy as well as the physical laws and constants that describe them and the historical universe we consistently experience may just be a part of it.

Let’s consider all the universes to be different planes of the Multiverse and our universe as one of those planes. We live our entire life on this plane, but directly above us there could be a parallel universe, hovering right over us in a higher dimension. Light travels beneath this universe, only in the 4 dimensions, so we never see the matter in this other universe. Therefore objects in this parallel universe would be invisible. But gravity goes between universes because gravity is nothing but the bending of space, so if the space between two levels is bent slightly gravity then moves across. The special feature of

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gravity is that everything causes gravity, in direct proportion to how much energy it contains. Nothing can hide from gravity. Therefore, matter in another universe would be invisible, yet it would have mass. Therefore a hidden galaxy perched behind our galaxy would be totally invisible; floating in another dimension, but it would give the appearance of a halo surrounding our galaxy containing 90 % of the mass

Fig. 4 Our Universe is just a part of the multiverse in Hyperspace

Normally communication between these universes is impossible. We can move freely about in three dimensions along our membrane universe, but we cannot leap off the universe into hyperspace, because we are glued onto our universe. We are "stuck" in a 3+1 dimensional (three spatial dimensions plus one time dimension). But gravity, being the warping of space-time, can freely float into the space between universes. So, dark matter maybe nothing but ordinary matter in another dimension.

5 Conclusions

It may be proposed that perhaps dark matter is nothing but matter, ordinary matter in another dimension hovering right above us and as a result invisible to us but interacting through gravity. The overall mass of such 'globular clusters' could thus be explained without having to resort to some exotic matter spread out as mist in our universe or some modified gravitational theories. Dark matter is the cutting edge of science. We have a picture of our universe which fits a remarkable variety of observations, but seems preposterous on its face. Seeking simplicity, we are led to astonishing ideas. A dark matter discovery could possibly affect our view of our place in the universe.

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