A Conceptual Review on Dark Matter and Dark Energy

Pooja

PG Scholar, Department of Physics, Kurukshetra University, Haryana

ABSTRACT

A large fraction of the mass of our Universe is made out of an exotic, non-baryonic component that is fundamentally different from the ordinary matter that forms visible objects such as stars, planets, galaxies and galaxy clusters. Dark energy and dark matter constitute 95% of the observable Universe. Yet the physical nature of these two phenomena remains a mystery. Einstein suggested a long-forgotten solution: gravitationally repulsive negative masses, which drive cosmic expansion and cannot coalesce into light-emitting structures. However, contemporary cosmological results are derived upon the reasonable assumption that the Universe only contains positive masses and the existence of a "dark energy" that is more powerful than gravitational attraction. These two hypotheses, it has been argued, account for the movement of stars in galaxies and for the accelerating expansion of the universe respectively. But these concepts may be no longer valid: the phenomena they are supposed to describe can be demonstrated without them. This paper reviews various concepts and models based on the scale invariance of the empty space, potentially solving two of astronomy's greatest mysteries.

Keywords: dark matter, dark energy, physics.

INTRODUCTION

It is generally accepted that the universe originated from the Big Bang, which occurred when the temperature of a very concentrated matter was about 1031 degree centigrade. Today scientists formulate that only about 4.6% of the mass of the universe seems to be of ordinary (visible) matter and about 23% is thought to be composed of dark matter (invisible or virtual). The remaining 72% is thought to consist of dark energy distributed diffusely in space. This paper tries to understand about the zero point of Big-Bang, which witnessed the creation of particles and anti-particles and the subsequent disappearance of anti-particles from our Milky Way but existing beyond our universe. Secondly, why gravitational force in our universe is attractive while it is repulsive beyond million- and hundred-million light year scale. Presenting the nature of matter and anti-matter, the paper goes further into the origin and existence of dark-matter and dark-energy, which would be eventually taken over by the second law of thermodynamics [1].

Several works in the last few years devoted to measure fundamental probes of contemporary cosmology have suggested the existence of a delocalized dominant component (the "dark energy"), in addition to the several-decade-old evidence for "dark matter" other than ordinary baryons, both assuming the description of gravity to be correct. Either we are faced to accept the ignorance of at least 95 % of the content of the universe or consider a deep change of the conceptual framework to understand the data. Thus, the situation seems to be completely favorable for a Kuhnian paradigm shift in either particle physics or cosmology. We attempt to offer here a brief discussion of these issues from this particular perspective, arguing that the situation qualifies as a textbook Kuhnian anomaly, and offer a tentative identification of some of the actual elements typically associated with the paradigm shift process "in the works" in contemporary science [2].

LITERATURE SURVEY

In 1933, the Swiss astronomer Fritz Zwicky made a discovery that left the world speechless: there was, claimed Zwicky, substantially more matter in the universe than we can actually see. Astronomers called this unknown matter "dark matter", a concept that was to take on yet more importance in the 1970s, when the US astronomer Vera Rubin called on this enigmatic matter to explain the movements and speed of the stars. Scientists have subsequently devoted considerable resources to identifying dark matter – in space, on the ground and even at CERN – but without success. In 1998 there was a second thunderclap [3] a team of Australian and US astrophysicists discovered the acceleration of the expansion of the universe, earning them the Nobel Prize for physics in 2011.

However, in spite of the enormous resources that have been implemented, no theory or observation has been able to define this dark energy that is allegedly stronger than Newton"s gravitational attraction. In short, dark matter and dark energy are two mysteries that have had astronomers stumped for over 80 years and 20 years respectively. Ptolemy (85 – 165 BCE), in his treatise the Almagest, explains that the earth is spherical, motionless, and positioned at the center of the universe. Even in the 1920s, most physicists believed that the universe was static, or unchanging in size.

In 1929, American astronomer Edwin Hubble studied, at the Mount Wilson Observatory, exploding stars known as supernovae. He found that nearly all galaxies were moving away from us and the farther away they were, the faster they were moving. The galaxies are rushing away from the Earth at about 40,000 Km/sec, that is about 90 million mph. [3] In 1933, Fritz Zwicky, a Swiss astrophysicist, inferred the existence of the unseen matter, which he referred to as dunkle Materie (dark matter). He indicated that there was much more estimated mass than was visually observable. This was the first proposition for the presence of "dark matter" [4]. Zwicky, further concluded that this non-visible form of matter would provide enough of mass and gravity to hold the visible galaxies in the cluster. Assuming that the visible material makes up only a small part of the cluster, galaxies show signs of being composed largely of a roughly spherically symmetric, centrally concentrated halo of dark matter with the visible matter concentrated in a disc at the centre. Thus most of the galaxies are in fact dominated by dark matter. (Dark Matter is non-luminous or sub-luminous material whose existence could be deduced from its gravitational effect on visible matter.

A new model based on the scale invariance of the empty space

The way we represent the universe and its history are described by Einstein's equations of general relativity, Newton's universal gravitation and quantum mechanics. The model-consensus at present is that of a big bang followed by an expansion. "In this model, there is a starting hypothesis that hasn't been taken into account, in my opinion", says Andre Maeder, honorary professor in the Department of Astronomy in UNIGE"s Faculty of Science. "By that I mean the scale invariance of the empty space; in other words, the empty space and its properties do not change following a dilatation or contraction. [5]" The empty space plays a primordial role in Einstein's equations as it operates in a quantity known as a "cosmological constant", and the resulting universe model depends on it. Based on this hypothesis, Maeder is now re-examining the model of the universe, pointing out that the scale invariance of the empty space is also present in the fundamental theory of electromagnetism.

Do we finally have an explanation for the expansion of the universe and the speed of the galaxies?

When Maeder carried out cosmological tests on his new model, he found that it matched the observations. He also found that the model predicts the accelerated expansion of the universe without having to factor in any particle or dark energy. In short, it appears that dark energy may not actually exist since the acceleration of the expansion is contained in the equations of the physics [6]. In a second stage, Maeder focused on Newton's law, a specific instance of the equations of general relativity. The law is also slightly modified when the model incorporates Maeder's new hypothesis. Indeed, it contains a very small outward acceleration term, which is particularly significant at low densities. This amended law, when applied to clusters of galaxies, leads to masses of clusters in line with that of visible matter (contrary to what Zwicky argued in 1933) [7]. This means that no dark matter is needed to explain the high speeds of the galaxies in the clusters. A second test demonstrated that this law also predicts the high speeds reached by the stars in the outer regions of the galaxies (as Rubin had observed), without having to turn to dark matter to describe them. Finally, a third test looked at the dispersion of the speeds of the stars oscillating around the plane of the Milky Way. This dispersion, which increases with the age of the relevant stars, can be explained very well using the invariant empty space hypothesis, while there was before no agreement on the origin of this effect. [8]

Maeder's discovery paves the way for a new conception of astronomy, one that will raise questions and generate controversy. Andre Maeder concluded that the announcement of this model, which at last solves two of astronomy's greatest mysteries, remains true to the spirit of science: nothing can ever be taken for granted, not in terms of experience, observation or the reasoning of human beings [9].

DARK MATTER- DARK ENERGY

Some physicists would agree that even seemingly solid matter is mostly empty space. Take an example of an atom: The distance between the centers of the atoms is so vast compared to their actual size – Still interesting, even the inside of an atom is mostly of empty space with core nucleus and electron cloud constantly in motion!

If an atom could be blown-up to the size of our planet earth, then the electrons would be visible to the naked eyes. What is more important is the vibration frequency, due to particles in motion, which is energy. Dark-Matter is a kind of blank-state: It is an embarrassment in science and an unsolved mystery in nature. What it is and how/why it was generated are not clearly known [10]. Dark matter does not interact with the electromagnetic force – That is, it does not absorb, reflect, or emit light.

Hence, it is extremely difficult to spot it. But researchers have been able to infer the existence of dark matter only from the gravitational effect it seems to have on visible matter. Dark matter seems to outweigh visible matter roughly six to one. Dark energy appears to be associated with the vacuum in space. It is assumed that it is evenly distributed throughout the universe, not only in space but also in time – That is, its effect is not diluted as the universe expands. The even distribution implies that dark energy does not have any local gravitational effects, but rather a global effect on the universe as a whole. This brings in a repulsive force, which tends to accelerate the expansion of the universe [20].

It is believed that the visible matter in the universe accounts for only 4.6% of the total matter (ie. mass and energy).This is called well behaved ordinary matter while 24% of the universe matter is invisible matter (known as dark-matter) and there is no clue regarding what it is and the rest, would be of dark-energy. This explains why there was a Big Bang with relatively smaller amount of mass in the beginning of the universe. Further, this was, as S. Weinberg would put it, "not an explosion like those familiar on earth, starting from a definite centre and spreading out to engulf more and more of the circumbient air, but an explosion which occurred simultaneously everywhere, filling all space from the beginning, with every particle of matter rushing apart from every other particle". 22 Today the universe is extended over 476 million light-years apart.23 Another argument in favour of the dark-matter is: The amount of matter visible in the cosmos is not nearly enough to account for the movement of the stars and galaxies that we observe. They behave as if huge amounts of invisible matter are pulling them about. Galaxies, like our Milky Way, contain about 10 times as much matter as is visible in stars. This invisible matter is known as the „dark-matter". The dark-matter holds the stars in their orbits and stops them from flying off into intergalactic space and at the same time causes expansion .

Dark-Matter vs Dark-Energy:

Are dark-matter and dark-energy the same or equivalent? It is believed that dark matter and dark energy need not be necessarily related. According to Robert Scherrer (at Vanderbilt University) the density of dark matter decreases as universe expands but density of dark energy stays constant even as universe expands – This may be, as per the Steady-State-Model of the Universe, that new matter is continually created to fill up the gaps between the galaxies created by expansion of the universe racing out at an ever-increasing faster space (as confirmed by the Hubble Space Telescope).
Hawking would explain, based on super symmetry model of the universe, that there are „force particles and matter particles as two facets of reality [12]. Dark energy is a strange force field, first formulated by Einstein, which permeates all of space, creating repulsive force that seems to be causing the universe ever to expand. Once Einstein knew the universe was expanding, he discarded the cosmological constant as an unnecessary fudge factor. He later called it the biggest blunder of his life, according to his fellow physicist George Gamow. [20] Physicists agree that this repulsive force stops the galaxies from falling into each other due to their mutual gravitational attraction. As dark matter is essential to hold galaxies together, dark energy keep off particles from anti-particle lest there should be mutual annihilation.

Implications of the Dark Matter/Energy:

Dark matter/energy seems to pervade all through the universe. Dark matter does not interact with the visible matter nor with electromagnetic force and it does not absorb, reflect, or emit light (except through gravitational effect). Though invisible and transparent, it has gravity. Dark matter seems to outweigh visible matter roughly six to one. Dark matter appears to form the scaffold (like DNA in biology) upon which the visible matter of the universe, the galaxies, is assembled [19].

It is the matrix for the universe – The dark-matter holds the stars in their orbits and stops them from flying off into intergalactic space and at the same time causes expansion. At the creation or at Big Bang particles and anti-particles would have been created. The anti-particles have been forced outside of our Milky Way, where the gravitational force is repulsive [20, 21].

It is believed that dark matter and dark energy need not be necessarily related. The density of dark matter decreases as universe expands but density of dark energy stays constant even as universe expands. The dark energy is propelling the expansion of the universe sustaining the stability of the universe at the same time. As dark matter is essential to hold galaxies together, dark energy keep off particles from anti-particle lest there should be mutual annihilation and radiation. Given the multi-reality, one wonders at the possibility of another universe. Our universe may be one of the many, physicists say. The scientists are now looking into the question of: Universe or Multiverse. The possibility of a multiverse is raised by the theory of cosmic inflation. However, science, especially the laws of nature, would tell us how the universe behaves, but would not answer the why questions. Science may understand and explain the universe as a Grand Design but science may not indicate who the Grand Designer is. And science has not said the final word [22, 23].

CONCLUSION

Condensed-matter and materials physics faces critical challenges in realizing this future. Investments in facilities and research infrastructure are essential to provide a world-class research environment and to enable breakthrough opportunities. Partnerships across disciplines and among universities, government laboratories, and industry are essential to leverage resources and strengthen interdisciplinary research and connections to technology. Finally, special attention must be given to condensed-matter and materials physics education to ensure the availability of intellectual capital to sustain the vitality of the field and its contributions to society.

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