CAN ENERGY POSSESSED BY A GALAXY CLUSTER ACCOUNT FOR ITS DARK MATTER CONTENT ?

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ABSTRACT

In this paper I present the study of massive galaxy clusters. I take into account the energy possessed by the galaxy clusters and the equivalent amount of mass that gets added to them due to that much amount of energy possessed by them. The study shows that the mass of dark matter within galaxy clusters that is believed to account for 90% of their mass nearly coincides with the mass equivalent to the energy possessed by them. The mass equivalent to the energy possessed by the galaxy clusters should amicably account for the observed gravitational lensing associated with galaxy clusters, stability of the clusters, as well as for the observed cluster kinematics and dynamics.

Key words: cosmology: theory - dark matter.

1 INTRODUCTION

The quest for the mysterious dark matter sparked in 1933 when Swiss astrophysicist Sir Fritz Zwicky while studying the rich Coma galaxy cluster pointed towards the mass discrepancy after observing that the galaxies within the cluster were moving much faster than their escape velocities calculated with respect to the mass of the luminous matter that the entire cluster contained. The study of the Virgo galaxy cluster by Sir Sinclair Smith in 1936 yielded a similar result of mass discrepancy.

Similarly, it was found after the study of numerous galaxies that the rotational or the orbital velocity of the galactic components does not decrease with increasing distance from the centre of the galaxy as shown by Babcock 1939; Rubin & Ford 1970; Roberts & Whitehurst 1975; Rubin et al. 1985. It was observed that instead of exhibiting a declining rotation curve or a Keplerian curve, galaxies exhibited rotation curves that either remained flat or inclined with increasing distance from the centre of the galaxy, this unusual behaviour led to the galaxy rotation problem.

Modern day observations using sophisticated scientific equipment, state-of-the-art space-based telescopes have confirmed the presence of mass discrepancies in all gravitationally bound large-scale structures to such an extent that by just looking at galaxies and galaxy clusters, the thoughts regarding the presence of the ever mysterious dark matter begin to emanate. The high orbital velocity of galactic components within galaxies and the high orbital velocity of galaxies along with the spooky gravitational lensing arcs observed within galaxy clusters act as catalysts to support the presence of dark matter within galaxies and galaxy clusters. A galaxy cluster in visible wavelength would just reveal the optically visible features such as the galaxies and the glowing halo around them. However, in X-ray wavelength the picture of the cluster is completely different. An X-ray telescope unravels the presence of the extremely hot X-ray emitting gas in the form of plasma distributed thoroughly throughout the cluster and engulfing all the galaxies within it. The ICM is composed of ionized hydrogen and helium. From the temperature of the hot X-ray emitting ICM we can infer its mass, and when this is done we find that the cluster harbours more mass than what could be observed. The confinement of the extremely hot X-ray emitting gas (plasma) constituting the intracluster medium (ICM) is a perplexing riddle, as one would expect the ICM to have dispersed out of the cluster. A dark matter dominated system can only account for such extraordinary and mind-boggling observations. It is believed that 90% of mass within galaxy clusters is in the form of dark matter, while the remaining 10% of minuscule mass is due to the baryonic or ordinary matter.

When most of the astronomers and astrophysicists rely only on a dark matter scenario to account for the mass discrepancy within such dark matter dominated systems, there are other researchers who have come forward with interesting theories that try to explain the kinematics and dynamics of galaxies and galaxy clusters by modifying the Newtonian laws of gravity. Such theories modify gravity at galactic and extra-galactic scales instead of involving dark matter to explain the observed anomalies. One of the very well-studied and very well-known is the MOND theory

(Modified Newtonian Dynamics) (Milgrom 1983c). The MOND theory works extremely well for galaxies (Milgrom 1983a, 1983b), unfortunately when applied to galaxy clusters the need for dark matter becomes a necessity again since much of the residual mass still remains unanswered while tackling the problem from a modified gravity perspective.

The aim of this paper is to explain the mass discrepancy in large-scale structures, particularly in galaxy clusters on the basis of their energy content or the energy possessed by them that makes them recede with particular recessional velocity. According to Sir Albert Einstein's Special Theory of Relativity, the mass of a body is a measure of its total energy content. This implies that sufficiently large amount of energy will add significant and substantial amount of mass to a system without the actual presence of any additional matter in them.

2 THE ENERGY POSSESSED BY A LARGE-SCALE STRUCTURE AND THE MASS INCREMENT

The energy possessed by an object moving with velocity v is given as,

$$E = \frac{1}{2}mv^2 \quad (1)$$

Equation (1) can be expressed in terms of velocity as,

$$v = \sqrt{\frac{2E}{m}} \quad (2)$$

Equation (2) suggests that an object possessing sufficient amount of energy will recede with certain velocity. This is exactly what is observed in the case of a large-scale structure. Every large-scale structure in the observable Universe is found to be receding, and, it is not because they are receding so they possess energy, but because they possess energy therefore they are receding. Nothing recedes without energy, be it a microscopic gas molecule or a gigantically-massive large-scale structure. From the value of the redshifts z exhibited by large-scale structures we can calculate the velocities at which they are receding as given by,

$$v = c\,z \quad (3)$$

where c is the velocity of light and z is the observed redshift.

El Gordo, a very massive galaxy cluster with mass of about 3 x 10^{15} $M_\odot$ (6 x 10^{45} kg) exhibiting a redshift z of 0.87 (Jee et al. 2014) is considered for the study. Since 90% mass of the cluster is believed to be constituted by the ever mysterious dark matter, therefore, 2.7 x 10^{15} $M_\odot$ (5.4 x 10^{45} kg) of mass is because of dark matter, while the remaining 10%, that is, 3 x 10^{14} $M_\odot$ (6 x 10^{44} kg) is baryonic matter. The energy possessed by the El Gordo cluster that is causing it to recede with a velocity corresponding to a redshift of 0.87 (261,000,000 m s^{-1}) equates to 2.0436 x 10^{62} J as given by equation (1). This is significant and substantial amount of energy.

According to Sir Albert Einstein's mass-energy equation,

$$m = \frac{E}{c^2} \quad (4)$$

the mass equivalent to this much amount of energy possessed by the cluster equates to 2.2706 x 10^{45} kg. This mass, equivalent to the energy possessed by the cluster nearly coincides with the mass of dark matter alleged to be present within the cluster. This mass equivalent to the energy possessed by the cluster is 2.3781 times less than the mass of dark matter alleged to be present within this cluster.

Now I consider another massive galaxy cluster that goes by the name IDCS 1426. The total mass of this galaxy cluster exhibiting redshift z of 1.75 is estimated to be 2.6 x 10^{14} $M_\odot$ (5.2 x 10^{44} kg) (Brodwin et al. 2016). 90% mass within this cluster is firmly believed to be because of dark matter, therefore, 2.34 x 10^{14} $M_\odot$ (4.68 x 10^{44} kg) is the mass of dark matter within this cluster. Redshift z of 1.75 indicates a recessional velocity of (525,000,000 m s^{-1}). The energy possessed by this cluster that is making it recede with this much velocity equates to 7.1662 x 10^{61} J. The mass equivalent to this much amount of energy possessed by the cluster equates to 7.9624 x 10^{44} kg. This mass equivalent to the energy possessed by this cluster is 1.7013 times greater than the mass of dark matter alleged to be present within this cluster, it is also 1.5312 times greater than the total mass of this cluster.

CONCLUSION

Based upon the energy content or the energy possessed by the massive galaxy clusters the missing mass problem associated with them has been discussed. The mass of dark matter alleged to be present within the galaxy clusters is most probably the mass equivalent to the energy possessed by them. The significant amount of energy possessed by the clusters may translate as the mass of dark matter alleged to be present in them without the actual or physical presence of any additional exotic matter. Such mass increment due to an equivalent amount of energy should account for the observed gravitational lensing associated with the clusters, stability of the clusters as well as for the observed cluster kinematics and dynamics.

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