NO PLACE FOR DARK MATTER IN GALAXY CLUSTERS

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ABSTRACT

Galaxy clusters are one of the most mysterious large-scale structures in the universe. The extremely hot X-ray emitting gas (plasma) that constitutes the intracluster medium (ICM) is also quite mysterious. The observed gravitational lensing and the high velocity dispersion of galaxies within the cluster add another mysterious dimension to a galaxy cluster. There are many puzzling questions adhered to galaxy clusters, such as, what causes the ICM to remain confined within the cluster? Is it dark matter that confines the ICM, or does the ICM possesses certain properties of its own which gives it the added advantage to remain confined within the cluster, instead of just dispersing or diffusing out of the cluster? Is dark matter really required to explain certain observations related to galaxy clusters, such as, ICM confinement, velocity dispersion of galaxies and the spooky gravitational lensing arcs observed within the cluster? Are we underestimating the baryonic mass? In this paper I present the study of a random galaxy cluster to completely rule out the possibility of dark matter's presence in all galaxy clusters. The study provides explanation for such discussed mysterious phenomena associated with galaxy clusters that would otherwise be difficult to explain without considering the presence of dark matter.

Key words: galaxies: clusters: intracluster medium - velocity dispersion - baryonic matter.

1 INTRODUCTION

Galaxy clusters cloak many unsolved mysteries of the universe. When one observes a galaxy cluster, thoughts regarding the presence of the ever mysterious dark matter begin to emanate. The high velocity dispersion of galaxies and the spooky gravitational lensing arcs observed within galaxy clusters act as catalysts to support the presence of dark matter within galaxy clusters. 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. Now, since the dispersion of ICM does not occur as expected, an additional mass is considered to be responsible for its confinement within the cluster. A dark matter dominated cluster can only account for such extraordinary and boggling observations.

A random galaxy cluster situated at a distance of about 7 billion light-years, spanning 4 Mpc across and home to about thousands of galaxies has been taken into consideration as an ideal example to study such puzzling observations. This galaxy cluster is extremely massive with total mass of about 5×10^{15} $M_{\odot}$; 5000 trillion solar masses (10^{46} kg). In visible wavelength the cluster 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 shows the presence of the extremely hot X-ray emitting gas in the form of plasma distributed 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.

It is believed that 90% of the cluster's mass is in the form of the ever mysterious dark matter, while the remaining 10% of cluster's mass is due to the baryonic matter. The difference between the mass obtained from cluster dynamics (velocity dispersion of galaxies) and the mass obtained from observable baryonic matter (mass of galaxies and the ICM) is the mass of dark matter present within the cluster. This colossal difference points towards the presence of a huge mass discrepancy lurking within the cluster.

The main objective of this paper is to completely rule out the possibility that dark matter is present in galaxy clusters on the basis that since dark matter is not present in galaxies (vixra.org/abs/1710.0007) it should not be present in galaxy clusters as well.

2 NO MASS DISCREPANCY IN GALAXY CLUSTERS

As already discussed that baryonic matter just makes 10% of cluster's mass, whereas the majority amount of mass is because of non-baryonic dark matter which makes 90% of cluster's mass. Since, 90% mass is due to dark matter, therefore, a cluster with total mass of about 5 x 10^{15} M_Θ (10^{46} kg) contains 4.5 x 10^{15} M_Θ (9 x 10^{45} kg) of dark matter, whereas the remaining mass of 5 x 10^{14} M_Θ (10^{45} kg) is baryonic. We infer this proportion from the temperature of the ICM. Without dark matter, that is, if the ICM was this massive, then its temperature would have been much higher than what is observed. The equation that provides us with the mass of the ICM corresponding to its temperature can be written as;

$$M = \frac{TRk_b}{Gm_H} \qquad (1)$$

where T is the temperature of ICM in Kelvin, R is the radius of the cluster, k_B is the Boltzmann constant, G is the gravitational constant and m_H is the mass of hydrogen atom. Equation (1) can be rearranged in terms of temperature T as,

$$T = \frac{GMm_H}{Rk_b} \qquad (2)$$

On substituting the values of the baryonic mass (5 x 10^{14} M_Θ (10^{45} kg)) which just makes 10% of the cluster, we obtain a temperature T of 131,002,392 K (10^8 K approximately). So, this is the temperature corresponding to the baryonic mass. If the temperature was much higher than this, then more would have been the amount of baryonic matter or the baryonic mass in the form of ICM within the cluster. Now, using the equation (2) again, we will find the temperature of the ICM if dark matter is not present within the cluster, that is, the total mass of the cluster is in the form of baryonic matter (5 x 10^{15} M_Θ (10^{46} kg)). Temperature T in this case will then be 1,310,023,921 K (10^9 K approximately). This would have been the temperature of the ICM if it made 100% mass of the cluster (a baryonic cluster). Comparing both temperatures, we find that there is a difference of 1,179,021,529 K (9 x 10^8 K approximately) or we can say that this much amount of temperature is missing. There are three possibilities to this missing temperature problem; (1) the cluster has lost this much amount of temperature before it was studied, (2) the cluster is still yet to achieve this much amount of temperature, (3) the temperature that corresponds to the baryonic mass is just the surface temperature of the ICM, implying that internal temperature is much higher, and higher is the amount of baryonic mass and more is the density of ICM than what is observed.

For instance, let us consider the Sun (R = 6.96 x 10^8 m). Internal temperature being unknown to us, and if we were to find the mass of the Sun by using equation (1), then the only temperature that we would consider would be the Sun's surface temperature (5800 K). From this temperature we obtain a mass of about 4.9936 x 10^{26} kg. However, the mass of Sun obtained from the orbital velocities of planets provides us with a different mass. For instance, planet Mercury which is situated at a distance of 5.7910 x 10^{10} m from the Sun, possesses an orbital velocity of 48 km s^{-1} (48,000 m s^{-1}). From this data we obtain the mass of the Sun to be 2 x 10^{30} kg (approximately). The mass of Sun obtained from orbital velocities of planets is 4000 times greater than the mass obtained from equation (1). Does this imply that 1.9995 x 10^{30} kg (99.975032%) of Sun's mass is due to dark matter, while the remaining 4.9936 x 10^{26} kg (0.024968%) of Sun's mass is baryonic? Of course not, mass discrepancy has been introduced because we have considered the surface temperature of the Sun in order to find its mass; internal temperature corresponding to the actual mass of the Sun (2 x 10^{30} kg) is much higher. We cannot observe this internal temperature directly, therefore, we calculate this internal temperature with the help of actual mass. However, in case of the Sun, the neutrino flux from the core also provides us with the core temperature.

The theoretical temperature calculation is proved to be correct if we use equation (2) and substitute the actual mass of the Sun (2 x 10^{30} kg) to find the actual temperature T at its interior which is as high as 23,229,579.68 K (10^7 K approximately). This temperature corresponds to X-ray wavelength, however, it must be noted, that by the time this X-ray photon reaches the surface of the Sun (the photosphere) it loses significant amount of energy due to collision with matter particles. This X-ray photon from the interior upon losing significant amount of energy is emitted in the form of a visible photon from the photosphere.

This is equally applicable for the ICM as well. An energetic photon from ICM's interior corresponding to 10^9 K loses its energy by the time it reaches the surface of the ICM. On reaching the surface of the ICM this photon corresponds to 10^8 K. Therefore, the temperature of the ICM that we have detected (for this particular cluster) is its surface temperature and not its internal or actual temperature corresponding to its actual mass and hence the actual density.

Observing the ICM by utilizing a particular or specific X-ray band-pass technique in order to study the extent of X-ray emission from the interior of the ICM will be of no help, because the photon from the interior will still have to travel through the external ICM layer that has not been considered or has been filtered out in the specific X-ray band-pass; the photon will still lose its energy when it crosses this external region of the ICM that has been filtered out in a particular X-ray band-pass.

The orbital velocities of galaxies (velocity dispersion of galaxies) and gravitational lensing provide us with the actual baryonic mass of the cluster that cannot be obtained accurately from the temperature of the ICM. Furthermore, since galaxies present within the cluster are clustered quite closely together, therefore, a collectively wide gravitational potential well is formed. This condition will cause the gravitationally lensed arcs to be longer than usual.

3 CONFINEMENT OF THE ICM

It is believed that dark matter is responsible for confining the ICM within the cluster. Without the presence of dark matter the ICM would just disperse out of the cluster just like some ordinary gas, that is, confinement would not be possible. It must however be noted that ICM is not in the gaseous phase and it should therefore not disperse out of the cluster. Gas at extremely high temperature is no more in the gaseous phase; it exists in the form of plasma. Plasma behaves more like fluid instead of behaving or exhibiting gaseous properties. The extremely high temperature of the ICM ensures us that ICM is indeed in the plasma phase. The property of fluid is to confine itself spherically. No wonder why the ICM is more or less spherically distributed. Confinement of ICM in spherical manner further suggests that ICM is in hydrostatic equilibrium, just like stars. The cosmic environment becomes an ideal place for fluid to exhibit spherical self-confinement (liquid forms spherical structure and remains self-confined without the presence of dark matter).

4 THE COLLAPSING DARK MATTER

The condition for hydrostatic equilibrium is the balance between the outward thermal pressure from the interior and the mass of the matter present on the exterior which presses against this outward thermal pressure; more precisely it is the balance between thermal pressure and gravity. Now, it is very well known that dark matter does not interact with electromagnetic radiation; therefore, dark matter should also be resistant or immune to the outward thermal pressure due to the thermal radiation. Dark matter in this case would be of no help to confine the ICM within the cluster (especially the ICM along the edges of the cluster); entire dark matter distributed throughout the cluster would simply collapse and collect at the centre of the cluster due to cluster's gravity.

Baryonic matter on the other hand interacts with electromagnetic radiation and will therefore also respond to the thermal pressure due to the thermal radiation. Baryonic matter for this reason is able to maintain the hydrostatic equilibrium as it is able to balance the thermal pressure against its own mass.

5 ORBITAL AND ESCAPE VELOCITY OF A GALAXY ALONG THE CLUSTER'S EDGE

With the given mass of the galaxy cluster spanning 4Mpc across to be 5 x 10^{15} $M_{\odot}$; 5000 trillion solar masses (10^{46} kg), the orbital velocity of a galaxy situated along the edge of this cluster with respect to the enclosed mass will be 3288.28 km s^{-1}, while the escape velocity of this galaxy with respect to this enclosed mass is 4650.33 km s^{-1}. The orbital velocity of the galaxy is found to be within the escape velocity limit due to the baryonic mass enclosed by this galaxy within its orbit, therefore, the galaxy should not escape the cluster.

CONCLUSIONS

(1) The possibility that dark matter is present within galaxy clusters has been ruled out.

(2) Mass discrepancy is not present in galaxy clusters; the consideration that ICM's observed temperature (surface temperature) is also the temperature at its interior gives rise to the mass discrepancy within galaxy clusters.

(3) The internal temperature of ICM corresponding to the cluster's observed dynamic mass ought to be much higher than what is observed.

(4) A photon from the interior region of the ICM corresponding to 10^9 K loses its energy by the time it reaches the ICM's surface, where it corresponds to 10^8 K. The mass of the cluster obtained from this temperature and then comparing this mass with the dynamic mass of the cluster has given rise to mass discrepancy within this particular galaxy cluster.

(5) Internal temperature can only be modelled with the help of actual or the dynamic mass; or we can say that the internal temperature is dynamic mass dependent.

(6) Utilizing a specific X-ray band-pass to study the ICM will not be of much help as the photon before reaching the detector from the interior of the ICM will still have to travel through the external region of the ICM that has been filtered out in the specific X-ray band-pass.

(7) Orbital velocity of galaxies (velocity dispersion of galaxies) and gravitational lensing provide us with the actual baryonic mass of the cluster.

(8) Since the galaxies within the cluster are clustered quite closely together, therefore, a collectively wide gravitational potential well forms which causes the formation of lensed arcs to be longer than usual.

(9) Dark matter is not required for confining the ICM within the cluster. At extremely high temperature a gas behaves more like fluid (plasma) which can self-confine in a spherical manner in cosmic environment due to its own mass. A spherically symmetric confinement suggests that the ICM is in hydrostatic equilibrium.

(10) Since dark matter does not interact with electromagnetic radiation, therefore, it remains resistant to the outward thermal pressure due to the thermal radiation as well. Dark matter would therefore be unable to satisfy the condition required for hydrostatic equilibrium, that is, dark matter would not be able to balance its own mass against the thermal pressure in order to maintain its position within the cluster as thermal pressure would not be acting on dark matter. This would cause the entire dark matter distributed throughout the cluster to collapse and collect at the centre of the cluster due to the cluster's gravity.

(11) The orbital velocity of a galaxy orbiting at a particular distance from the centre of the cluster provides us with the amount of baryonic mass enclosed by it within its orbit.

(12) The orbital velocity of the galaxy is found to be within the escape velocity limit due to the baryonic mass enclosed by it within its orbit, that is, the escape velocity is always greater than the orbital velocity, therefore, the galaxy should not escape the cluster.

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