EXPLAINING THE MASS DISCREPANCY IN GALAXY CLUSTERS

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ABSTRACT

Galaxy clusters and mass discrepancy blend and dwell together quite harmoniously. Mass discrepancy is always stumbled upon when galaxy clusters are studied. The orbital velocities of galaxies within galaxy clusters are unusually higher than expected and the observable baryonic matter alone cannot account for all the mass and gravity for the overall observed stability of the cluster. The presence of additional matter in the form of dark matter is required to explain the gravitational stability at such high velocities as baryonic matter is insufficient to explain the anomaly. In this paper I present a theory that looks into the actual reason for causing the mass discrepancy within galaxy clusters without involving dark matter.

Key words: galaxy clusters - mass discrepancy - baryonic matter.

INTRODUCTION

The quest for the mysterious dark matter began almost 84 years ago. In 1933, Swiss astrophysicist Fritz Zwicky while studying the Coma 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 due to the luminous matter that the galaxies contained. The study of the Virgo cluster (Smith 1936) yielded a similar result of mass discrepancy.

A rich galaxy cluster such as the Coma cluster contains thousands of galaxies distributed in an almost spherical enclosure. The mass of the cluster can be obtained from the orbital velocities of galaxies (velocity dispersion of galaxies) or from the observable luminosity of all the galaxies present within the cluster. However, a bizarre mass discrepancy is introduced when these two methods are compared. This was exactly what Fritz Zwicky came across in the 1930s while studying the Coma cluster. The mass of cluster obtained from velocity dispersion of galaxies was found to be more than the mass that could be optically observed, that is, much of the mass within the cluster was not emitting any visible photons like ordinary matter, this gave rise to the mass discrepancy (difference between the mass obtained from cluster dynamics and the observable baryonic mass).

In simple, there is more mass within the cluster that cannot be observed and is keeping the galaxies and hence the entire cluster gravitationally bound, because, the luminous matter alone cannot account for all the mass and hence the gravity to keep the cluster gravitationally bound in a stable configuration, that is, the cluster should have broken apart, because the orbital velocities of galaxies are greater than their escape velocities calculated with respect to the observable mass that the cluster contains. Since all galaxy clusters appear quite stable as they do not expand or break apart, therefore, a necessity originated to consider the presence of invisible mass responsible for keeping the clusters stable. This invisible gravitating mass was termed as dark matter.

It would be quite interesting to note that the Coma cluster and the Virgo cluster were studied back in the 1930s when astronomers and astrophysicists relied mostly on optical techniques to study the celestial objects. Non-optical astronomy gained importance after many years; particularly the space-based X-ray astronomy that became possible only after 1970s. The baryonic intracluster medium (ICM) that forms the enclosed mass between the galaxies and shines brightly in X-rays would remain optically invisible while still adding mass to the galaxy cluster. Therefore, we can say that the ICM was also the dark matter back then in optical wavelength. Study of galaxy clusters by utilizing modern day astronomical techniques has revealed much of the baryonic mass present within the clusters that initially remained hidden, however, much of the mass within galaxy clusters still remains lurking in an unknown form (probably non-baryonic dark matter) as the ICM and the galaxies (baryonic part of the cluster) are not massive enough to account for the entire mass of the cluster. Mass discrepancy within galaxy clusters still remains at large.

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The observed mass discrepancy within galaxy clusters can be attributed to the "mass defect" (a characteristic that holds true for a bound system). Mass defect can be held responsible for the difference between the observed mass (baryonic) and the actual or the dynamic mass of the cluster. According to mass defect, some amount of mass disappears and is converted into energy that is utilized for binding the cluster. Therefore, the observed mass of the cluster (baryonic) is less than the actual or dynamic mass of the cluster. It is not possible that entire mass will remain conserved as mass when the cluster forms, some amount of mass will be converted into energy; this energy binds the cluster stable and accounts for the mass discrepancy (Δm).

The theoretical explanation for the mass defect or the mass discrepancy is based on Einstein's mass-energy relation $E = mc^2$. The mass defect or the mass discrepancy (Δm) is therefore the mass that gets converted into energy. The energy equivalent to this mass defect or the mass discrepancy is the binding energy of the cluster. The mass discrepancy can therefore be written as, $\Delta m = M_D - M_B$; where M_D is the observed dynamic mass and M_B is the observable baryonic mass. The difference $M_D - M_B$ or Δm (best considered to be the mass of dark matter present within the galaxy cluster) is actually the amount of baryonic matter that is missing as it has been converted into binding energy.

Now, just for instance, consider that the baryonic mass within the cluster has not been converted into energy. The orbital velocities of galaxies would therefore be with respect to the 100% mass observable. Now, when some of the mass gets converted into energy (binding energy) the high orbital velocities that the galaxies exhibited initially will still remain conserved, because, the binding energy that has appeared is due to the conversion of an equivalent amount of mass, the galaxies should therefore not escape the system as they would now be bound by the virtue of both; the binding energy of the cluster as well as the amount of baryonic mass left unchanged or unconverted. The amount of baryonic matter will appear less than the initial amount as much of the baryonic matter gets converted into binding energy. A galaxy orbiting within the cluster is not just held by the observable baryonic mass, it is also held by the unobservable binding energy of the cluster. The observable baryonic mass is matter entity, whereas the amount of mass that has been converted into energy is energy entity, therefore, it remains undetectable and appears as mass discrepancy. Much of the baryonic matter gets converted into energy and whatever amount of baryonic matter remains appears to be extremely less. Mass that gets converted into binding energy is the missing mass.

CONCLUSIONS

Mass discrepancy within galaxy clusters has been explained. The mass discrepancy seems more like mass defect. Non-baryonic dark matter may not be present at all in galaxy clusters. The conversion of mass into energy during the formation of the cluster gives rise to the mass discrepancy.

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