The Study of Mass to Light Ratios in Cluster of Galaxies

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The Study of Mass to Light Ratios in Cluster of Galaxies

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ABSTRACT

Our analysis of observed Hickson Compact Groups shows that there is a strong and statistically significant (p=.002) relationship between mass to light ratio (M/LR) and group mass, with more massive compact groups having substantially higher M/LRs, scaling roughly with mass to the .76±.09 power. This relationship holds even after dropping clusters of galaxies whose log mass differs from the mean log mass by more than two standard deviations. For a sample of Abell clusters of galaxies, a similar but weaker relationship is observed, with more massive galaxies having a mass to light ratio that scales with mass to the .73±.09 power (p=.010). This relationship implies that heavier galaxy clusters have dramatically higher fractions of dark matter.

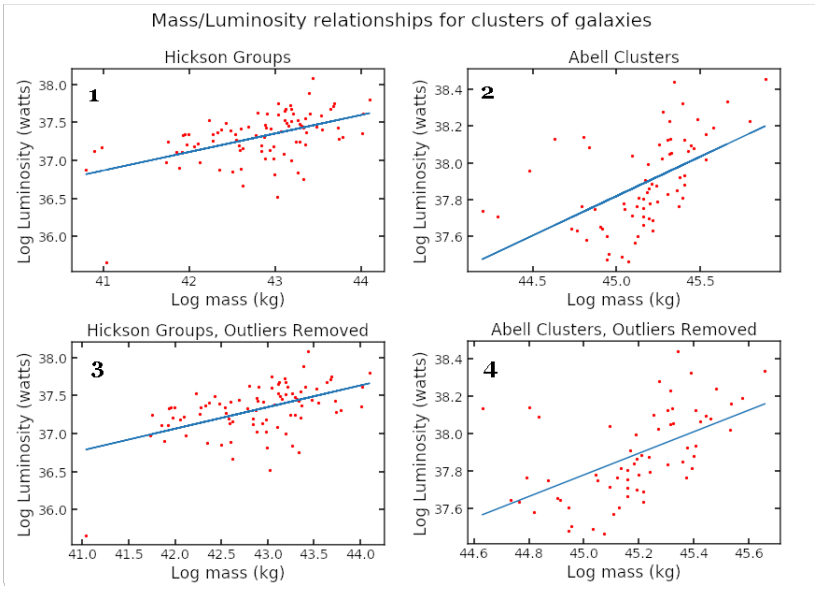
1. INTRODUCTION

Originally, compact groups were quantitatively determined using a criteria determined by J.A. Rose (Rose 1977), who searched for groups containing three or more galaxies with a limiting magnitude of 17.5 (Hickson 1997).In 1982, Paul Hickson elaborated on this method by selecting groups where four or more of the galaxies magnitudes differed by less than 3.0. This greatly improved visual searches of galaxy clusters as it reduced the distance-dependent bias inherent in a fixed magnitude criteria. The Hickson Compact Groups, or HCG, were determined by the Palomar Observatory Sky Survey red prints where Hickson found exactly 100 applicable galaxy clusters of moderate distances with a mean surface brightness brighter than 26.0 magnitude per arcsecond squared. In 1992, Hickson measured the radial velocities of 457 galaxies in the HCG (Hickson 1992), and subsequently found the velocity dispersions and virial masses of 89 of the groups. Hubble's constant = 100 km/s/Mpc for all of Hickson's calculations. Abell clusters are based on George O. Abell's four main criteria of richness, compactness, distance, and galactic latitude. Using these criteria, 4,073 galaxies were classified as Abell clusters, which have a nominal redshift of $z > 0.2$. However, this was found using a Hubble's Constant of 180 km/s/Mpc (Abell 1957), which was the predicted value at the time of Abell's research and sky surveys. This had a major impact on determining the compactness of clusters.

2. DATA

Data for the Hickson clusters were collected using NASA's High Energy Astrophysics Science Archive Research Center (HEASARC) Hickson catalog (HEASARC 2005), which contains the data found in Hickson's papers detailing galactic clusters (Hickson 1982), (Hickson 1992). Data for the Abell Clusters of Galaxies were collated from two sources. Masses were collected from an existing data source (A. Mantz et al. 2010). Distances were computed using redshifts from the NASA Extragalactic Database (NASA 2021) using Hubble's constant, and luminosities were then calculated using the apparent magnitude and distance. This data was then log transformed and analyzed statistically below.

3. RESULTS



One can observe a relationship between mass and luminosity, where the most luminous galaxies are more massive than the least luminous. However, this relationship deviates from the line which is what would be expected if there was no statistically significant relationship between mass and mass to light ratio. The slope of the line between log mass and log luminosity corresponds to a sublinear relationship between the two. As a cluster of galaxies increases in mass by one order of magnitude, its expected luminosity will increase by a factor of just 2.43±0.90 (p=.002), (Plot 1). Even after excluding outliers (clusters of galaxies with a log mass more than two standard deviations removed from the mean), the relationship holds, with a cluster of galaxies that increases in mass by an order of magnitude only increasing in expected luminosity by a factor of 2.85±1.05 (p=.003), (Plot 3). As the clusters of galaxies examined here span nearly three orders of magnitude in their masses, this implies that heavier clusters of galaxies are overwhelmingly composed of non luminous matter, likely corresponding to dark matter. With the sample of Abell clusters of galaxies, the relationship is less strong, but it is still statistically significant. For these clusters of galaxies, as a galactic cluster increases in mass by one order of magnitude, its expected luminosity will increase by a factor of just 2.69±0.85 (p=.010) (Plot 2). As with the Hickson compact groups, removing outlier clusters of galaxies weakens this relationship, with the expected luminosity increasing by a factor of 3.77±1.54 (p=.032) (Plot 4).

4. CONCLUSIONS

In both types of clusters of galaxies examined, compact groups and non-compact clusters, we see a strong correlation between the mass of the group and the mass to light ratio, with the most massive clusters of galaxies being strongly less luminous relative to their mass than the least massive clusters of galaxies. This implies a significantly higher concentration of dark matter in the most massive clusters of galaxies, and as the most massive Hickson Compact Groups have mass to light ratios less than 1/50th that of the least massive, they must be predominantly dark matter by mass.

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