Project 1 : Estimating the Dynamical Mass of a Galaxy Cluster

Handbook :

1. **Identify galaxies that you think are members of a cluster. For this, use of knowledge of velocity dispersions (redshift dispersions) within a cluster due to peculiar motion. The choice of lower and upper redshift cut for cluster members will be subjective but should be guided by some logic.**

Identifying Our Galaxy Cluster Members

The notebook identifies galaxies as cluster members by applying a **3-sigma cut** on their spectroscopic redshifts (specz). This means that any galaxy with a redshift value beyond three standard deviations from the mean redshift of the dataset is considered not to be a part of the cluster. This is a common practice in astronomy to define a group or cluster of galaxies based on their velocity distribution.

The calculated redshift limits for cluster membership are:

- **Mean Redshift:** 0.0808
- **3-sigma Lower Limit:** 0.0551
- **3-sigma Upper Limit:** 0.1066

Therefore, galaxies with a spectroscopic redshift between 0.0551 and 0.1066 are considered members of this cluster.

2. **After the required analysis of the table of data, determine the cluster redshift, and obtain an estimate for the characteristic velocity dispersion of galaxies that belong to the cluster in units of km/s**

- **Cluster Redshift:** The characteristic redshift of the cluster is determined to be the mean spectroscopic redshift of the averaged galaxy data, which is **0.0808**.
- **Characteristic Velocity Dispersion:** The characteristic velocity dispersion of galaxies belonging to the cluster is calculated from the standard deviation of the spectroscopic redshifts and the speed of light. This value is **2571.93 km/s**.

3. **Estimate the characteristic size of the cluster in Mpc**

The characteristic size of the cluster is estimated by calculating the projected physical diameter of the member galaxies (those within the 3-sigma redshift cut). The notebook uses the maximum projected separation in arcminutes and converts it to Megaparsecs (Mpc) using the

cosmological distance.

- Characteristic Size (Diameter): The estimated diameter of the cluster is 3.88 Mpc.

4. Estimate the dynamical mass of the cluster and quote the value in units of solar mass.

The dynamical mass of the cluster is estimated using the virial theorem, based on the velocity dispersion and the cluster's characteristic size.

- **Dynamical Mass:** The estimated dynamical mass of the cluster is **4.48 x 10^14 solar masses**.

5. Is the estimate of dynamical mass consistent with what is expected from the luminous mass? If not, explain with the support of numbers the inconsistency.

The notebook also calculates an estimate for the luminous mass of the cluster. The luminous mass is derived by summing the luminosity of the member galaxies and assuming a typical mass-to-light ratio of 10 for a galaxy cluster.

- **Luminous Mass:** The estimated luminous mass of the cluster is **6.54 x 10^11 solar masses**.

Inconsistency Explanation: The estimated dynamical mass (4.48 x 10^14 solar masses) is significantly higher than the estimated luminous mass (6.54 x 10^11 solar masses).

To quantify the inconsistency: Dynamical Mass / Luminous Mass = (4.48 x 10^14) / (6.54 x 10^11) ≈ 685

This large discrepancy suggests that there is a substantial amount of **dark matter** present in the cluster. The dynamical mass, which is derived from the gravitational effects on the galaxies' motions, accounts for all mass, both luminous and dark. The luminous mass, however, only accounts for the mass that emits light (stars, gas, dust). The fact that the dynamical mass is approximately 685 times greater than the luminous mass indicates that the majority of the mass in the cluster is non-luminous, consistent with the presence of dark matter.