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# Empirical Dependencies for Irregular and Elliptical Dwarf Galaxies

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**Abstract**

This study examines the physical properties and correlations for dwarf galaxies, including irregular (dIrr) and elliptical (dE) types. Data from the NASA/IPAC and HyperLEDA databases were used to analyze relationships among parameters such as distance to galaxy, absolute magnitude of galaxy, mass of galaxy, and surface brightness of galaxy using regression analysis. Results show strong negative correlations between absolute magnitude and mass of galaxy, and strong positive correlations between mass of galaxy and both redshift of galaxy and surface brightness. A moderate positive relationship between dIrr and dE types in terms of galaxy mass and brightness is also observed. These findings enhance our understanding of dwarf galaxy formation and evolution.

**Keywords:** dwarf galaxy; Hyperleda data base; irregular dwarf galaxies; elliptical dwarf galaxies; empirical dependencies; correlation; catalog; Universe' Local Group; Local Volume; galaxy; surface brightness; distance to galaxy; absolute magnitude of galaxy; redshift of galaxy; massive; evolution; population

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## 1. Introduction

Dwarf galaxies have become crucial to advancing our understanding of galaxy formation and evolution. As the smallest, faintest, and most prevalent galactic systems in the universe, they exhibit a broad spectrum of physical properties and are found in a variety of environments. This diversity makes them ideal for studying the fundamental processes driving galaxy evolution. Their typically low masses and metallicities indicate that dwarf galaxies may closely resemble the primordial building blocks from which larger galaxies assembled in the early Universe [1,2].

A comprehensive understanding of dwarf galaxy evolution remains challenging to achieve. Traditionally, evolutionary models have been framed around a dual morphological classification: dwarf spheroidals (dSphs) and dwarf irregulars (dIrr). Dwarf spheroidals are identified by their smooth appearance, lack of visible star-forming regions, and generally low gas content. In contrast, dwarf irregulars display structural signs of ongoing or recent star formation and possess a high gas fraction. A third, less common category—referred to as 'transition' dwarf galaxies—contains systems that retain significant gas fraction but exhibit minimal or no recent star formation [3,4].

Dwarf galaxies, especially irregular (dIrr) and elliptical (dE or dSph) types, represent the most abundant galaxy population in the Universe and play a crucial role in our understanding of galaxy formation and evolution. Despite their low mass and luminosity, these systems are sensitive to both internal processes such as supernova feedback and external environmental effects including tidal interactions and ram-pressure stripping [5]. Particularly, irregular and elliptical dwarf galaxies show distinct evolutionary paths, as evidenced by their morphology, gas content, star formation activity, and spatial distribution. Irregular dwarf galaxies are typically gas-rich, star-forming, and located in the field or at the outskirts of galaxy groups, whereas elliptical dwarf galaxies are more gas-poor, quiescent, and

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often found as satellites of massive galaxies. Understanding the empirical differences and similarities between these types can shed light on the mechanisms driving morphological transformation and quenching in low-mass galaxies [6–8].

## 2. Observational Data and Analysis Tools

The observational data on dwarf galaxies used in this study were obtained from the NASA/IPAC Extragalactic Database [9], the HyperLEDA database for physics of galaxies [10], and the Catalog–Atlas of the Local Volume Galaxies [11,12], as well as from the publications "The Observed Properties of Dwarf Galaxies in and around the Local Group" [13], "The Local Volume Database: A Library of the Observed Properties of Nearby Dwarf Galaxies and Star Clusters" [14] and "Special summary catalog of dwarf galaxies in Universe up to distance 121 Mpc" [15]. Based on these sources, a compiled catalog of dwarf galaxies was constructed for analysis. This study investigates the statistical relationships among key physical characteristics of dwarf galaxies through linear regression and correlation analysis. Similar analyses have been performed for other astrophysical objects [15–19]. All computations were carried out using MATLAB R2024a.

## 3. Results

Table 1 below displays the correlation coefficients that quantify the relationships between various physical parameters observed in dwarf irregular (dIrr) and dwarf elliptical (dE) galaxies. These values were identified through statistical analysis to illustrate the connections between different galaxy features.

**Table 1.** Correlation coefficients of Dwarf Irregular (dIrr) and Dwarf Elliptical (dE) Galaxies.

| Parameter | dIrr | dE |
|---|---|---|
| $D \to M_V$ | -0.67 | -0.71 |
| $D \to \lg(M/M_{\text{sun}})$ | 0.76 | 0.80 |
| $M_V \to z$ | -0.74 | -0.78 |
| $\lg(M/M_{\text{sun}}) \to z$ | 0.76 | 0.79 |
| $\lg(M/M_{\text{sun}}) \to \mu_e$ | -0.60 | -0.89 |
| $M_V \to \lg(M/M_{\text{sun}})$ | -0.97 | -0.99 |
| $M_V \to \mu_e$ | 0.61 | 0.87 |

*Absolute Magnitude of galaxy and Distance to galaxy:* A moderate to strong negative correlation is observed for both dIrr (-0.67) and dE (-0.71) galaxies. This suggests that galaxies located farther away tend to appear fainter, which is consistent with expectations from observational cosmology.

$$M_v = -0.1175(\pm 0.0097) \cdot D - 12.9320(\pm 0.1469) \quad \textit{(for dIrr-galaxies)} \tag{1}$$

$$M_v = -0.0921(\pm 0.0134) \cdot D - 12.5866(\pm 0.3704) \quad \textit{(for dE-galaxies)} \tag{2}$$

*Mass of galaxy and Distance to galaxy :* The positive correlation (0.76 for dIrr, 0.80 for dE) implies that more massive galaxies are more likely to be observed at greater distances, possibly due to selection effects or intrinsic properties of galaxy populations.

$$lg\left(\frac{M}{M_{\text{Sun}}}\right) = 0.0478(\pm 0.0045) \cdot D + 7.1892(\pm 0.0975) \quad \textit{(for dIrr-galaxies)} \tag{3}$$

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$$lg\left(\frac{M}{M_{\text{Sun}}}\right) = 0.0451(\pm 0.0062) \cdot D + 6.8006(\pm 0.2094) \quad \textit{(for dE-galaxies)} \tag{4}$$

*Redshift of galaxy and Absolute Magnitude of galaxy:* A strong negative correlation is observed for both galaxy types (dIrr: -0.74; dE: -0.78), indicating that brighter galaxies are generally found at lower redshifts.

$$z = -0.0009(\pm 0.00009) \cdot M_v - 0.0116(\pm 0.0012) \quad \textit{(for dIrr-galaxies)} \tag{5}$$

$$z = -0.0013(\pm 0.0002) \cdot M_v - 0.0143(\pm 0.0029) \quad \textit{(for dE-galaxies)} \tag{6}$$

*Redshift of galaxy and Mass of galaxy:* Both galaxy types show strong positive correlations (dIrr: 0.76; dE: 0.79), suggesting that galaxies observed at higher redshifts tend to have higher masses, potentially reflecting cosmic evolution.

$$z = 0.0029(\pm 0.0002) \cdot \lg\left(\frac{M}{M_{\text{Sun}}}\right) - 0.0199(\pm 0.0022) \quad \textit{(for dIrr-galaxies)} \tag{7}$$

$$z = 0.0033(\pm 0.0004) \cdot \lg\left(\frac{M}{M_{\text{Sun}}}\right) - 0.0211(\pm 0.0038) \quad \textit{(for dE-galaxies)} \tag{8}$$

*Surface Brightness of galaxy and Mass of galaxy:* The correlation is negative for both dIrr (-0.60) and dE (-0.89) galaxies, with a stronger effect in dE type. This means that more massive galaxies generally have lower surface brightness, particularly in the case of dwarf elliptical galaxies.

$$\mu_e = -1.1899(\pm 0.2108) \cdot \lg\left(\frac{M}{M_{\text{Sun}}}\right) + 32.9185(\pm 1.6779) \quad \textit{(for dIrr-galaxies)} \tag{9}$$

$$\mu_e = -1.5697(\pm 0.1830) \cdot \lg\left(\frac{M}{M_{\text{Sun}}}\right) + 36.1563(\pm 1.4867) \quad \textit{(for dE-galaxies)} \tag{10}$$

*Mass of galaxy and Absolute Magnitude of galaxy:* A very strong negative correlation is observed in both types (dIrr: -0.97; dE: -0.99). This confirms that more luminous galaxies are significantly more massive, as expected from standard scaling relations.

$$lg\left(\frac{M}{M_{\text{Sun}}}\right) = -0.4046(\pm 0.0096) \cdot M_v + 1.9386(\pm 0.1441) \quad \textit{(for dIrr-galaxies)} \tag{11}$$

$$lg\left(\frac{M}{M_{\text{Sun}}}\right) = -0.4395(\pm 0.0106) \cdot M_v + 1.5433(\pm 0.1541) \quad \textit{(for dE-galaxies)} \tag{12}$$

*Surface Brightness of galaxy and Absolute Magnitude of galaxy:* A moderate positive correlation is found for dIrr (0.61) and a stronger correlation for dE (0.87), indicating that more luminous galaxies tend to have higher surface brightness, particularly among elliptical type.

$$\mu_e = -1.1899(\pm 0.2108) \cdot M_v + 32.9185(\pm 1.6779) \quad \textit{(for dIrr-galaxies)} \tag{13}$$

$$\mu_e = -1.5697(\pm 0.1830) \cdot M_v + 36.1563(\pm 1.4867) \quad \textit{(for dE-galaxies)} \tag{14}$$

From the above regression equations, it can be seen that the *a* and *b* coefficients *(y=ax+b)* of dE and dIrr galaxies are close to each other. This closeness indicates the reliability of the observational data.

## 4. Conclusion

Both types of galaxies show a clear negative correlation between absolute magnitude of galaxy and mass of galaxy, meaning brighter dwarf galaxies are generally more massive. This supports the idea that luminosity is a good indicator of mass of galaxy in these systems. Additionally, both dIrr and dE galaxies exhibit a positive correlation between mass of galaxy and redshift of galaxy, suggesting that more massive galaxies are observed at higher redshifts, which could be due to how they are selected for observation or how they have grown over time. As anticipated by cosmological observations, brighter dwarf galaxies of both types are typically found at lower redshifts. Where these galaxy types truly diverge is in the relationship between mass of galaxy and surface brightness of galaxy. While both show a negative correlation (more massive galaxies tend to have lower surface brightness), this trend is significantly stronger in dE galaxies. This suggests that dE galaxies are more evolved structurally, being more compact and having less gas. The link between absolute magnitude of galaxy and surface brightness of galaxy is also more evident in dE galaxies, indicating a greater uniformity in their structure compared to dIrrs. In essence, while both dIrr and dE galaxies follow similar fundamental patterns, dE galaxies display tighter and often stronger correlations, pointing to more uniform and potentially more evolved populations. These findings offer valuable insights into how different types of dwarf galaxies form and evolve in various cosmic environments.

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**Conflicts of Interest:** The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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