Physical Properties Of Globular Clusters In Several Kinds Of Galaxies: A Review

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ABSTRACT

Understanding the origins of galaxies and their subsequent evolution is one of the most often asked problems in astrophysics today. Studying globular clusters (GCs) in these galaxies is an important approach to answering this question since GC features reveal important information about the creation and evolution of the clusters and their host galaxies. The precise frequency of globular clusters in different galaxies is a crucial GC metric that is highlighted in this article. The genesis and development of globular clusters are discussed. Our results show that different types of galaxies have varied ratios of the specific frequency of GCs to the luminosity of their host galaxies.

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1. Introduction

Globular clusters (GCS) are compact, gravitationally bound groups of stars that are among the oldest structures in the universe. They contain tens of thousands to several million stars with similar chemical compositions and ages. They possess a total mass ranging from 10^4 to 10^6 $M_\odot$, with an approximate age of 10 Gyr, e.g., [1 –3]. Globular clusters are found in the galactic halos and bulges, which host old stars exclusively (Population II) and contain no young stars or dust [4]. During the reionization stage, GCs formed in environments with a high redshift [5 –7]. Many studies indicate that the peak of GC formation predates the stellar formation within galaxies; as [8] pointed out, such clusters may have been important in the early galaxy formation stages and may have even aided in re-ionization. Different types of galaxy morphology contain GCs, from giant elliptical to dwarf galaxies [9 –11]. While the precise process of GC formation is unknown, there are a few theories on how they might form. Cote et al. [12] have proposed that GCs form in the halo's hierarchical collapse, which occurs inside distinct chemically isolated proto-galactic fragments that are later integrated into the galactic spheroid. Kimm et al. [13] have performed a simulation of such a case in a cosmic context and have discovered that it has accurately reproduced fundamental GC properties like the size, mass, and history of star formation or throughout galaxy mergers resulting from colliding gas. Furthermore, it is thought that they form quickly in high-density, high-pressure areas with high star formation efficiency. Under such conditions, they might acquire sufficient mass to form before the halt of star formation by feedback processes [14 –16]. Regardless of how they formed the system, GC systems provide a rare window into the most active and primordial eras regarding star formation in the galaxy [17]. The mass, age, metallicity, total number, and structural parameters regarding GC systems have been thoroughly investigated as they provide valuable insights into the formation and evolution of GCs as well as the evolutionary history of their host galaxies [18 –25] Here, we will provide a more thorough analysis of the properties of GC. Galaxies are defined as massive systems composed of stars, planets, gas, dust, and dark matter, interconnected by gravity. They are classified into four main types based on their shapes: elliptical, spiral, irregular, and dwarf galaxies. The largest galaxies can contain trillions of stars and may span over a million light years in diameter. In contrast, the smallest galaxies can contain only a few thousand stars and extend over just a few hundred light years. These galaxies provide host environments for globular clusters, and their structure and evolution play a crucial role in the formation and distribution of these clusters within their halos and bulges. These clusters are primarily located in the galactic halo [10]. Recent studies emphasize their significance in exploring stellar evolution within their specific environments [26]. Each type of these galaxies exhibits distinctive characteristics that influence the distribution and properties of the globular clusters they host. For instance, spiral galaxies like our Milky Way are rich in globular clusters of the ancient type, characterized by low metallicity, which reflects their formation during the early stages of the galaxy. In contrast, elliptical galaxies host a greater number of globular clusters compared to spiral galaxies. Unlike spiral galaxies, they encompass a broader range of metallicities, which are also distributed throughout the galaxy, including the core and halo regions [27]. Irregular galaxies contain relatively few globular clusters and lack a defined structure. Their small size and dynamic characteristics—marked by continuous interactions among the stars within them—make the formation of globular clusters in these galaxies more complex [28]. Dwarf galaxies also contain fewer globular clusters due to their small size and low stellar density. As a result, the globular clusters found within them are sparse and of low density. Additionally, Karachentsev et al. (2014) suggested that there is a strong connection between the globular clusters in dwarf galaxies and their interactions with larger host galaxies. Globular clusters remain crucial for investigating the formation and evolution of galaxies, offering key insights into the conditions of the early universe [29].

2. Observations and study methods

To study relationship between the absolute magnitude of a galaxy and the specific frequency of globular clusters, we use the database from the Mieske et al. [30]. Which build on the compilation of Harris et al. (2013) [31], but are restricted to early-type galaxies (E/SO, dE/SO) for which dynamical mass estimates are available. The relationship between the S_N and the luminosity of a galaxy is strongly influenced by the erosion of gas in the galaxies. This trend reflects those large, luminous galaxies have relatively more globular clusters due to their strong gravity, while smaller galaxies lose their clusters due to weaker gravity and tidal effects. This analysis enhances our understanding of the role of absolute magnitude in explaining the association and evolution of globular clusters with their host galaxies. The Specific frequencies of globular clusters in different types of galaxies (See Table 1), which data being from Kissler-Patig [32]. The selected the stellar systems of globular clusters for more than 50 early and elliptical galaxies. The table includes the names of the galaxies, their types, and the specific frequency to each galaxy, reflecting the influence of globular clusters on galaxy evolution, especially in the early types that are mostly devoid of gas and dust.

3. Relationship of globular clusters to galaxies

Understanding the origins and ages of globular clusters is key to unraveling their connection to galaxy formation and evaluating theoretical models. The age of GCs places significant constraints on models of galaxy cluster formation. Despite significant progress, many fundamental questions about GCs remain unanswered, including their precise formation timelines and mechanisms. Evidence suggests that the peak of GC formation predates most stellar formation in galaxies, potentially playing a pivotal role in early galaxy formation, re-ionization, and even influencing the size of the universe [8,33]. The traditional view of GCs as simple stellar populations formed from a single giant molecular cloud, where all stars share nearly identical ages and abundances. Several theories have been proposed, yet the formation of multiple stellar populations through successive star formation episodes, each with distinct chemical properties, seems to be a universal characteristic of GCs. However, the extent of these variations differs significantly from one cluster to another [34, 35]. This suggests that the formation of multiple generations of stars is an inherent outcome of GC formation. Globular clusters may form locally within their host galaxies, occurring when stars are born in high-density and high-mass environments, such as the central regions of the galaxy. It is believed that these globular clusters develop during the early stages of galaxy formation when conditions are favorable for the emergence of high-efficiency stars [5]. Alternatively, these clusters can be obtained through mergers between galaxies; when two galaxies merge, globular clusters may be transferred from smaller galaxies to larger ones, resulting in an inhomogeneous distribution. Globular clusters serve as strong indicators of galaxy evolution; by examining their characteristics—such as age, mass, and metallicity—scientists can trace the history of star formation within these galaxies, revealing the various stages that galaxies have experienced over time [11].

4. The physical properties of globular clusters

4.1 Basic properties

The basic properties of globular clusters are crucial for understanding their formation, evolution, and their role in galactic dynamics. These properties are detailed as follows:

4.1.1 Age

Globular cluster systems are considered among the oldest structures in the universe (most of them with ages >10 Gyr) [36,37]. GCs provide a unique window into the early stages of galaxy formation, preserving the conditions that prevailed during the formation of their host galaxies. They contain the imprints of the initial conditions of galaxy formation. An important part of the historical record of galaxy formation is locked up in the ages and metallicities of the earliest stellar populations, particularly those found in the halos of galaxies.

4.1.2 Metallicity

The metallicity distributions of globular cluster systems in galaxies are a critical test of any GC formation scenario. The observed metals of GCs reflect the initial physical conditions between the interstellar medium in their host galaxies. Metallicity is a measure of the number of heavy elements (more than hydrogen and helium) in stars or star clusters. the metallicity of star and star clusters is expressed in logarithmic units relative to the chemical abundance of the Sun:

$$\left[\frac{Fe}{H}\right] = \log\left(\frac{N_{Fe}}{N_H}\right) - \log\left(\frac{N_{Fe}}{N_H}\right) sun$$

where N_{Fe}/N_H is the relative number of iron and hydrogen atoms a good proxy for overall metallicity. Classification of globular clusters based on metallicity:

4.1.2.1 Metal-poor clusters:

Contain very old stars that formed in the early stages of the universe, when heavy elements were rare. These clusters are considered remnants of early galaxy formation [38].

4.1.2.2 Metal-rich clusters:

Contain stars that formed after the increase in heavy elements in the universe as a result of supernovae explosions in previous generations of stars. These clusters are often associated with the inner or disk regions of galaxies [39].

4.1.3 Size and density

The size of globular clusters ranges from 1 to 10 parsecs, typically measured in (Half-light Radius), the distance from which half of the total light emitted by the cluster is produced. Regarding the density of globular clusters, they are characterized by a high stellar density at the center compared to their outer regions. The stellar density at the center can reach between 10^3 and 10^5 stars per cubic parsec, giving it a luminous central appearance [10]. The relationship between the size and density of globular clusters reveals an inverse correlation, whereby larger tend to have denser cores. There are two types of clusters based on their structure: Core-collapsed Clusters, which possess very dense nuclei, and Extended Cores, which have less dense and more dispersed nuclei [27]. The light radius depends on the environment in which the cluster exists; clusters located near the center of the galaxy are generally smaller than those found in the halo, where they tend to be larger due to the presence of strong gravitational forces [40].

4.1.4 Mass

Mass is a fundamental property of globular clusters, significantly influencing their stability and the dynamics of their stars. Globular cluster masses typically range between $10^4 M_\odot$ to$10^6\ M_\odot$ and are commonly estimated using methods such as stellar kinematics or integrated light modeling [10]. High-mass clusters are able to retain their stars due to their strong gravitational binding, whereas lower-mass clusters are more susceptible to losing stars. This loss is often driven by tidal interactions with their host galaxy or external gravitational forces [41]. Investigating the masses of globular clusters offers essential insights into their role in the broader context of galaxy evolution [5].

4.2 Dynamic properties

4.2.1 Spatial distribution

The spatial distribution ϕ (number of clusters per unit volume) of globular clusters within the Milky Way provides crucial insights into our Galaxy's structure and formation history. The projected radial distributions are often fitted with power laws over a restricted range in radius, and it is clear that more luminous galaxies have shallower radial distribution. Current GC systems of most galaxies are probably compounds of smaller GC systems acquired through mergers. Blue and red GCs have different spatial distributions, red clusters are usually more spatially concentrated than blue clusters [22]. Due to the spatial distribution of globular clusters, Ricotti, (2002) [42] suggested that GCs could have reionized the universe. The extended spatial distribution of GCs relative to their parent galaxies implies a high escape fraction of ionizing photons, which appears sufficient to achieve reionization if near unity. However, this hypothesis necessitates detailed modeling, including radiative transfer, within an appropriate cosmological framework. Hong et al., (2019) [43] find that the present-time spatial distribution is affected by the differences in the binary fractions, and that the relative incidence of first-generation (FG) and second-generation (SG) binaries might very well show considerable radial dependence even after the spatial distribution of single stars from the two populations become identical. The GCS spatial distributions of massive compact early-type galaxies (ETGs) from are similar to those in normal ETGs in that they are more extended than the starlight [44].

4.2.2 Stellar motion

The motion of stars within globular clusters provides critical insights into their internal dynamics and overall structure. Stars in these clusters exhibit a range of velocities, influenced by the cluster's total mass and gravitational potential. The velocity dispersion—variation in the speeds of stars—is one of the key observables used to estimate the dynamical mass of the cluster via the virial theorem [45]. The stellar motion is affected by internal interactions between stars, such as close encounters and binary interactions, which can lead to phenomena like mass segregation, where massive stars sink toward the center, and less massive stars move outward. Moreover, studying stellar motion is essential for exploring the gravitational dynamics of the cluster. By combining proper motion data from space telescopes like Hubble and Gaia with radial velocity measurements, astronomers can reconstruct the three-dimensional velocity distribution of stars, providing a comprehensive view of the cluster's kinematics [46]. These motions can also offer indirect evidence for the presence of dark matter or intermediate-mass black holes (IMBHs) in the cluster's core. Anomalies in the velocity dispersion profile, such as unexpected rises toward the center, could indicate the gravitational influence of a compact dark object. Overall, stellar motion studies enhance our understanding of the formation, evolution, and long-term stability of globular clusters, as well as their interactions with the host galaxy. Gravitational interactions, both internal and external, play a significant role in the evolution of globular clusters. Externally, tidal forces exerted by the host galaxy during close encounters near the galactic center or disk can strip stars from the cluster, a process that contributes to mass loss and can lead to eventual dissolution over time [47].

4.2.3 Presence of black holes

Globular clusters are known to host a variety of stellar remnants. Recent studies have suggested that some of these clusters contain black holes at their centers. The most common type observed is the intermediate-mass black hole (IMBH), which has a mass ranging between 100 to 1000 solar masses, significantly larger than stellar-mass black holes but smaller than supermassive black holes. These black holes can form through the collapse of a dense stellar core or through successive mergers of stellar remnants within the cluster [48]. The presence of a central black hole in a globular cluster can be inferred from the observed stellar dynamics and velocity dispersion profiles. Anomalies in the velocity distribution, such as a higher-than-expected velocity near the center of the cluster, may indicate the gravitational influence of a compact, invisible object [49]. Additionally, X-ray observations may reveal compact objects like stellar-mass black holes or detect material being accreted by a central IMBH. The detection of black holes in globular clusters provides important clues about the evolution of these dense stellar systems and their role in the broader context of galactic formation and the development of supermassive black holes in galaxies [50].

4.3 Spectral properties

4.3.1 Spectra of stars

Spectroscopic analysis of globular cluster stars is an essential method for studying their chemical and physical properties. The absorption lines of various elements, such as hydrogen and helium, reveal the chemical composition of globular clusters [51]. Since stellar spectra provide valuable and detailed information about blackbody radiation temperature, they also allow for the determination of stellar ages by comparing their spectral features with theoretical models of star formation and evolution [10]. The strength of Balmer lines is sensitive to the presence of intermediate-age stars, while older stars exhibit weaker Balmer lines and stronger metal lines.

4.3.2 Effect of absorption lines

The absorption lines in the spectra of stars play a crucial role in determining the metallicity of stars in globular clusters. By analyzing these absorption lines and their strengths, we can infer the metallicity of elements such as iron, magnesium, and other heavy elements [51]. Among these lines, the iron absorption lines are particularly significant because iron serves as a proxy for total metallicity. The equivalent widths of these lines, measured using high-precision spectra, are expressed in the logarithmic ratio of iron to hydrogen [Fe/H][10]. Another method for determining metallicity is through the absorption lines of trivalent calcium found in the near-infrared region of the spectrum, widely used for analyzing the metallicity of globular clusters outside our galaxy

[22]. The differences in these lines among the stars in the same cluster indicate the presence of multiple stellar groups and a distinctive chemical enrichment history.

4.3.3 Radial Velocity

Radial velocity is a fundamental property of globular clusters, representing the component of a star's motion along the line of sight. It is measured using Doppler spectral lines, which shift towards shorter wavelengths (blue shift) or longer wavelengths (red shift), indicating whether the star is moving towards or away from the observer [27]. By examining the variations in radial velocities among individual stars within a cluster, researchers can estimate the velocity dispersion, which can then be used to determine the cluster's dynamical mass through the application of the Virial Theorem [41].

4.4 Radiological properties

4.4.1 X-ray sources

Space telescopes like the Chandra telescope are useful for studying X-rays and their sources in globular clusters, which host a variety of X-ray sources. One of the most common X-ray sources in globular clusters is low-mass X-ray binaries (LMXBs), composed of either a neutron star or a black hole [10]. A second type of X-ray source is cataclysmic variables (CVs), which originate from binary systems; these emit weaker X-rays than LMXBs but are more abundant, thus increasing the X-ray brightness of globular clusters [52], The discovery of pulsars has provided important insights into the late stages of stellar evolution.

4.4.2 Luminosity of stars

One of the fundamental properties of globular clusters is their luminosity, which reflects stars' energy production and stages of formation and evolution. In these clusters, the brightest stars, such as red giants, are concentrated near the core due to mass segregation. This phenomenon occurs because massive stars gradually lose their kinetic energy toward the center over time, while less massive stars move outward to the edges [4]. Thus, the luminosity of these stars helps us determine the age of the globular cluster and its metallic composition by comparing their position on the Hertzsprung-Russell (H-R) diagram [1]. The globular clusters in external galaxies exhibit similar characteristics, with their bright stars acting as primary tracers of the cluster's properties [22]. Additionally, the total luminosity of the globular cluster provides valuable information regarding the number of stars and the mass-to-light ratio. Clusters with high brightness host the greatest number of massive stars, and these clusters can be influenced by dynamic factors that result in the loss of dimmer stars [41].

5. The number of globular clusters (NGCs)

The number of globular clusters (NGC) is one of the most observable parameters, which correlates directly with a galaxy's stellar mass. Notably, NGC varies among various morphological type of galaxies, ranging from a small number in dwarf galaxies to several tens of thousands in massive galaxies, and the ratio of NGC to star luminosity is not constant either. Perhaps the earliest historical identification of a GC can be traced back to when human eyes first observed ω Centauri, the largest galactic GC, which was barely visible in the southern hemisphere. The first 'astronomical' detection occurred in the 18th century. John Herschel discovered a dense concentration of star clusters towards Sagittarius in the 1830s. The number of known globular clusters was rising consistently. Melotte [53] identified 83 MW GCs; by 1947, that number had risen to 97. In 1999, the number grew to 147. In 2010, Harris [54] provided 157 GCs. The list of Galactic GCs has been updated by developments in GC studies, including large the sky survey [55 –62]. The ESO-VVV survey provided a list that contains 84 globular clusters candidates toward the bulge [63 –65]. The two new globular clusters discovered in the galactic bulge by Ryu and Lee [66] happened to be located accidentally close to the galactic plane in the sky. Five new GCs have been found in the galactic bulge [67]. FSR1758 was discovered by Barba et al. [68] in the Milky Way Bulge. Recently, observations show that the Milky Way galaxy contains nearly 170 globular clusters [69]. The NGC can be determined by identifying the peak of the globular cluster luminosity function (GCLF) at an identified magnitude and then integrating it over the entire luminosity function and surface density. The GCLF is defined as the relative number of globular clusters per unit magnitude, as shown in Fig. 1. When a Gaussian distribution accurately describes the GCLF, the NGC is determined by multiplying the number of GCs that are brighter than the GCLF turnover by two [70].

6. The specific frequency of GC (S_N)

The Specific frequency of globular clusters was first proposed by Harris and van den Bergh [71] to measure the galaxy's globular cluster system richness. S_N defined as the number of globular clusters per unit galaxy luminosity, normalized to a galaxy with an absolute V magnitude of −15.

$$S_N = N_{GC} 10^{0.4(Mv+15)} \quad (1)$$

Harris and den Bergh [71] discovered that there is a proportional relationship between the number of GCs and the galaxy luminosity. Ever since, scientists have conducted extensive research on the S_N parameter in several galaxies with varying masses, morphological types, and environments. Kissler-Patig [32] investigated the properties of 53 GCs in both faint and bright galaxies. The found low specific frequency less than 5 for fainter galaxy ($M_V > -21.5$) while for brighter galaxy ($M_V < -21.5$) S_N higher than 5 (See Table 1).

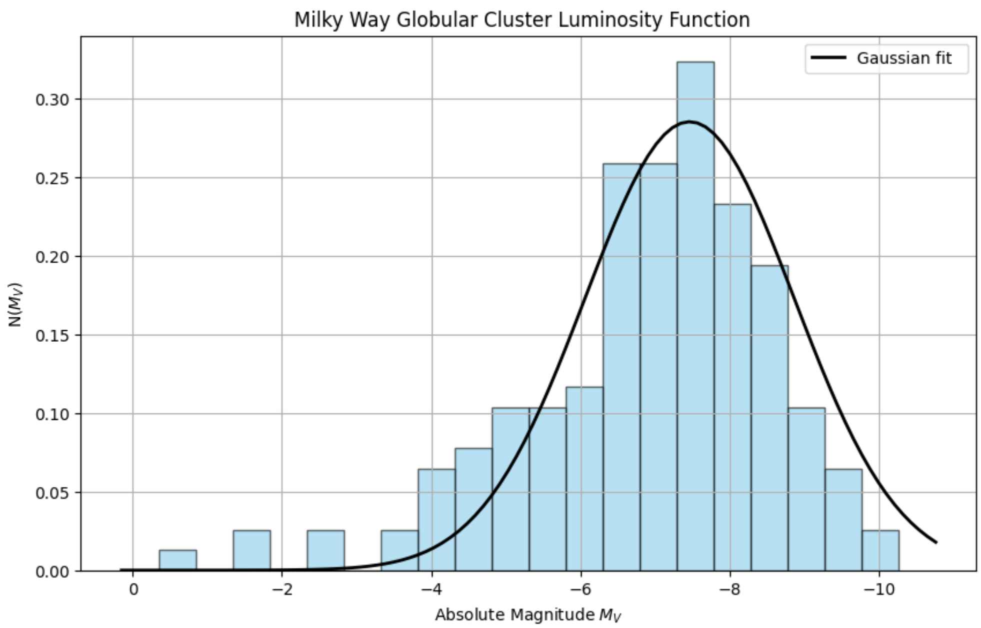

Figure 1: The GCLF for the MW with a fitted Gaussian to the distribution, based on the Harris data [10].

Table 1: Specific frequencies of globular clusters for different galaxy types.

Name (NGC+)	Type	S_N	Name (NGC+)	Type	S_N
artif.	dE	6 ± 0	4697	E6	2.5 ± 1.0
221	E2	0.8 ± 0	4881	E0	1 ± 0.1
3115DW1	dE1	4.9 ± 1.9	4636	E0	7.5 ± 2
3226	E2	7 ± 2.4	4374	E1	6.6 ± 0.9
4278	E1	8.7 ± 1.4	1399	E1/cD	12.4 ± 3

1374	E1	4.9 ± 1.3	5629	E/cD	5 ± 0
1379	E0	3.4 ± 0.9	4406	E3	6.3 ± 0.8
1427	E3	5.1 ± 1.3	4365	E2	5 ± 0.4
4340	S0	8 ± 3.2	524	S0	4.8 ± 1.1
4564	E6	10 ±3	5128	E0p	2.6 ± 0.6
3377	E5	2.1 ± 0.5	5846	E0	4.5 ± 2.7
1387	S0	3.2 ± 1.1	3923	E3	6.4 ± 1.5
5481	E3	2.5 ± 0.6	4649	E2	6.9 ± 0.2
3384	S0	1.1 ± 0.5	3311	E0/cD	15 ± 6
1052	E4	3 ± 0.4	4486	E0	13.9 ± 0.5
3607	S0	4.2 ± 3	5018	E4p	1.1 ± 0.5
1549	E0	0.8 ± 0.3	3557	E3	0.4 ± 0.3
5813	E1	7.2 ± 1.9	4472	E2	5.6 ± 1.7
3379	E1	1.2 ± 0.7	6166	E2/cD	9 ± 6
4494	E0	5.4 ± 1.3	7768	E2/cD	2.8 ± 1.8
1404	E1	3.5 ± 0.8	4874	E0	14.3 ± 1.7
1553	S0	2.3 ± 0.5	4073	E1/cD	4.8 ± 0.3
3115	S0	2.3 ± 0.5	3842	E3	7.7 ± 1.4
720	E5	2.2 ± 0.9	1275	Ep/cD	4.3 ± 1.4
4552	E0	8 ± 0	UGC9958	E/cD	12 ± 5.6
4621	E5	6.3 ± 1.2	UGC9799	E/cD	21 ± 7
4526	E0	7.7 ± 1.2	4889	E4	6.9 ± 1.2

Miller et al. [72] studied the specific globular cluster frequencies for 24 dwarf elliptical (dE) galaxies that photographed with the Hubble Space Telescope in the Virgo and Fornax Clusters, as well as the Leo Group reported. They discovered that nucleated dE (dE, N) galaxies, which have a spatial distribution similar to giant elliptical galaxies in galaxy clusters, have S_N equal to 6.5 ± 1.2. This S_N value increases as the absolute magnitude (Mv) increases. On the other hand, nonnucleated dE (dE, noN) galaxies, which are distributed like late-type galaxies, have an S_N of

3.1 ± 0.5, and there is little to no correlation with Mv. Kavelaars [73] investigated the relationship between the universality of GCLF and the specific frequency (S_N) variation. By conducting a comparison between mass estimations derived from the radial velocities of GCs and the number of clusters present in different galaxies, he found a consistent fraction of mass converted into globular clusters, independent of galaxy type and environment. This lends support to the hypothesis of a universal GCLF by indicating that GC formation is not dependent on the host galaxy. The S_N differs between galaxies with various morphological types, elliptical galaxies with values ranging from $2< S_N < 10$. In dwarf galaxies, this amount is much larger; it could reach values as large as $S_N > 100$ and increase with decreasing galactic luminosity [74 –76]. $S_N = 1$ is usually the value for spiral galaxies [12, 31]. The specific frequency problem is the term used to describe significant differences in S_N values. The ability of galaxies to form GCs was directly linked to explanations for observed changes in S_N, e.g. [59,75], [77-80]. McLaughline [80] demonstrated that changes in the mass-to-light ratio and the amount of x-ray gas can explain S_N morphological fluctuations, resulting in a relatively constant ratio of GC mass to total baryon mass. In the studied galaxy mass range, scales of GC depletion vary with the luminosity of the galaxy, with larger values in denser, less luminous elliptical. This is consistent with the observed S_N values. Miller and Lotz [72] have utilized the HST WFPC-2 Dwarf Elliptical Galaxy Snapshot Survey to investigate the characteristics of GCs in dwarf elliptical galaxies. They found that the specific globular cluster mass (S_M) in a nucleated dwarf elliptical is about twice as high as it is in non-nucleated ones and that the specific globular cluster frequency rises as the host galaxy's brightness drops. These results provide credence to the hypothesis that nuclei could be the consequence of increased star formation rates in cluster environments and that the stripping of dwarf irregular galaxies contributes to the formation of certain dwarf elliptical. Sanchez-Janssen and Aguerri [81] explain that in nearby clusters, the great majority of galaxies are early-type dwarfs (dEs). Whether such objects are primordial or recent results of several physical processes that may alter galaxies as they reach environments of high density is not well understood. They offered a distinct approach to testing these possibilities by comparing the characteristics of Virgo dE globular cluster systems and their likely predecessors to fundamental forecasts from gravitational and hydrodynamic interaction models. Many studies show that low-mass ($M\times\leq 2\times10^8 M\Theta$) dEs exhibit GCs consistent with gas-stripped late-type dwarf offspring. Wu and Kroupa [82] studied dark matter halos' phantom or apparent virial mass (Mvir) in the context of Milgromian dynamics. A connection between S_N and Mvir functions was discovered. When Mvir is greater than 10^{12} MΘ, the number of GCs rises, and when it is less than 10^{12} MΘ, the number of GCs decreases. Tidal erosion of GC causes a U-shaped specific frequency, which was investigated according to Mieske et al. [30]. Figure 2 shows the relation between the specific frequency of GC and absolute luminosity, which is the characteristic U-shape. This U-shape trend means higher S_N for very luminous and faint galaxies, with a minimum S_N for intermediate luminosity galaxies. They have studied numerous simulations that have been provided previously by Brockamp et al. [78] with the aim of quantifying this impact, and they have performed the computation of GC survival rates in the spherical models of the galaxy. Through using their approaches, they have discovered that the U-shape relationship of specific frequency as a galaxy luminosity function is highly affected by GC erosion. Mieske et al. [30] used tidal erosion as one method of GC destruction as well as dynamical friction of stellar components in different galaxies to try to explain the association between S_N and M_V. Katz and Roctti [83] investigated how globular clusters form and change over time in a galaxy similar to the Milky Way by using merger tree data from the Via Lactea II simulation. They aimed to determine the efficiency of globular cluster formation across different periods in cosmic time. They suggested that globular cluster Galactocentric distances and metallicity distributions are extremely sensitive to globular cluster formation efficiency as a function of redshift and halo mass. Furthermore, the effectiveness of GC formation is dependent on the environment under which galaxies develop.The nova rates within Virgo galaxies, specifically M87, M49, and M84, were investigated by Curtin et al. [84]. The proposed potential relationship between these nova rates and the frequencies of globular clusters in these galaxies. Despite observed variations in the specific frequencies of GCs, overall nova rates seem mainly linked to the galaxies' stellar mass. Mistani et al. [85] studied dwarf galaxy properties in different environments using the Illustris simulation. The S_N discovered in galaxies exhibits a wide range of properties that shed light on chemical enrichment and galaxy assembly and the processes that influence the formation and longevity of GCs across cosmic time. Some of the many subjects in these studies are the 23 central galaxies, the brightest, found in 19 Abell groups, which have been the subjects of a globular cluster system study. Results have shown that the S_N was well correlated with the characteristics of the cluster in general, which included the dispersion of velocity and Lx [86].

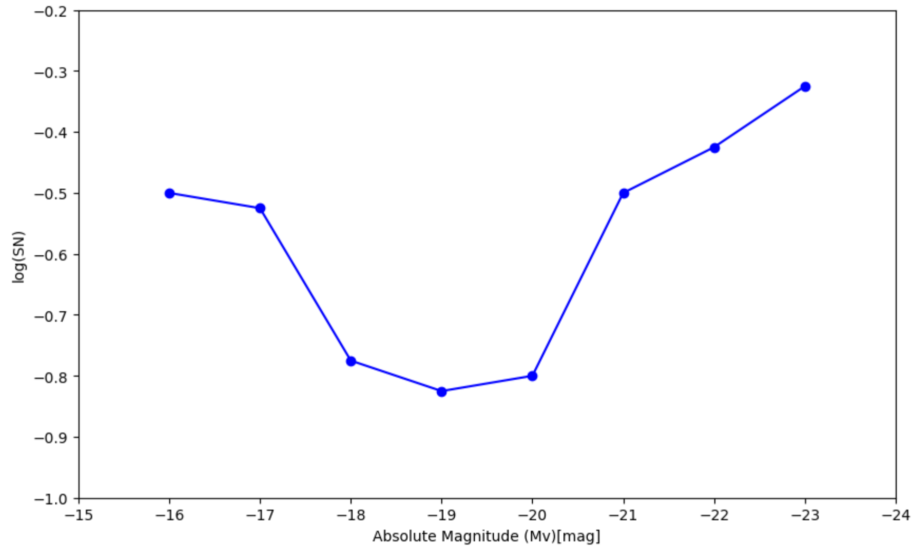

Figure 2: The average value of specific frequency (S_N) of the globular cluster (GC) is plotted against the absolute luminosity of the parent galaxy (Mv) [30].

Abdullah and Kroupa [87] investigated the relationship between the host galaxy's global properties and the cluster population. They suggested that the correlation between cluster population (NGC) and host galaxy baryonic mass (Mb) is best characterized as 10^6 Mb, and they have built a theoretical model for S_N for the galaxies of early type to comprehend the origins of the U-shaped correlation between the S_N and Mb. According to the findings, Abdullah et al. [88] showed that low-density galaxies have a larger S_N, whereas high-density ones have a smaller S_N since globular cluster erosion is thought to be a significant factor in defining this relationship. The specific frequency of GC for 43 early-type galaxies was studied by Liu et al. [89]. They have specified that dwarfs in denser cluster regions have a slightly higher S_N, yet otherwise, there was no difference in the S_N between the dwarfs in Fornax and Virgo, and although the two clusters are nearly one magnitude order different in mass, another possibility for a big galaxy with minimal S_N is a post-starburst resulting from recent gas accretion. Using observational data, Tadjibaev [90] investigated the specific frequency and proposed a quadratic relationship between the S_N and the host galaxy's absolute star magnitude. There may be some empirical relationships between the host galaxy's absolute frequency and the particular frequency that was discovered. Alamo-Martinez et al. [91] conducted a study on the GC systems of 15 massive compact early-type galaxies (ETGs) to highlight the influence of the environment on their formation and they found that these galaxies had a lower S_N compared to other ETGs of similar mass. A comparable analysis for GCs in 12 nearby massive and compact elliptical galaxies (MCEGs) was given by Kang and Lee [92] to determine whether or not GC systems that are hosted by those MCEGs are different from the ones of the local massive ETGs. Using hydrodynamical simulations on a dwarf galaxy, Andersson et al. [93] found that the timing of feedback initiation has a big effect on the initial cluster mass function, which affects the specific frequency. In addition to efficient Globular Cluster and field star formation the current theories and restrictions on GC evolution state that the high S_N of GCs in dwarf galaxies is a result of efficient cluster disruption in these environments [94]. Moreno-Hilario et al. [95] studied five dwarf galaxies utilizing cosmological simulations and found that after 12 Gyr of development, the GC systems have maintained a considerable and significant part of their initial masses with the low-mass dwarfs have an extremely low globular cluster mass loss efficiency and this supports the theory that the mechanisms disrupting GCs strongly influence the specific frequency of GCs in dwarf galaxies.

Conclusions

Globular clusters (GCs) are highly condensed stellar aggregates that are bound by gravity found primarily in the halos and bulges of galaxies. GCs can be useful to determine the formation processes of early galaxies since they contribute significantly to the understanding of GC formation and distribution. We discuss the properties and formation of GCs, emphasizing the S_N of GCs across different galaxy types. S_N proportional varies from galaxy to galaxy based on the morphology and mass distribution where it is higher amongst dwarf galaxies and lower amongst spiral galaxies. This variation is depending on a number of factors such as the galaxy's mass, density, and environmental conditions. We also discuss the historical context and methodologies for determining the number of GCs, of using quantitative methods alongside new developments in GC studies. The results contribute to a better understanding of the relationship between GCs and their host galaxies, giving a clue for understanding the galaxy formation and evolution.

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الخصائص الفيزيائية للمجموعات الكروية لأنواع مختلفة من المجرات: مراجعة المقالة

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الخلاصة

أحد الأسئلة الأكثر شيوعًا في الفيزياء الفلكية اليوم هو فهم تاريخ تكوّن المجرات وتطورها اللاحق. وإحدى الطرق الحاسمة لمعالجة هذا السؤال هي دراسة العناقيد الكروية (GCs) داخل هذه المجرات، حيث تحتوي خصائص العناقيد الكروية على معلومات مهمه حول تكوين وتطور العناقيد الكروية نفسها والمجرات المضيفة لها. تسلط هذه البحث الضوء على أحد المعايير الرئيسية للعناقيد الكروية، وهو التردد النوعي للعناقيد الكروية عبر الأنواع المختلفة من المجرات. نعرض مناقشات حول أصل وتطور العناقيد الكروية. تشير النتائج إلى أن نسب التردد المحدد لـ GCs إلى لمعان المجرات المضيفة لها تظهر اختلافًا عبر المجرات المختلفة.