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AN ANALYSIS OF THE MILKY-WAY-GLOBULAR-CLUSTER SYSTEM

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Abstract. The authors study various properties of the Milky-Way globular clusters. It is found that their various characteristics can be divided into five groups. Considering possible correlations among the characteristics belonging to different groups the authors conclude that a minimal set of independent parameters may form: the structural parameters (total mass, limiting and core radii), the age, the chemical composition and the parameters of the galactocentric orbit.

1. INTRODUCTION

The globular clusters (further on referred to as GCs) are among the most interesting objects in our Galaxy. Besides, many other galaxies are known to contain GCs. Among others they are believed to be perhaps even the oldest objects in the universe. As for the GCs belonging to our Galaxy, their system has been often subjected to various studies. It has been established, among others, that they probably form two distinct populations concerning their chemical composition (e. g. Zinn, 1985), for some of them the proper motion has been determined allowing the calculation of the galactocentric orbit (e.g. Brosche *et al.*, 1991), some interesting properties in the morphology of the horizontal branch in their HR diagrams have been pointed out (e. g. van den Bergh, 1993), etc. All this indicates that the globulars possess a substantial importance for our understanding of the universe evolution as a whole, as well as when it concerns the galaxies in it. Recently, a paper (Djorgovski, 1995) has appeared wherein the correlation among different properties of a GC is studied. Regardless of the results of that paper, the number of properties describing a GC as a whole is so large that it is difficult, indeed, to enclose all of them. Therefore, the present authors try to find a system of GCs properties as comprehensive as possible, but also concise enough to enable eliminating all superfluous parameters.

2. THE CHARACTERISTICS OF GCS

There is no doubt that various GCs characteristics should be systematised. In order to do this we divide the physical quantities describing these stellar systems into the following groups:

Group I describing their structure and comprising the quantities such as total mass, "tidal" radius, core radius, etc;

Group II ("light" parameters such as integrated magnitudes, luminosity, integrated spectral type, etc);

Group III (age, morphology of HR diagram);

Group IV (chemical composition, iron-hydrogen ratio, etc);

Group V (kinematics, coordinates, velocity components, orbit parameters, etc).

Within each of these groups it is possible to indicate the basic parameters, which are, certainly, mutually independent. In this way one obtains a minimal number of mutually independent physical quantities which describe the total set of the GCs in a galaxy, in the particular case considered here, the Milky Way.

If Group I is considered, then in view of the usual procedure the structure of a GC is described by three independent parameters: its total mass, its limiting radius and a characteristic or core radius. Usual procedure means that a GC is described by means of the King model involving a given formula for the mass distribution (King, 1962) and the isotropy in the velocity distribution (King, 1965; 1966). The number of three independent parameters is not surprising; it can be seen from the potential-energy formula for the spherical-symmetry case (e. g. Ninković, 1994) that this quantity is described by three constants (parameters) so that the case when they are all mutually independent seems as an optimal one.

Here it is worth noting that there can be some relationship between the mass and the limiting (or tidal radius) if one takes into account that, strictly speaking, GCs are not self-consistent systems. Fortunately, this effect is not so significant and the self-consistency approximation is quite acceptable for the case of GCs.

Within Group II there is no doubt that the luminosity and the spectral type are the most important. The integrated apparent magnitude, though observable, depends on both the luminosity and the heliocentric position of the cluster.

Group III seems to be most interesting. Though it seems that the HR-diagram morphology may clearly indicate the age of a GC (e. g. Lightman, Shapiro, 1978), the situation seems not too clear. On the other hand, a possibility of a relationship between the HR morphology and the cluster kinematics cannot be excluded (e. g. van den Bergh, 1993).

In the case of the chemical composition as the most frequently used indicator appears the iron-hydrogen ratio - [Fe/H] - usually known as metallicity. It is now available for a majority of the Milky-Way GCs (e. g. Zinn, 1985). The relationship between this parameter and the abundance of other elements, such as helium and heavier elements, is not quite clear.

Group V appears as the most heterogeneous one. The direction is by far the easiest to be determined; the line-of-sight has been no longer a serious problem. Due to the significant recent progress in photometry the accurate distances are now available for most of the galactic GCs. In view of this they have been frequently used in the determination of the galactocentric distance of the Sun (e. g. Racine and Harris, 1989).

It seems that a similar progress can be expected in the case of proper motions. They are, doubtlessly, the least accurate among the globular-cluster data. Nevertheless, some of them have been already used for the purpose of calculating the galactocentric orbits of GCs (e. g. Brosche *et al.*, 1991).

3. THE QUESTION OF CORRELATIONS

The importance of this question is indisputable. Here possible correlations between the characteristics of different groups are borne in mind. It is clear that some of them have been already studied rather intensively.

When the quantities from the first two groups are mentioned, then, certainly, as the most studied and best established appears that between mass and luminosity (e. g. Djorgovski, 1995). It seems as almost generally accepted that a mass of a GC (that quantity out of the two much more difficult to be determined) is obtained by simple multiplying the luminosity by a factor of ~ 1. This is, at the same time, an indication that the GCs do not contain substantial quantities of dark matter. With regard to both difficulties accompanying the mass determination and the importance of this correlation, in our opinion the mass-luminosity relationship should be subjected to frequent verifications.

Another important correlation is, no doubt, that concerning the spectral type (also Group II) and the metallicity (Group IV). That there are differences among the GCs of the Milky Way in their integrated spectral types which are accompanied by corresponding differences concerning the chemical composition is known since long ago (e. g. Morgan, 1959; Woltjer, 1975). Nowadays other quantities are also known (e. g. Ca II line - Armandroff Zinn, 1988) to correlate with metallicity. It may be finally said that the integrated spectral type is not quite well established as a definitive indicator of the chemical composition.

Among the best known correlations is, certainly, that concerning the relationship between the metallicity and the spatial distribution (e. g. Zinn, 1985). Therefore, it has been almost generally accepted that there are two types, or two populations, among the GCs of the Milky Way (and not only in the Milky Way), usually known as "disc" and "halo" GCs. As a, now, well established boundary dividing the two types of GCs one usually gives the metallicity value of -0.8. In the distribution one finds two tails corresponding to under-abundant GCs (less than -2), and to over-abundant ones respectively (greater than -0.3); it is questionable if the latter one is realistic (e. g. Armandroff Zinn, 1988). A correlation has been also found between the HR-diagram structure and the metallicity for the "halo" GCs, except the under-abundant ones (van den Bergh, 1993).

4. CONCLUSIONS

A tentative conclusion of the present authors could be that at the level of the current knowledge it is still early to indicate clearly those parameters which give a complete description of a GC. The five groups proposed above help us in solving this problem. The structural parameters (mass and the two radii mentioned above), age, chemical composition and the orbital parameters (galactocentric orbit) may serve the purpose if it becomes possible to reconstruct the integrated spectrum (luminosity and spectral type as two main characteristics) on the basis of the mass, age and chemical composition only, provided that the mass distribution of stars is known.

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