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GLOBULAR CLUSTERS - INTERESTING STELLAR SYSTEMS

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Abstract. For a long time, globular clusters excite interest of the astronomical community. Here is presented a review, concerning first of all an ensemble of around 150, belonging to the Milky Way. These systems may exist sufficiently long (in comparison with Hubble time), but however, traces of relaxation should be noticeable. It is possible that some of them survived the colapse of their cores.

1. INTRODUCTION

Globular clusters (GCS) are well known stellar systems. They are, especially, known to have shapes closer to perfect spheres than any other kind of stellar systems. Usually the number of stars within a GC is between $10^4 - 10^6$. Many of them seen from the northern hemisphere were known already to C. Messier in the XVIII century. Their distribution in space is, like for many other celestial bodies, not uniform. They mainly form systems identified with galaxies, though it cannot be excluded that some GCS are not bound to any galaxy (for instance, in the case of our own galaxy such cases are known, but they are probably bound to the Local Group of Galaxies). There are even dwarf galaxies having their own globular clusters (e.g. Fornax Galaxy). It may be concluded that globular clusters are very frequent. They can survive over a very long time.

There are several aspects in the studying of GCS. The most important ones are, certainly, the internal structure and the GCS belonging to the Milky Way. One may also mention the studies concerning GCS associated with other galaxies.

2. INTERNAL STRUCTURE OF GCS

The internal-structure studying for GCS starts usually with the examining of their spatial distribution which is based on star counts. First attempts of such kind belong as early as to the beginning of the twentieth century. Plummer's (e.g. 1915) interpretation of star counts, according to which the mass distribution in a typical GC follows the Schuster density law (due to this referred to very often as Plummer-Schuster law), is very well known. However, some later studies (e.g. Kostitsyn, 1922) questioned Plummer's conclusion. Star counts of sufficient quality became available at about 1960. King's (1962) model, today almost generally accepted as explanation of mass distribution within GCS, is approximately from that time. It should be said that Veltmann (1961), practically at the same time, indicated another mass- distribution model (alternative model) yielding almost an identical fit as King's one. It should be added that this alternative model is also known under the name of modified Hubble-Reynolds formula (e g. Binney and Tremaine, 1987 - p. 39).

In the case of King's model, as well as in the case of the alternative one, the spatial distribution is determined with three parameters: total mass (or central density instead), core radius and limiting or tidal radius. The core radius is very important. It is determined from the run of the surface density since at it the surface density should be one half that at the centre. A comparison of the observed surface-density curve to the one following from the comparison model yields the ratio tidal-to-core radius; the former one is defined as the radius where the surface density vanishes. With regard that in GCS the matter is said to be very strongly concentrated to their centres, as a measure of this concentration one usually uses the logarithm of the ratio of these two radii, the so-called concentration parameter. A comparison between the King model and the alternative one can be found in a paper of the present author (Ninković, 2004). King's model has a disadvantage that from its density formula it is impossible to obtain analytically the corresponding formula for the cumulative mass, i. e. potential. Therefore, the present author (Ninković, 2003) has proposed a formula for the gravitational potential which cannot be applied to the infinity because in it the (volume) density vanishes at a finite distance to the centre. King's model has the same property since there not only the surface density vanishes at a finite distance to the centre, but also the volume one, at the same distance (tidal radius). Unlike King's model in the case of the alternative one at the tidal radius only the surface density vanishes, whereas in the volume one there is a boundary discontinuity. This circumstance seems, in the present author's opinion, more natural because the apocentric distances of stars, clearly, cannot exceed the limiting-radius value, i. e. on the inner side of the boundary the density is still expected to be over zero, whereas on the outer one it should vanish. The potential proposed by the present author (Ninković, 2003) comprises both cases since as the boundary of the system can be assumed also another sphere closer to the centre than that where the density vanishes.

A question to be answered is also the amount of the total mass of a GC. Mass models mentioned above can be useful in such determinations.

3. INTERNAL RELAXATION

The structure of GCS as described above concerns their steady state, as if they were subjects to no evolution. However, the process of internal relaxation consisting of kinetic-energy exchange, usually between stars in pairs, can result in significant changes within a GC. It is characterised by a time interval known as the relaxation time. The calculation of the relaxation time for a typical GC shows that it is significantly shorter than the Hubble time. Therefore, observations with which one can verify theoretical predictions are of interest. The core-radius determinations are among them. Indeed, for some GCS of the Milky Way, the best known example is M15, the core radius strives practically to zero. This phenomenon is referred to as the core colapse. Its cause is in the fact that massive stars due to the internal relaxation sink towards the centre. In principle the core colapse is the final, extreme, phase of the internal relaxation. For many GCS one can expect the mass segregation. Observations aimed at examining the effects of mass segregation are currently done at many observatories.

4. GCS OF THE MILKY WAY

They are available on the Internet. This sample contains a total of 147 GCS. There are three groups of data. The first one gives the data concerning the internal structure - structural parameters. The concentration parameter is under 1 for 20 GCS (for nine of them no such data), whereas in the case of more than 25 GCS it exceeds the value of 2; its highest value in the sample is 2.5 and it is found for several GCS (about 15). As a final statement one can say that among the GCS with known concentration parameter some 70% have its value in the interval 1-2. As for the GCS with high concentration parameter, say over 2, a majority of them have suffered the core collapse. For example, this is the case with all of them having the highest concentration- parameter value (that of 2.5), nevertheless there are GCS with collapsed cores for which the concentration parameter is less than 2. More precisely for GCS with collapsed cores the core radii are usually estimated to a few seconds of arc. This value is probably near the lower limit of the possibilities of the modern equipment and hence it is not surprising that for so many GCS the concentration parameter is found to be 2.5. This value seems to be an upper limit for the concentration parameter, probably because the tidal or limiting radius is very often between some 15 and 25 arc minutes. In any case the concentration parameter is an important characteristic of a GC. However, there is a question to be answered - how large are its initial amounts - since, no doubt, the internal relaxation contributes to the decreasing of the core radius, i. e. automatically to the increasing of the concentration parameter.

Another important characteristic of a GC is its metallicity. It is seen that for about two thirds of the Milky-Way GCS the metallicity under the value of -1. This value has been very often cited as a limiting one for the objects of the galactic halo with regard to Zinn's (1985) results. It is also known that these metal-poor GCS form a gaussian metallicity distribution with a mean value of about -1.6. A vast majority of them is within limits of -1.3 and -1.9. There are only a few extremely metal-poor GCS in the Milky Way for which the metallicity is lower than -2. However, there is no single GC with metallicity under -2.5. In other words even the most metal-poor GCS are not deprived of metals.

The spatial distribution of the Milky-Way GCS is sufficiently well known. They belong to the halo, i. e. they do not concentrate strongly towards the galactic plane. This is especially true for the metal-poor GCS. However, the metal-rich GCS seem to show a concentration towards the galactic plane so that it is not quite clear if they should be attributed to the halo. There are views (e.g. Nagl, 2000) classifying them, nevertheless, to the halo taking as a criterion the behaviour of their line number density (in projection to the axis of galactic rotation). For some of the Milky-Way GCS the proper motions have been determined. Although their accuracy is not high (for instance, there are many cases where the discordance in the results obtained by different authors for the same cluster exceeds the indicated error limits), the possibility of calculating the galactocentric orbits have been used. The forms and sizes of these orbits agree well with what can be expected from the spatial distribution (e.g. Ninković et al., 1999). This is a rather qualitative conclusion in view of the comment concerning the accuracy of the proper motions.

5. CONCLUSION

GCS are important stellar systems. Their properties are worth of further studies. Among them are certainly those concerning the distribution of the surface brightness, mass segregation, statistical studies of the Milky-Way sample of GCS including also the search for other, still undiscovered, GCS. Some of these fields are expected to be comprised in the scientific cooperation between Bulgarian and Serbian astronomers.

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