ASTRONOMY AND SPACE SCIENCE
eds. M.K. Tsvetkov, L.G. Filipov, M.S. Dimitrijević, L.Č. Popović,
Heron Press Ltd, Sofia 2007

On Galactocentric Orbits of Globular Clusters

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Abstract. A review of galactocentric orbits for many globular clusters is given. It is pointed out that the proper-motion data, necessary to orbit determinations, are still not sufficiently reliable. On the other hand, realistic models of the Milky Way yield very similar galactocentric orbits for the same globular cluster. However, slight changes of both the parameters of a Milky-Way model and initial conditions can result in strong changes of the shapes of these orbits, though the dimensions remain practically unchanged. As a possible interpretation the present authors suggest that the so-called box orbits might be explained by using the two classical integrals (energy and angular momentum) only.

1 Introduction

Our Galaxy, the Milky Way, is known to contain about 150 globular clusters. With regard that their proper motions are poorly known, or even completely unknown, we cannot be sure that all of them are bound to the Milky Way (MW). For example, Pal 3 has a very high modulus of the heliocentric line-of-sight velocity so that only this velocity component is enough to result in a very large specific (per unit mass) galactocentric kinetic energy that even in the dark-matter presence that cluster can be hardly retained in a finite galactocentric orbit. In the case of, practically, all the other globular clusters (GCs) it might be accepted that they are bound. This circumstance allows us to undertake studies concerning their motion with respect to the MW centre. Due to the proper-motion problem, mentioned above, two different approaches in this matter have appeared. The first of them consists, in fact, of an orbit estimate and, consequently, requires no proper-motion data (*e.g.* Peterson 1974, House & Wiegandt 1977, Ninković 1983). The other one is more rigorous since it requires both the MW potential and the initial conditions to be specified (*e.g.* Brosche *et al.*, 1991, Dauphole *et al.*, 1996).

No matter how we know the potential and the proper motions, the latter approach is more correct and it offers the possibility to get an insight in the real galactocentric motion of GCs. What can be seen from the available results (*e.g.* Ninković *et al.* 1999), is that usually GCs move throughout the Galaxy along real spatial orbits, unlike objects of the galactic disc which almost all the time remain in the galactic plane, in the vicinity of a given circle. The shapes of these orbits, as well as the influence of the potential parameters, however, deserve further comments.

2 General Comments on Orbit Calculation

The potential of MW is usually presented as stationary and axially symmetric. In such an approach there has been a well-known and long-existing problem. Namely, as an immediate consequence of the steady state appears the integral of energy, whereas the axial symmetry implies the conservation of one component of the angular momentum (that along the axis of symmetry). In other words, we can be sure that there are at least two independent isolating integrals of motion. However, the orbits of MW objects seen in the so-called meridional plane or RZ-plane (R is distance to axis of rotation, modulus of Z is distance to galactic plane) show some properties which are in favour of the possibility that the total number of independent isolating integrals for the two assumptions given above (steady state + axial symmetry) is, nevertheless, three. As can be seen from the figures, the same GC can have rather different orbits caused by a moderate change in only one potential parameter. The differences between, say, two orbits of the same GC are most frequently qualitative, *i.e.* the dimensions in the RZ plane remain, practically, unchanged, whereas the shape of the orbit can be subject of significant changes. These changes of the orbits are not only consequences of the variations in the potential parameters, but also of those in the initial conditions.

3 Results

In the figures given below one can find a number of nice examples for galactocentric orbits of various GCs. These orbits were obtained by applying a particular MW potential, that by Miyamoto *et al.* (1980). Some properties of this potential, of importance to the present work, were described in more details in the paper by Ninković *et al.* (1999). Here it should be pointed out that the pairs of the galactocentric orbits concerning the same GC, seen in the figures, are obtained by varying one of the parameters of the assumed potential, that concerning the flattening of the galactic corona (dark-matter subsystem). In other words, neither the other model parameters nor the initial conditions are subjected to any variations. We have found similar effects also in cases of using alternative potentials (*e.g.* Ninković 1992).

4 Discussion and Conclusion

The present authors find as noticeable that applications of different models (potentials) of MW do not result in significant changes of galactocentric orbits of

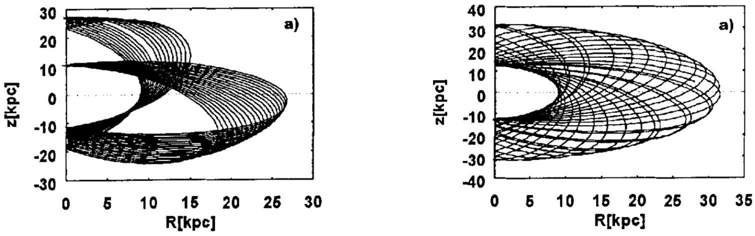

Fig 1. a and b . Orbit of GC 7089 for different values of model parameters

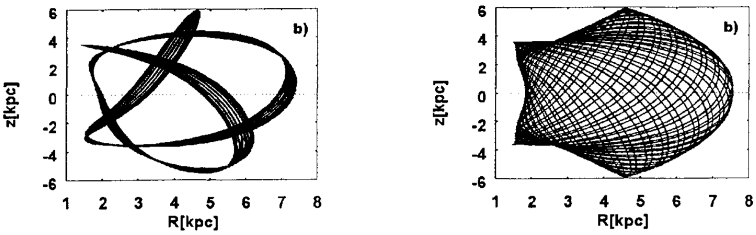

Fig 2. a and b . Orbit of GC 7099 for different values of model parameters

GCs as for their dimensions; of course one here deals with realistic MW models.

However, the uncertainty of the proper-motion data for these clusters is still very large so that the differences in their values between, say, two determinations concerning the same GC usually exceed the error limits indicated by the authors of these determinations. It is quite clear then that the use of two data sets for the same GC based on two different proper-motion sources lead to completely different orbits for the given GC. On the other hand, slight changes of either potential parameters or initial data can result in significant changes of the shape of galactocentric orbits, for instance to convert a box orbit in a tube one and vice versa. Such a change of the shape followed by negligible changes of the orbit dimensions could be due to the existence of a third isolating integral independent of the two classical ones. In the opinion of the present authors the classical integrals (energy and angular momentum) might explain the so-called box orbits alone, without any need for a further isolating integral, independent of them, because they provide natural limits in both R and Z.

Though, at present, no reliable galactocentric orbits for GCs are available for reasons indicated above, it can be, nevertheless, concluded that among GCs groups distincted according to their physical properties, such as, say, chemical composition, clear differences of galactocentric orbits do exist.

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