Finding out the Velocity Anisotropy Parameter for some Globular Clusters: the case of stationary model

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Abstract. The problem of determination of the velocity anisotropy parameter from star density profiles in globular clusters is considered. The calculations are performed for 10 globular clusters. The simple way for study of the dependence of anisotropy parameter on radial distance is used.

1. Introduction

The anisotropic models occupy an important place among various realistic models for study of the dynamical evolution of globular clusters. In frame of this models it have been worked out the many evolution theories of the kinematics and dynamics of spherical self-gravitating systems (e.g., Bettwieser & Spurzem 1986; Spurzem 1996; Louis 1990; Solanes & Salvador-Sole 1990; Takahashi 1996). At the same time have been accumulated many observational data. These data mostly concerned star counts and surface brightness profiles, proper motions, stellar radial velocity dispersion, etc. (Meylan & Heggie 1997). Despite of the presence such great quantity information, still there are difficulties in comparison problem the observational data with results of numerical simulations in the frame work of anisotropic models. One of causes of this phenomenon perhaps is concluded in that for their performe we must have at least the value of the anisotropy parameter $A = 2-2\sigma_r^2/\sigma_t^2$, where $\sigma_r^2$ and $\sigma_t^2$ are radial and tangential components of velocity dispersion respectively ($0 \leq A < 2$). In general case it depends on radial distance and time. The aim of this work is to determine the value of anisotropy parameter for 10 globular clusters, to try find out the its dependence on limiting magnitude and on radial distance.

2. The Method

We have used the method that was proposed by Agekian and Petrovskaya (1962). Let us assume: 1) the star ensemble has an equal-mass spectrum; 2) the cluster is spherically symmetric and is in stationary state in the regular force-field; 3) the cluster consists of single stars; 4) $\sigma_r^2 = \text{const}$ and $\sigma_t^2 = \text{const}$ along radius
(so \( A = \text{const} \)). Then the cluster is described by means of the equation

\[
\frac{d}{d\xi} \left( \frac{\xi^2 dD}{D d\xi} \right) = -D\xi^2 - A, \tag{1}
\]

where \( \xi \) and \( D \) are undimensional radial distance and undimensional spatial density. A theoretical surface mass density profile is determined as

\[
F_{\text{theor}}(r) = -2\beta \int_{r/\alpha}^{\infty} \sqrt{\xi^2 - (r/\alpha)^2} D'(\xi) d\xi - F_0, \tag{2}
\]

where \( \alpha \) and \( \beta \) are scale factors, \( F_0 \) is constant taking into account the infinity radius of the model and \( D'(\xi) \) is the solution of (1). From assumption 1) it follows that \( \rho \propto n \), where \( n \) is spatial number star density. Then \( F_{\text{theor}}(r) \) is theoretical surface number density of stars. Here constants \( \alpha \), \( \beta \) and \( F_0 \) are determined by minimization of the function \( \Phi(A) = \sum_{i=1}^{N} [F_{\text{theor}}(r_i) - F_{\text{obs}}(r_i)]^2 \) where \( N \) is number of star counts zones and \( F_{\text{obs}}(r) \) is observed surface number density of stars. That value of \( A \) that gives minimum \( \Phi(A) \) is adopted as most probable value of \( A \).

3. Results and Discussion

We determined the value of anisotropy parameter \( A \) for following 10 globular clusters: M3, M12, M13, M15, M55, M56, Palomar 3, Palomar 14, NGC5139 (\( \omega \) Cen) and NGC6535. The results are given in Table 1. For most clusters we have \( A = 0 \), i.e. they have almost isotropic velocity distribution. It is interesting that for all clusters theoretical number density profiles are in good agreement with observational ones. But the theoretical density profile in the halo almost in all cases is lower than observational one. Perhaps the cause is in the assumption about equal-mass. The fact is, as a result of mass segregation the low-mass stars prevail in the halo and consequently we overestimated mass density in this region. In reality the mass density less than we suppose.

For M56 at limiting magnitude \( B = 21^{m}5 \) we found \( A = 0.8 \). Hence in this cluster the velocity distribution is strongly anisotropic yet. Besides in order to find out an influence of limiting magnitude to value of \( A \), we calculated it at \( B = 19^{m}0 \) and found \( A = 0.3 \), i.e. if in this case the limiting magnitude decreases, then the anisotropy parameter decreases also. Perhaps it is because, in first case (\( B = 21^{m}5 \)) it is expected the influence of low-mass stars to value of \( A \) that generally are in halo and move along elongated orbits.

In order to find out the possible dependence of the anisotropy parameter on the radial distance we performed for NGC5139 (\( \omega \) Cen) additional calculations in three separate regions. The results show that in the central region \( A = 0 \), in middle region \( A = 0.1 \) and in the halo \( A = 0.3 \). In this case the agreement of the theoretical and observational density profiles essentially was improved than one for whole cluster.

We think this way allows to solve partly the problem of dependence of the anisotropy parameter on radial distance for any globular cluster. If we will
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Table 1. Value of anisotropy parameter for 10 globular clusters.

| Cluster | A or Exp. time | Limit. magnit. | Source of observational data | Note |
|---------|----------------|----------------|-----------------------------|------|
| M3      | 0              | 10 min         | King et al. 1968            |      |
| M12     | 0              | 9 min          | King et al. 1968            |      |
| M13     | 0              | 10 min         | King et al. 1968            |      |
| M15     | 0              | 30 min         | King et al. 1968            |      |
| M55     | 0              | 2 min          | King et al. 1968            |      |
| Pal 3   | 0              | 30 min         | King et al. 1968            |      |
| Pal 14  | 0              | V=22$^{m}.4$   | Harris & van den Berg 1984  |      |
| NGC6535 | 0              | B=20$^{m}.0$   | Peykov & Roussev 1988       |      |
| M56     | 0.8            | B=21$^{m}.5$   | Peykov & Roussev 1986       |      |
| -/-     | 0.3            | B=19$^{m}.0$   | Peykov & Roussev 1986       |      |
| NGC5139 | 0              | 30 min         | King et al. 1968            | 6.27 \leq r' \leq 23.82 |
| -/-     | 0              | -/-            | King et al. 1968            | 6.27 \leq r' \leq 10.22 |
| -/-     | 0.1            | -/-            | King et al. 1968            | 10.22 < r' \leq 14.75 |
| -/-     | 0.3            | -/-            | King et al. 1968            | 14.75 < r' \leq 23.82 |

make use of the more precise observational data, e.g. surface brightness profile received from Hubble Space Telescope, then we can find the more precisely dependence of anisotropy parameter on radial distance in the concrete observed globular cluster. Further we plan to study nostationary effects.

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