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Improved dynamical modelling of the Arches cluster

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Abstract. Recently, Clarkson *et al.* (2012) measured the intrinsic velocity dispersion of the Arches cluster, a young and massive star cluster in the Galactic center. Using the observed velocity dispersion profile and the surface brightness profile of Espinoza *et al.* (2009), they estimate the cluster's present-day mass to be $\sim 1.5\times10^4$ $M_\odot$ by fitting an isothermal King model. In this study, we trace the best-fit initial mass for the Arches cluster using the same observed data set and also the anisotropic Fokker-Planck calculations for the dynamical evolution.

Keywords. Galaxy: globular clusters: individual(Arches)–Galaxy: kinematics and dynamics

1. Introduction

The Arches cluster is a young, massive and dense cluster near the Galactic center. It is located ~26 pc in projection from the Galactic center. Clarkson *et al.* (2012) detected the intrinsic velocity dispersion of the Arches cluster. By comparing the model with their velocity dispersion data sets, the present-day mass for the Arches cluster was traced. In this paper, we study the dynamical evolution of the Arches cluster using Fokker-Planck calculations and trace the initial mass range of the Arches cluster, which simultaneously represent the observations of velocity dispersion (Clarkson *et al.* 2012), surface density (Espinoza *et al.* 2009) profiles, and the mass function (Kim *et al.* 2006).

2. Initial conditions

For initial conditions of Fokker-Planck models, we adopt a King model. To trace the initial mass range of the Arches cluster, we tried various parameters for King models. The concentration parameter, W_0, was tried at values 1, 4, and 8. As galactocentric radius, R_g, we use 30, 40, 50 and 70. The tidal Radius, R_t, is constrained by R_g and the initial mass of the cluster. For the lower and upper mass boundaries, we used 0.1 and 150 $M_\odot$, and we adopted the Kroupa mass function. For all of the parameters, we surveyed an initial mass range of the cluster for each model, $(1-7)\times10^4$ $M_\odot$.

3. Results

We compare the observational data with our Fokker-Planck results at 2 Myr and calculate the figure of merit of χ^2_v, χ^2_Σ and χ^2_{mf} (for velocity dispersion, surface density and mass function). Each figure of merit is

$$\chi^2_{v,\Sigma,mf} = \sum_{i=1}^{N} \frac{[data - model]_i^2}{\Delta^2_{data,i}}$$

Table 1. FP models with different initial conditions

Model	W_0	R_g	Model	W_0	R_g	Model	W_0	R_g
130	1	30	430	4	30	830	8	30
140	1	40	440	4	40	840	8	40
150	1	50	450	4	50	850	8	50
170	1	70	470	4	70	870	8	70

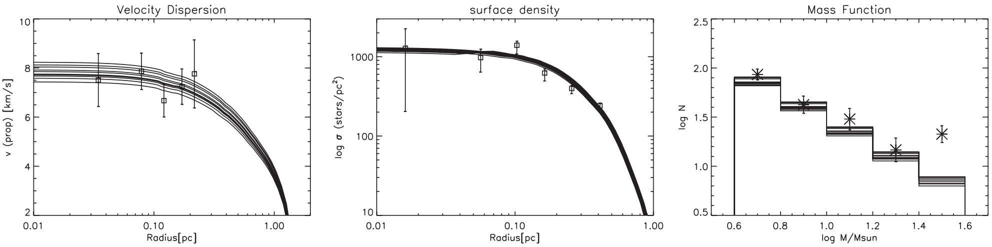

Figure 1. The velocity dispersion, Surface density and Mass function profiles.

Here, N is the number of data points and Δ^2 represents the squared errors on each data point. Then the full figure of merit is $\chi^2_{full} = \chi^2_v + \chi^2_\Sigma + \chi^2_{mf}$.
To find the plausible initial mass range for the Arches cluster, we choose the model which has the smallest value of the full figure of merit varying the M_{init}. We calculate the acceptable initial mass range having χ^2_{full} within 95.4% significance (less than 8.02) for model 140, and find the initial mass range of the Arches cluster as $M_{init} = (1.9-2.4)\times10^4$ $M_\odot$.

Figure 1 shows the velocity dispersion (left panel), surface density (middle panel) and mass function profile (right panel) of model 140 within $\Delta\chi^2_{full} < 8.02$. Data of velocity dispersion (Clarkson *et al.* 2012), surface density (Espinoza *et al.* 2009) and mass function (Kim *et al.* 2006) are used.

4. Summary

Using Fokker-Planck calculation, we compare the results of the calculation with the observations of velocity dispersion, surface density, and mass function. We find that the acceptable initial mass range of the Arches cluster, which has the smallest χ^2_{full} value in our models, to be $M_{init} = (1.9 - 2.4) \times 10^4$ $M_\odot$.

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