The Validation of Made-to-measure Method for Reconstruction of Phase Space Distribution Functions

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Investigating the dynamical structures of galaxies is important to infer their formations and evolutions especially in the era of highly precise Galactic survey mission, Gaia [1] and JASMINE [2]. To infer the real phase-space distribution function (DF) of the total of matters in a galaxy by the comparison of the theoretically constructed stellar DFs with precise observational data, accurate theoretical construction of the stellar DFs is very important.

For that purpose, we investigate how accurately phase-space DFs in galactic models can be reconstructed by a made-to-measure (M2M, [3]) method, which constructs N-particle models of stellar systems from various observational data, such as photometric and various kinematic data. The advantage of the M2M method is that this method can be applied to various galactic models without assumption of the spatial symmetries of gravitational potentials adopted in galactic models, and furthermore, numerical calculations of the orbits of the stars cannot be severely constrained by the capacities of computer memories. Therefore, when we construct DFs using immense data such as Gaia data, the M2M method is best suitable method among crrently proposed methods.

Although the M2M method has been applied to various galactic models, the degree of accuracy for the recovery of DFs derived by the M2M method in galactic models has never been investigated carefully. Then we investigate the degree of accuracy for the recovery of the DFs for the anisotropic Plummer model and the axisymmetric Stäckel model, which have analytic solutions of the DFs. Furthermore, this study provides the dependence of the degree of accuracy for the recovery of the DFs on various parameters and procedures adopted in this paper. The parameters which we investigate are the total number of particles used in the M2M modelling run, the number of constraints such as the mass or kinematic observables, the initial phase space distribution of the particles, configurations of the kinematic observables, higher order velocity moments, and a temporal smoothing.

As a result, we derive the dependence on the particle number and the data number (Figure 1). We find that the degree of accuracy for the recovery of the DFs derived by the M2M method using N_d observational data is $6.5 \times 10^2 \, N_d^{-1.6}$ % for the spherical target model, and $24.3 \, N_d^{-0.075}$ % for the axisymmetric target model. Therefore, by using the Gaia data of $N_d \sim 10^9$, the DFs can be constructed with the uncertainty of about 5 % [4].

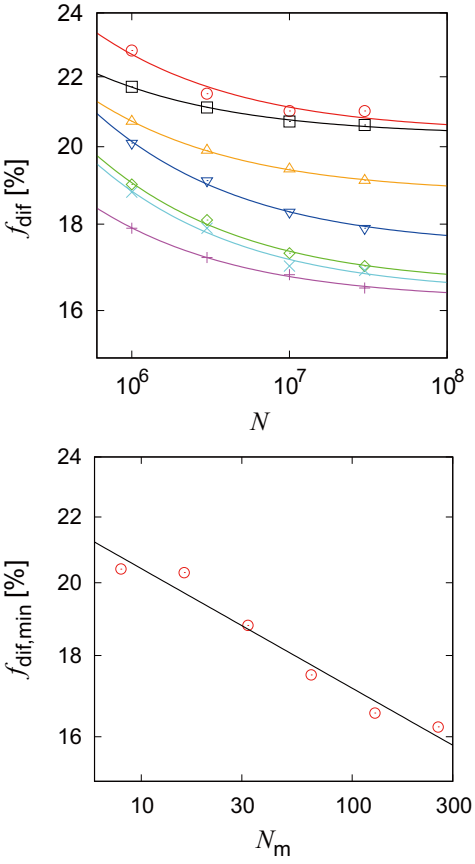

Figure 1: The upper panel shows the degree of accuracy for the recovery of the DFs $f_{\rm dif}$ for the axisymmetric three integral target model as a function of the particle number N. Red circle, black square, orange triangle, blue inverted triangle, green diamond, and magenta plus plots represent the results for the kinematic data number $N_{\rm k}$ = 16 and the mass data number as $N_{\rm m}$ = 8, 16, 32, 64, 128, and 256, respectively. Cyan cross plot represents the results for $N_{\rm k}$ = 64 and $N_{\rm m}$ = 128. Each line represents the curve fitted by $f_{\rm dif} = a \times N^{-0.5} + f_{\rm dif,min}$ for concolorous plots. The lower panel shows $f_{\rm dif,min}$ as a function of $N_{\rm m}$ for $N_{\rm k}$ = 16. The line represents the curve fitted by $f_{\rm dif} = a \times N_{\rm m}^{b}$.

References

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