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Clarification of the formation process of the super massive black hole by Infrared astrometric satellite, Small-JASMINE

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Abstract. Small-JASMINE (hearafter SJ), infrared astrometric satellite, will measure the positions and the proper motions which are located around the Galactic center, by operating at near infrared wave-lengths. SJ will clarify the formation process of the super massive black hole (hearafter SMBH) at the Galactic center. In particular, SJ will determine whether the SMBH was formed by a sequential merging of multiple black holes. The clarification of this formation process of the SMBH will contribute to a better understanding of merging process of satellite galaxies into the Galaxy, which is suggested by the standard galaxy formation scenario. A numerical simulation (Tanikawa and Umemura, 2014) suggests that if the SMBH was formed by the merging process, then the dynamical friction caused by the black holes have influenced the phase space distribution of stars. The phase space distribution measured by SJ will make it possible to determine the occurrences of the merging process.

Keywords. Galaxy: bulge, Galaxy: kinematics and dynamics, Galaxy: structure

1. Introduction

A super massive black hole (SMBH) resides in the central region of a galaxy. Its possible physical formation process is divided into two; a gas accretion onto a seed BH or a merger of BHs. From a viewpoint of the standard scenario for galaxy formation, it is natural to regard a SMBH as an end result of the merger of BHs. However, it was considered that there exist fatal problems in forming a BH merger. Recently, N-body simulations with a high resolution have overcome such problems and have shown that a sequential merger of multiple BHs is possible. Accordingly we aim at observationally investigating whether a SMBH in the Milky Way resulted from BH mergers through the analysis of stellar kinematics. A numerical simulations (Tanikawa and Umemura 2014) suggests that the merger process of BHs influenced the distributions of density and velocity of bulge stars within a distance of 10∼100pc from the Galactic center. Our method to verify the presence/absence of BH mergers is to assess the distribution function corresponding this region.

2. Method

First, we model the distribution functions form the results of numerical simulations of the Galactic bulge. Secondly, we deduce the distribution function P from the mock catalogue which we make with the assumed observational errors for stars within the circular region with the radius of 0.7deg centering around the Galactic center (the region that SJ will observe). Third, we make a few different models Q_i (i is the suffix for each model) of the distribution functions. Finally, we judge which model Q_i fits with P the best using the test of Kullback-Leibler (KL) divergence. Here the KL divergence means

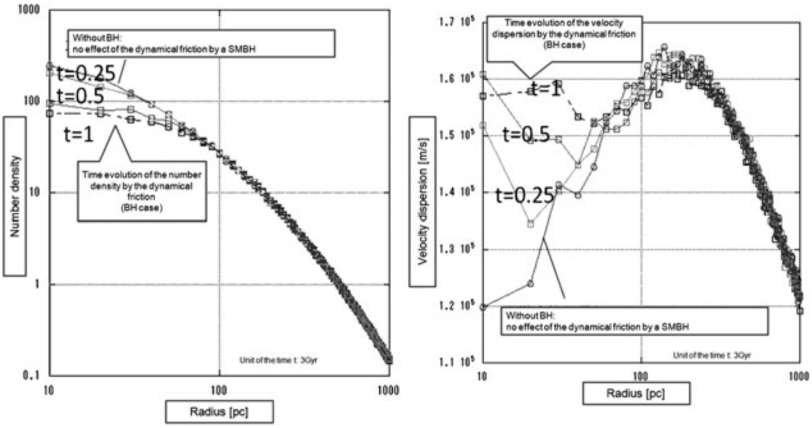

Figure 1. Evolution of the number density (left) and the velocity dispersion (right) of the central region of the Galactic bulge.

the expectation of the logarithmic difference between P and Q_i. Note that the divergence gives a smaller value for a more agreement case.

3. Preparation of models and mock catalogue:

We prepare two models of central region of the Galactic bulge with/without SMBH. We also prepare a mock catalogue using the above model with SMBH including the observational error and the effect of extinction by the dust (Gonzalez *et al.*, 2012). Bulge model parameters are assumed as follows: Bulge mass $M_{bulge} = 9 \times 10^9 M_{sun}$, BH total mass $M_{BH} = 4 \times 10^6 M_{sun}$, Virial velocity $v = 120$km/s, and Calcuratied time $T = 3$Gyr.

4. Evolution of the Number Density and Velocity Dispersion — Dynamical Friction by the Black Holes —

Evolutions of the number density and the velocity dispersion of the central region of the Galactic bulge are shown in Fig. 1. When the merger process of black holes has occurred, dynamical friction by black holes make the distribution of stars and velocity dispersion within the radius of 100pc change.

5. Results

We check whether we correctly judje using KL divergence. We have investigated 64000 trials. We obtain the numbers of stars, error of parallaxes, error of proper motion in order to judge with a confidence level of 99.7%. Criterion for judging with high confidence level is as follows: Number of stars we need is more than 3500 stars. Error of parallaxes and proper motions are less than 20μas and 200μas/yr, respectively.

References

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