MASSIVE BLACK HOLE BINARIES IN GALACTIC NUCLEI

JUNICHIRO MAKINO
Department of Systems Science, College of Arts and Sciences, University of Tokyo, 3-8-1 Komaba, Meguro-ku, Tokyo 153, Japan

Many large ellipticals were believed to have large, flat core, of which the radius is typically a few percents of the effective radius (*e.g.*, Lauer, 1985). However, HST observations (*e.g.*, Lauer *et al.*, 1995) have revealed that they are not flat cores at all. The "cores" observed by HST are actually very shallow central density cusps ($\rho \sim r^{-0.5\sim-1}$). Such a shallow cusp poses a serious problem to almost any scenario of the formation of ellipticals. If these ellipticals do not have central black holes (MBHs), we are faced with very strange structure with the velocity dispersion decreasing inward. Neither dissipationless/dissipational collapse nor merging have been able to make such a density distribution.

Ebisuzaki et al. (1991) proposed the merging of galaxies with central MBHs as the mechanism to form "flat cores". In the present paper, we give the result of self-consistent direct N-body simulations of merging of two galaxies with central MBHs, with the number of particles much larger than previously used. Details of the result are presented in Makino & Ebisuzaki (1996) and Makino (1997).

Figure 1 shows the result of "hierarchical" merging simulations with and without central BH (Makino & Ebisuzaki, 1996). Here, we performed the simulation in essentially the same way as (Farouki *et al.*, 1983), who used the merger product of one simulation as the initial galaxies for the next simulation. In order to prevent the increase of the number of particles, we selected half of the particles in the merger remnant. In addition, we replaced the BH binary in the merger by a single BH particle. Total number of particles was initially 31746, and mass of the BH was 1/32 of the mass of the galaxy. We performed direct simulation on GRAPE-4 (Makino *et al.*, 1997). In figure 1, we show the density profiles scaled in such a way that all merger remnants have roughly the same mean density and half-mass radius. In the case of the successive merging without central BH, it is clear that the core radius relative to the half-mass radius becomes smaller after each

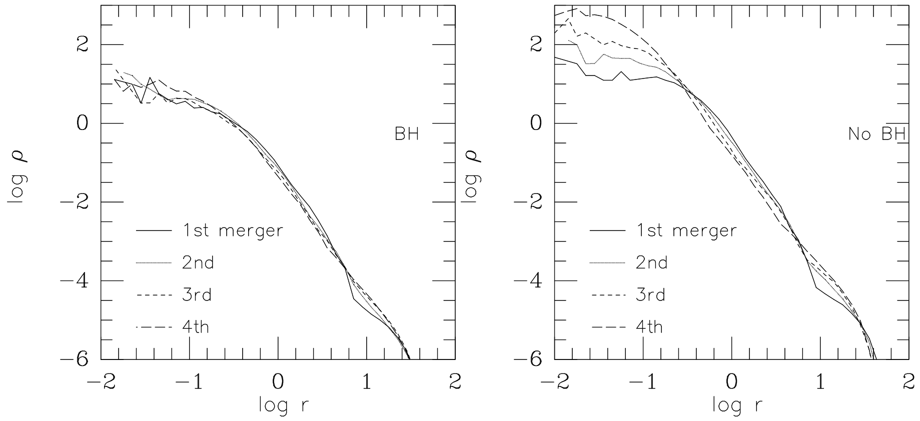

Figure 1. The density profiles the merger remnant. Left: mergings with BH; Right: density profiles for mergings without BH.

merging. This is because the real core radius remains almost unchanged, while half-mass radius increases (Farouki *et al.* 1983, Okumura *et al.* 1991).

In the case of the mergings with BH, however, we can see that there is no really flat core, but a region of very shallow cusp is formed. Moreover, the relative size of this cusp is almost constant, which means the real size of this region increases. In BH runs, both the size of the cusp region and the half-mass radius increases, while in No-BH runs, only the half-mass radius increases and core radius remains roughly constant.

This result explains quite nicely the observed central structures of large ellipticals. From ground observations, it has been know that the core radius shows strong correlation with the effective radius, and HST observations revealed that the cores are actually very shallow cusps. Thus, our model of merging of galaxies with massive central BH successfully reproduced both of these two essential features of the central region of large ellipticals.

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