N-body models of black holes with star accretion in galactic nuclei

Shiyan Zhong, Peter Berczik, Rainer Spurzem
National Astronomical Observatories of China, Chinese Academy of Sciences (NAOC/CAS)
20A Datun China Rd., Chaoyang District, Beijing 100012,

Supermassive Black Holes in Galactic Nuclei

Many, if not all galaxies harbour supermassive black holes. If galaxies merge, which is quite common in the process of hierarchical structure formation in the universe, their black holes sink to the centre of the merger remnant and form a tight binary. Depending on initial conditions and time supermassive black hole binaries are prominent gravitational wave sources, if they ultimately come close together and coalesce. We model such systems as gravitating N-body systems (stars) with one or more massive bodies (black holes), including if necessary relativistic corrections to the classical Newtonian gravitational forces (Kupi et al. 2006, Bérentzen et al. 2009).


References:

Model Description

In this work we have done a set of N-body simulations with a single massive black hole, adopting the widely used N-body model unit system: G=1, total mass of the cluster M=1 and total energy of the cluster E= -0.25 (Heggie & Mathieu 1986).

Initially, all the models have a seed black hole at the origin with zero velocity. The black hole's mass is set to be 0.01 in model unit. The model cluster contains N=16k, 32k, 64k particles, following a Plummer distribution.

The black hole's mass at time t subtracts its initial mass (e.g. 0.01). Those runs with R_t=1e-3 have a final mass one order of magnitude larger than the initial mass.

Simulation Results

We report results from our simulations. All simulations are running with the massively parallel direct N-body code phiGRAPE (using many GPU's for acceleration in parallel) on the GPU cluster at NAOC, up to 1000 N-body time units, which is about 300 half-mass crossing times.

References:

Heggie D.C., and Mathieu R. D. 1986, in N-body models of black holes with star accretion in galactic nuclei.

Figure 2 Number of disrupted stars as a function of time. In the R_t=10 case, we see large differences among the 3 models. While in the R_t=10 case, the differences are much smaller, indicate that they have approximately same disruption rates (see Figure 4).

Figure 3 Mean mass accretion rate. The data points are averaged over 100 N-body time. Different behaviors can be seen between the two R_t cases. The accretion rate of R_t=1e-3 runs begins to decrease after about 200 N-body time unit, while the R_t=1e-4 runs keep on increasing, except for the 16k run which slightly decreased at the end.

Figure 5 (below left) R_{max} distribution of the disrupted stars. R_{max} is the maximum radius a disrupted star can reach in the cluster. This region is around the critical radius, within which a loss-cone is presented (Frank & Rees 1976). (below right) normalized R_{max} distribution. All data points are divided by the total number of disrupted stars over the whole simulation.

Figure 6 (left) Density profile. We measured the cluster's density profile at 3 different times. As the system evolves, a central cusp forms within the black hole's influence radius. But we didn't see a -1.75 cusp (Bahcall & Wolf 1976) in all the models. The black hole's Brown motion and large tidal radius may suppressed the central density.

References: