The Topology of Equal Potential Surfaces in Galaxies with Supermassive Binary Black Holes

Li-Chin Yeh and Ing-Guey Jiang

Department of Applied Mathematics, National Hsinchu University of Education, Taiwan
Department of Physics & Institute of Astronomy, National Tsing Hua University, Taiwan

Abstract & Summary

Extending from the galactic models with supermassive binary black holes in Jiang & Yeh (2014), we study three-dimensional equal potential surfaces. The conditions of topological changes for these equal potential surfaces, and the properties of these surfaces' corresponding Jacobi integrals are investigated. The results of stellar scattering are also presented here.

E-mail: lcyeh@mail.nhcue.edu.tw
jiang@phys.nthu.edu.tw

Model

Two point-mass m at (R,0) and (-R,0) embedded in an environment with density

$$\rho = \rho_c r^{-1} \left\{1 + r^2\right\}^{-2}$$

and total mass Mg.

The equations of motion in rotating frame for the test particles are:

$$\begin{cases} \frac{d^2x}{dt^2} = 2n\frac{dy}{dt} + n^2 x - \frac{m(x+R)}{r_1^3} - \frac{m(x-R)}{r_2^3} - \frac{M_g x}{r}\left(\frac{1}{1+r^2}\right), \\ \frac{d^2y}{dt^2} = -2n\frac{dx}{dt} + n^2 y - \frac{my}{r_1^3} - \frac{my}{r_2^3} - \frac{M_g y}{r}\left(\frac{1}{1+r^2}\right), \\ \frac{d^2z}{dt^2} = -\frac{mz}{r_1^3} - \frac{mz}{r_2^3} - \frac{M_g z}{r}\left(\frac{1}{1+r^2}\right), \end{cases}$$

where n is the angular velocity of rotating frame,

$r^2 = x^2 + y^2 + z^2$, $r_1^2 = (x+R)^2 + y^2 + z^2$, and $r_2^2 = (x-R)^2 + y^2 + z^2$.

Results & Conclusions

- We prove that new equilibrium points, i.e. Jiang-Yeh Points, exist in embedded binary systems.
- Two Roche lobes get separated
- There is one more lobe whose surface cutting through two Jiang-Yeh Points
- Most particles initially around the right black hole would not transfer to another black hole
- Most particles go to outer regions
- These results might lead to the formation of core structures.

Roche Lobes

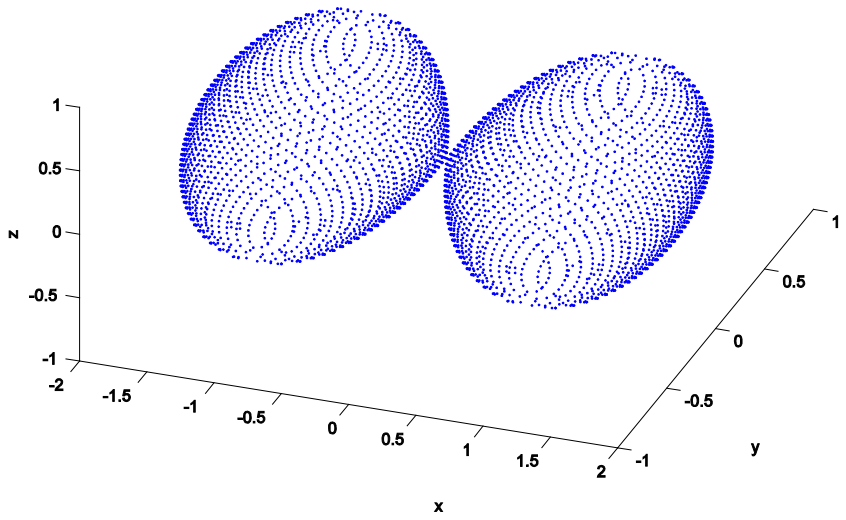

Fig. 1(a): Mg=0

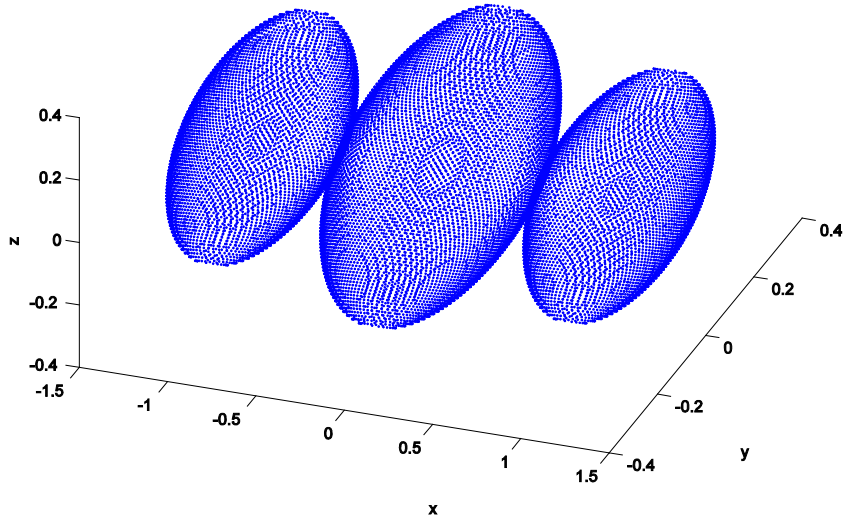

Fig. 1(b): Mg=30

Evolution of Particle Distribution from t=0 to 11

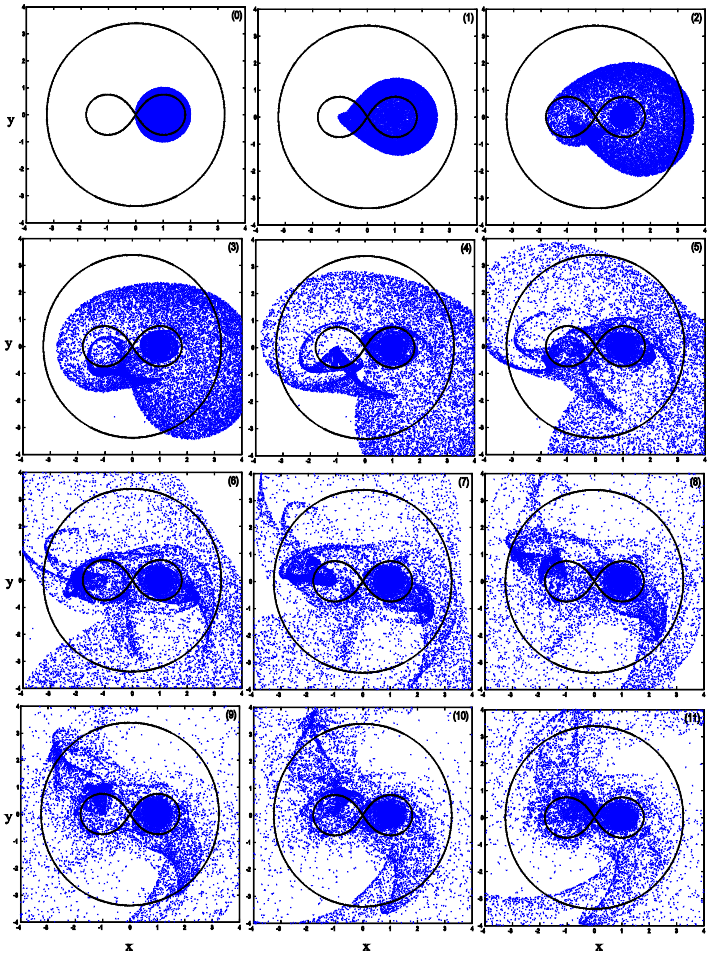

Fig. 2(a): Mg=0

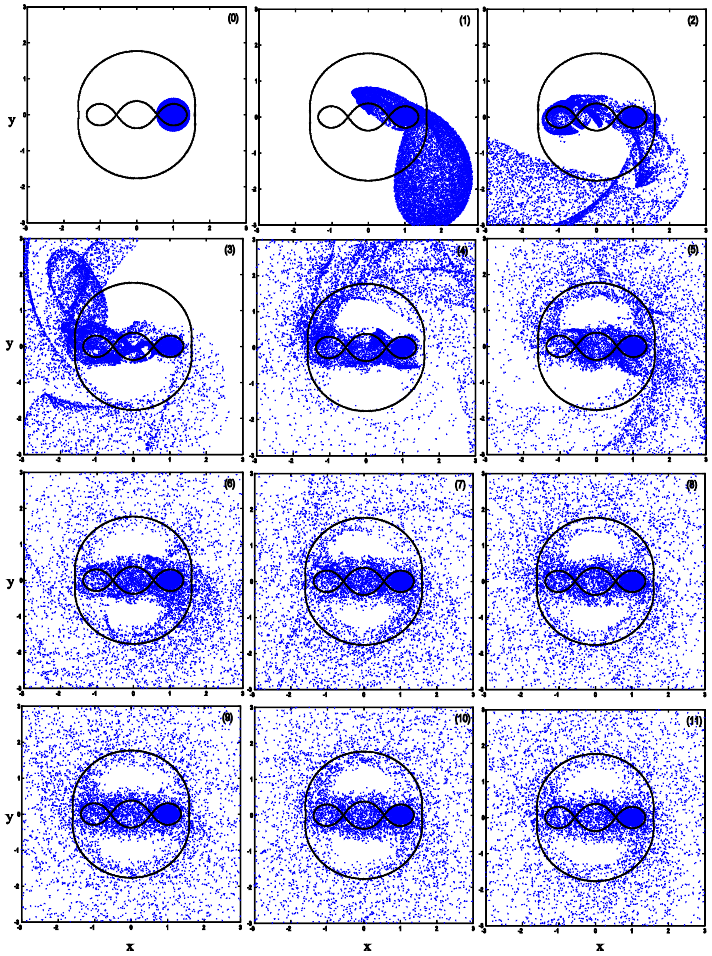

Fig. 2(b): Mg=30

The Numbers of Particles in Different Regions as a Function of Time

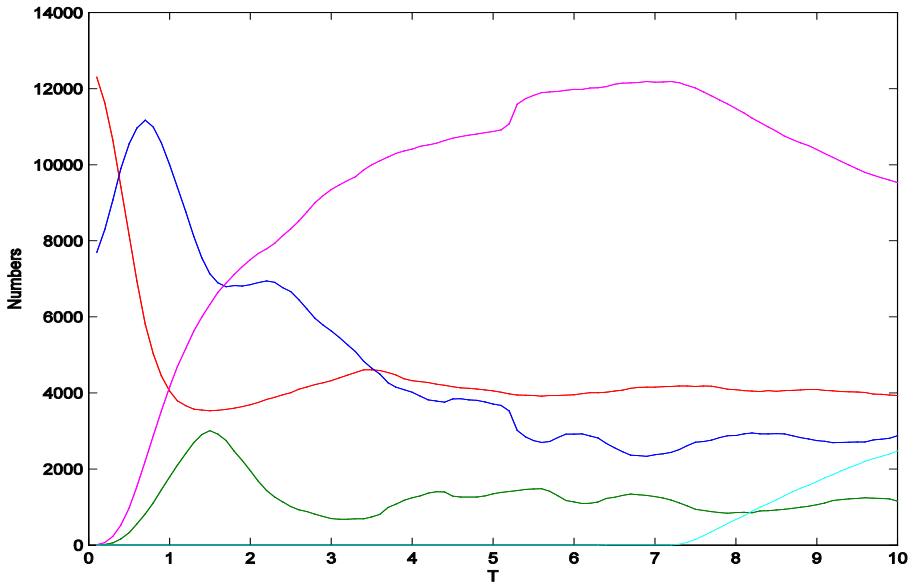

Fig. 3(a): Mg=0

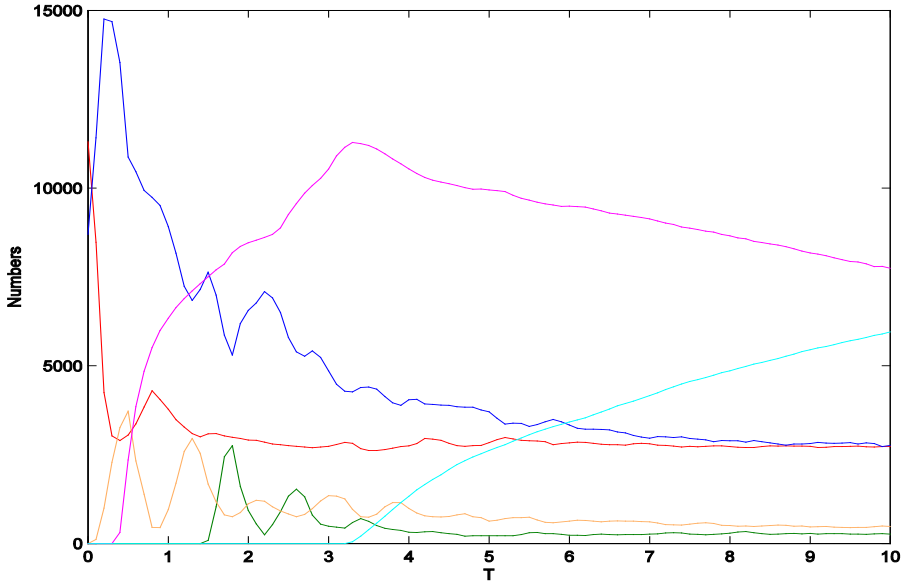

Fig. 3(b): Mg=30

red: in right Roche lobe

green: in left Roche lobe

orange: in the central new lobe

dark blue: out of lobes and r<2

purple: 2<r<10

light blue: r>10