GR effect on Hill stability

Haruka Suzuki *& Shoichi Yamada †

April 27, 2019

Nowadays, many body systems with some compact objects orbiting around SuperMassive Black Hole (SMBH) attract researchers' interest. It is because the unstable complicated motion in many body systems due to gravitational interaction may cause mergers of compact objects which give us chance to observe gravitational waves in short timescale. Some researchers are also interested in stable orbits of compact objects around SMBH. The system is called Extreme Mass Ratio Inspiral (EMRI) and expected to be observed with LISA. In order to understand such interesting motions, it is necessary to analyse stability of the many body systems with strong gravitational field.

We focused on one of the famous stability problem of many body systems, Hill stability. It is the well-known topic in the planetary formation field. When two planets' orbits become closer than Hill radius, usually the system become unstable, that is, two planets collide or show chaotic motion and go out of the system. For three-body systems, the analytical Hill stability criterion was derived by Gladman (1993). For more than three-body systems, Chambers et al. (1996) did numerical simulations and showed empirical relation between the distance of orbits and time for the system become unstable and many authors extended their simulation for large parameter space. However, these studies are all given in Newtonian mechanics and cannot be employed for the system with strong gravitational field.

So, in our study, we analysed the Hill stability around SMBH in the same manner with Chambers et al. (1996) but using General Relativity (GR). We used post-Newtonian equations of motion instead of Newtonian ones and did numerical simulations for some three-body and four-body systems. It was shown that GR effect made the system more unstable than Chambers's empirical relation obtained by Newtonian calculation. We conclude that the periastron shift of orbit by GR effect is the main cause.

References

Chambers, J. E., Wetherill, G. W., & Boss, A. P., 1996, Icarus, 119, 261

Gladman, B., 1993, Icarus, 106, 247

*Graduate School of Advanced Science and Engineering, Waseda University

†Advanced research Institute for Svience and Engineering, Waseda University