Theory of Gravitational Encounters

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[1] The forces acting on a star can be divided into two kinds. The gravitational potential of the galaxy as a whole generates a force that can be approximated as a smoothly varying function of position and (if need be) of time. This smooth force determines the orbit of the star. Each star is also influenced by other forces arising from the fact that the mass making up a galaxy is discrete: it is composed of individual stars and stellar remnants, as well as more massive objects like star clusters and giant molecular clouds. As a star moves along its orbit, it experiences fluctuations in the total force as its distance from these objects changesdue both to the stars own motion, and to the motion of the other bodies. The gravitational encounters alter the kinetic energy and the direction of motion of each star, causing its orbit to deviate gradually. The relaxation time, T_r, can be defined as the time over which the cumulative effect of gravitational encounters becomes significant for a typical star. The relaxation time can also be defined as the mean time for E to change by of order itself as a result of encounters. If $\Phi(\boldsymbol{x}, t)$ is spherically symmetric, a second relaxation time can be defined in terms of changes in L; and so forth. These different ways of defining T_r can sometimes yield very different estimates for the time of relaxation. In

the case of stars orbiting near the center of a galaxy containing a supermassive black hole (SBH), it turns out that changes in L due to gravitational encounters can occur much more rapidly than changes in E. This is due to that the unperturbed orbits are nearly Keplerian and the encounters are correlated over time.

Consider the effect of random encounters on a star that is following a rectilinear, unaccelerated orbit in an infinite, homogeneous galaxy.

References

[1] D. Merritt. *Dynamics and Evolution of Galactic Nuclei.* July 2013.