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Statistical Mechanics in the Galactic Center: Anisotropic Mass segregation and Phase Transition

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Galactic nuclei, the densest stellar environments in the Universe, exhibit a complex geometrical structure. The stars orbiting the central supermassive black hole follow a mass segregated distribution both in the radial distance from the center and in the inclination angle of the orbital planes. This distribution may represent the equilibrium state of vector resonant relaxation (VRR).
In this talk, I present simple statistical physics models to understand the equilibrium distribution found previously in numerical simulations. Using the method of maximising the total entropy and the quadrupole mean-field approximation, we determine the equilibrium distribution of axisymmetric two-component gravitating systems with two distinct masses, semimajor axes, and eccentricities. We explore the parameter space of energy and angular momentum and find evidence of vertical mass segregation.
I will also discuss disk-isotropic transitions in the statistical mechanical models. When one component dominates, the transition from a spherical disordered state to a flattened ordered state is continuous as a function of stellar mass, semimajor axis, eccentricity, and net angular momentum. This can help to determine the features of these massive perturbers from the observations of the stellar orbits. We identify the system parameters where a discontinuous phase transition occurs both in the canonical and in the microcanonical ensembles. We also study negative absolute temperature equilibria for which the more energetic states are relatively more populated.
Lastly, I will present the N-body VRR dynamical simulation results. Two-component systems are found to relax to the theoretical thermal equilibrium. This occurs even when the two components have small inter-component interaction energy, where a phase transition could occur. We demonstrate in the simulations that the change in one of the components can induce a (discontinuous) transition in the other component between a disk state and an isotropic state. Additionally, the simulations reproduce the negative absolute temperature states.

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