Astrophysical Sciences & Technology
Ph.D. Dissertation Defense

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Evolution of Massive Black Hole Binaries in Rotating Stellar Nuclei and its Implications for Gravitational Wave Detection

Advisor: David Merritt

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Abstract:

According to the currently prevailing cosmological paradigm, mergers between galaxies are an important part of their evolution. Given that most of the galaxies are known to contain a supermassive black hole in their center, that implies the existence of binary supermassive black holes (BSBH) as products of galactic mergers.

The subject of my dissertation is the dynamical evolution of a BSBH in the center of a galactic nucleus. I calculate the rate of change of its orbital elements due to interactions with the stars of the galaxy by means of 3-body scattering experiments. My model includes a new degree of freedom - the orientation of the BSBH's orbital plane - which is allowed to change due to interaction with the stars in a rotating nucleus. The binary's eccentricity also evolves in an orientation-dependent manner. I find that the dynamics is qualitatively different compared to non-rotating nuclei: 1) BSBH's orbital orientation changes towards alignment with the plane of rotation of the nucleus; 2) BSBH's eccentricity decreases for aligned BSBHs and increases for counter-aligned ones.

Then I apply my model to calculate the effects of stellar environment on the gravitational wave background spectrum produced by BSBHs. Using the results of recent N-body/Monte-Carlo simulations I account for different rate of stellar interactions in spherical, axisymmetric and triaxial galaxies. I also consider the possibility that supermassive black hole masses are systematically lower than usually assumed. The net result of the new physical mechanisms included in my model is a spectrum for the stochastic gravitational wave background that has a significantly lower amplitude than in previous treatments, which could explain the discrepancy that currently exists between the models and the upper limits set by pulsar timing array observations.