Astrophysical Sciences & Technology
Ph.D. Dissertation Defense

Dennis Bowen

General Relativistic Gas Dynamics of the Central Cavity in Binary Black Holes

Advisor: Manuela Campanelli

Thursday July 27th, 2017 10:00am
Location: Carlson Auditorium 76 – 1125

Abstract:

Supermassive binary black holes (SMBBHs) represent an excellent candidate for future combined gravitational wave and electromagnetic astrophysics, commonly referred to as multimessenger astrophysics. While much is known about the gravitational wave signal of merging BBHs, little is known about the electromagnetic emission. Modeling the electromagnetic emission coincident with gravitational waves requires simulations of SMBBHs coupled to their astrophysical environment, particularly during the late stages of inspiral and merger. These simulations necessitate a broad range of physics including general relativity, magnetohydrodynamics, and radiation physics.

In this Dissertation we present the *first ever* simulations capable of such predictions. We explore, for the first time, the gas dynamics in a relativistic BBH system in which an accretion disk (a "mini-disk") orbits each black hole. In addition to studying the structure and dynamics of the mini-disks, we present spectra from the first ever ray-tracing calculations of SMBBH accretion including mini-disks. Due to the immense computational burden of these simulations (millions of CPU hours per binary orbit), we restrict our study to equal-mass, non-spinning SMBBHs.

Relativistic effects alter the dynamics of gas in this environment in several ways. Because the gravitational potential between the two black holes becomes shallower than in the Newtonian regime, the mini-disks stretch toward the L1 point and the amount of gas passing back and forth between the mini-disks increases sharply with decreasing binary separation. This "sloshing" is quasi-periodically modulated at 2 and 2.75 times the binary orbital frequency, corresponding to timescales of hours to days for SMBBHs. In addition, relativistic effects add an azimuthal $m = 1$ component to the tidally driven spiral waves in the disks that are purely $m = 2$ in Newtonian gravity; this component becomes dominant when the separation is less than 100 gravitational radii. We find that the spiral structure of the mini-disks is further altered through a coupling of the mini-disks to an $m=1$ mode in the circumbinary accretion disk via streams of gas peeled off the inner edge of the circumbinary. This modulation in the accretion stream flux has a quasi-periodic nature of 0.74 times the binary orbital frequency. Both the sloshing and the spiral waves have the potential to create distinctive radiation features that may uniquely mark SMBBHs in the relativistic regime. Finally, we observe a broadened thermal spectrum due to the combined photospheres of the mini-disks and circumbinary disks in the range of 1-1000eV, and an inverse Compton spectrum at tens to hundreds of keV dominated by the mini-disks.