Stellar and Galactic Astronomy with Ultracompact Binaries

M. Benacquista, K. Holley-Bockelmann, V. Kalogera, S. Larson, T. Littenberg

Developing a clear and coherent understanding of the birth, death and evolution of astrophysical systems that live far longer than any human requires high quality observational data from as many systems as possible. The Galaxy is host to tens of millions of short-period binaries built from compact objects such as white dwarfs or neutron stars. Currently only a few dozen are known, but these ultra-compact binaries (UCB) are a copious supply of gravitational radiation, believed to be the dominant source on the gravitational-wave (GW) sky in the millihertz band. Because these binaries are faint they are challenging electromagnetic targets, making gravitational wave observations the best way to discover and characterize these systems.

Space-based GW observatories will single-handedly detect more ultra-compact binary systems in the first year of operations than all electromagnetic observations combined in the last five decades. UCBs must evolve through complex phases including mass transfer and common-envelope evolution, or through dynamical interactions in dense clusters. More than 10,000 UCB systems are expected to be well characterized through their gravitational radiation, enabling:

- detailed statistical studies of the highly evolved stellar population in the Galaxy, including the distribution of masses -- a fossil record of the Milky Way's star formation history;
- insight into the complex mass-transfer history that drives the evolution of UCBs;
- inferences of the merger rate for different classes of compact binary systems, from gamma ray bursts to Type Ia supernovae;
- identification of stability criteria and heretofore unknown details of cluster dynamics.
- a deep survey of the Galaxy in regions that are inaccessible to electromagnetic observations.

UCBs are a continuous source of GWs for space-based observatories. The GW observations are particularly sensitive to the orbital phase evolution of each system explicitly predicted by General Relativity. Departures from the expected orbital decay will provide precise insight into interactions between close stellar remnants, including mass transfer, tidal interactions, compact stellar structure, and ultra-dense equations of state.

Low-mass, nearby, accreting systems can be detected through electromagnetic emissions and observed with large-scale survey telescopes, and hundreds to thousands of these systems will be detectable to both GW detectors and electromagnetic telescopes; a few dozen systems have already been detected and characterized using ground-based telescopes and coming surveys will continue to increase the known population. Multi-messenger observations provide a complementary view of UCBs, as the gravitational wave detectors are sensitive to the mass, distance, and orientation of the binary while electromagnetic emission is a probe of the stellar surfaces and environment. Joint observations will provide methods for measuring accretion disk radii and pressure profiles in accretion disks.