Research Statement

I focus on exploring binary black holes with future gravitational wave detectors, which includes stellar- and intermediate-mass black holes. It involves primarily assessing detection capabilities (detection number and source parameters estimation), as well as constraining population properties and formation channels of sources. My research statement is organized as follows:

I worked on stellar-mass binary black holes (SBBHs), during my PhD study. SBBHs detected by gravitational waves (GWs) are heavier than those observed by electromagnetic waves. These heavy SBBHs are promising sources for scheduled space-borne GW detectors focusing on millihertz, e.g., LISA and TianQin. We adopted five mass distribution models of SBBHs calibrated by events detected LIGO/Virgo to study them with LISA and TianQin. We predict that dozens of sources would be resolved, and source parameters would be measured accurately. We also argue that formation scenarios (isolated binary evolution and dynamical interaction) of sources could be distinguished by measuring their orbital eccentricities. In addition, the detection and measurement capabilities for SBBHs could be improved significantly by joint observation of TianQin and LISA. This work [published in Phys.Rev.D 101 (2020) 10, 103027] provides a basis and guidance for detecting SBBHs and distinguishing their formation channels by future GW detectors.

LIGO/Virgo observed a special SBBH event named GW190521 whose primary component mass and merger remnant fall in the mass gap and mass range of intermediate-mass black holes (IMBHs), respectively. The event directly confirms the existence of black holes in the mass gap and IMBHs for the first time. We investigate GW190521-like sources [host China Postdoctoral Science Foundation, Grant No. 2021TQ0389 (180K CNY)], after I become a postdoctoral fellow. Same as before, we simulate GW190521-like SBBHs in the Universe by the mass and merger rate of GW190521, and estimate the detection capabilities of LISA/TianQin for them. A dozen of sources could be detected and their source parameters could be measured with high precision. We could tell whether sources originate from isolated binary evolution or dynamical interaction by measuring their orbital eccentricities. For sources with extremely large orbital eccentricities, they would be identified by multiband observation of LISA (TianQin) and the third generation ground-based detectors Cosmic Explorer (CE) or Einstein Telescope (ET). This work [published in Phys.Rev.D 105 (2022) 2, 023019] provides the basis and guidance for detecting GW190521-like sources and studying their formation channels by future GW detectors. Meanwhile, I participated in constraining the Hubble constant with SBBHs detected by multiband observation (e.g., LISA+ET) as one of the important contributors. The Hubble constant would be constrained within 1% by the Bayesian method. This work [published in Sci.China Phys.Mech.Astron. 65 (2022) 5, 259811] is of great importance for studying cosmology with SBBHs detected by future multiband GW observation. Now, I am working on exploring inner SBBHs in hierarchical triple black hole systems in Population III star clusters by future GW detectors. The orbital evolution of the SBBH could be affected by the third black hole, so I plan to study these SBBHs by GWs in three different aspects: distribution of orbital eccentricities, the evolution of orbital eccentricities, as well as multiband observation numbers. Then, I will constrain the formation scenarios of SBBHs depending on these results. I have completed the evolution of Population III star clusters by N-body simulation and selected hierarchical triple black hole systems. I am analyzing their population properties. This work will provide a method to study population properties and formation mechanisms of SBBHs in hierarchical triple black hole systems in Population III star clusters by forthcoming GW detectors.

In the future, I will shift my attention to hierarchical triple black hole systems in globular clusters (GCs) where IMBHs are generally thought to exist. Due to the dense environment of GCs, SBBHs and IMBHs would form hierarchical triple black hole systems, if there exist IMBHs. The orbital evolution of SBBHs would be affected by IMBHs, making GWs from the former carry informaiton of the latter. Same as before, I will evolve GCs harboring IMBHs with N-body simulation and select the targeted hierarchical triple systems formed. I will study SBBHs in triple systems by future GW detections in the distribution and evolution of orbital eccentricities, as well as multiband observation number, respectively. Then, I will analyze the population properties of these SBBHs and infer the existence of IMBHs depending on the above results. This project would provide a novel approach to detect IMBHs and explore the formation channels of SBBHs in GCs by future GW detections.

I focus on studying SBBHs and IMBHs with GWs. I think that my current and future and research projects on hierarchical triple black holes systems are very relative to one of current topics of research in the institute, i.e., gravitational wave studies. I believe that my current and future research will be completed, due to my rich knowledge in astrophysics, experience and skills (e.g., gravitational wave and N-body simulation). If I have an opportunity to be awarded the fellowship, I think we could benifit and enrich scientific payoff from each other.