Chapter 1

Introduction

General relativity is a very rich theory that makes many exciting predictions about the universe's most extreme environment. One of those predictions is the emission of gravitational waves (GWs) from accelerating objects (e.g., orbiting compact binaries), which have yet to be detected directly. To that end, the Laser Interferomenter Graviational-wave Observatory (LIGO) detectors have been built and measure these waves as they pass through the earth. Recently, the LIGO detectors reached their design sensitivity and recorded data from their fifth science run, which accumulated a year's worth of coincident data where multiple detectors were in operation. The first part of this thesis will focus on a search for GW signals from compact binary coalescence (CBC) (LIGO's flagship search) in the first year of data from this science run. In those chapters we describe the signals we search for, the design of the GW detectors, how the search was performed, and its results. For this part of the thesis, my role was to tune and run the analysis mentioned above. This included contributing to the code base used for the analysis, implementing new features in many stages of the pipeline, and designing and implementing the postprocessing pipeline to calculate the detection statistic. Finally, this included managing the writing of and acting as the corresponding author on the resulting paper.

In the second part of this thesis, we focus on testing the effects of a massive graviton. That chapter describes a massive graviton's effects on the propagation of GWs and uses those effects to constrain the graviton's mass for a given CBC GW signal observation. The main result of my work is an application of previous methods to a new class of CBC waveforms that contain more information (i.e., complete CBC waveforms) and can more stringently constrain the graviton's mass.

The final part of this thesis focuses on the dynamics of compact objects as they interact and subsequently merge. Momentum flow between the bodies and the surrounding gravitational field is studied and found to explain interesting features seen in Numerical Relativity simulations of orbiting black holes that have nonzero spin angular momentum. For this part of the thesis, my role was to perform and verify the surface and volume integral calculations associated the momentum conservation results.